Report No. 7: Textile

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Hantex Corporation Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Hantex Corporation Ltd. —

1. Outline of The Factory

Address	99/1 Nadee, Mahachai, Samut Sakhon Thailand	
Capital	400 million Bt	
Type of industry	Textile	
Major products	Nylon fiber	
Annual Product	3,675 t/year	
No. of employees	280	
Annual energy consumption	Electric Power	15,991,000 kWh/year
	Fuel	Bunker C 1,800 kℓ
Interviewees	Mr. Jerry Chen, Mr. Nikom, Mr. Yongyut and 7 person	
Date of diagnosis	Jan. 17 ~ 18, 1983	
Diagnosers	K. Nakao, Y. Ohno and M. Matsuo	

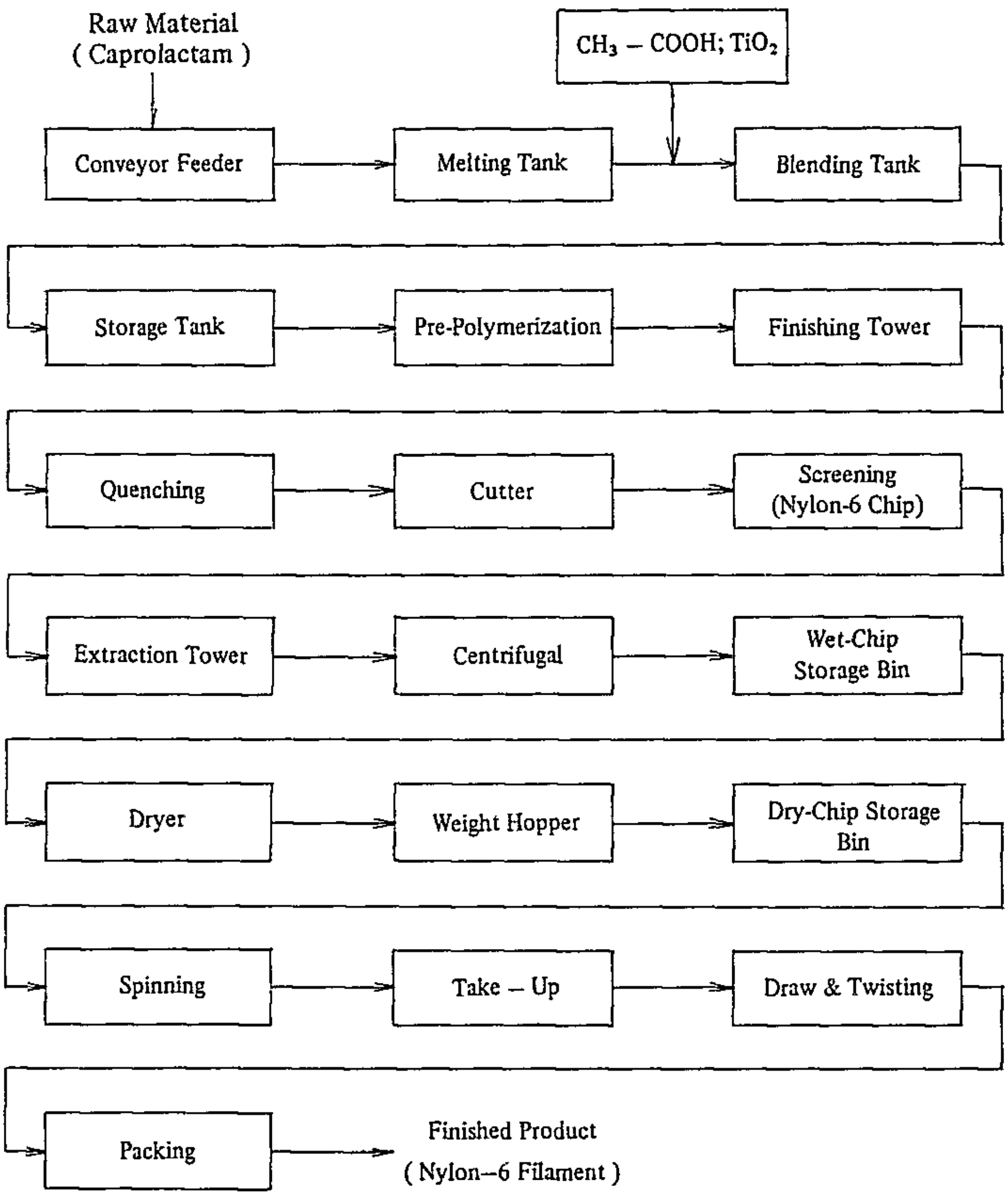
The factory belongs to the BIS Group and is one of the three nylon fiber manufacturing factories in Thailand. Since 1975, the factory has been producing Nylon-6 filaments using caprolactam imported from Poland and Italy as raw material based on technology offered by Chemex of the United States. In the beginning phase, the factory encountered a variety of technical problems which the factory has been able to surmount.

The factory had to operate at a rate of 50% capacity between April and August, 1982 due to the weak market. At present, the factory is producing nearly 13.5 t/day, which is full production.

Its products are principally nylon filaments in 20 to 40 denier which are sold and then processed into drapery, stockings, sports wear, underwear, etc.

2. Manufacturing Process

Flow – Chart of Nylon – 6 Filament Process

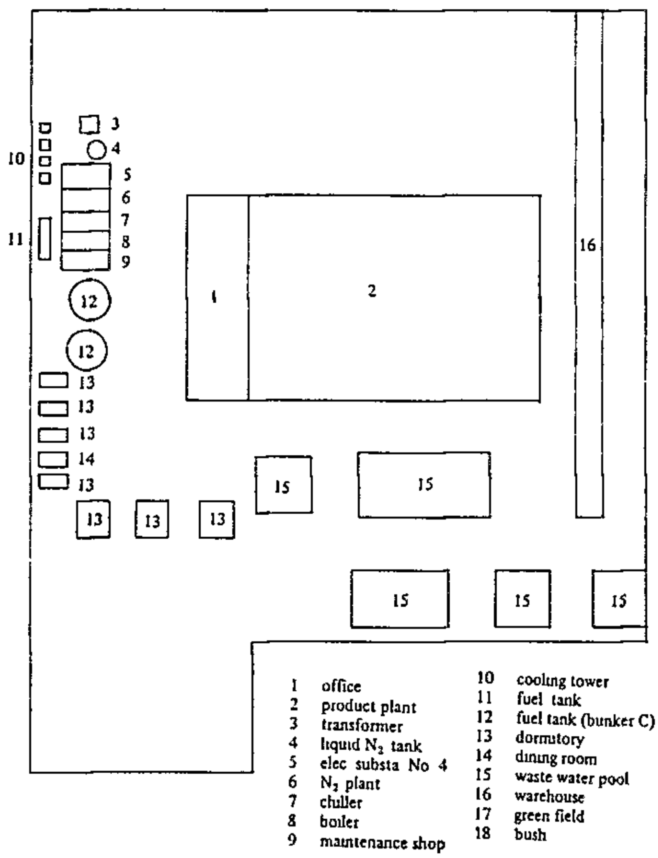


3. Major Equipment

3.1. Major Equipment

Name	No. of units installed	Type, etc.
Boiler	2	Babcock & Wilox Evaporating volume 5.4 t/h Operating pressure 9 kg/cm^2 One is stand by
Vacuum dryer	4	Reducing pressure by steam ejector Jacket heating
Evaporator	1 set	Double effect evaporator
Extractor	1 set	
Melter		
Polymerization tower	1 set	541 kW
Spinning plant	6 line	435 kW
Chiller	1 set	450 kW
Nitrogen gas plant	1 set	112 kW

3.2. Layout



4. State of Energy Management

4.1. Investment in Energy Conservation and Cases of Improvement

No target have yet been set for energy conservation. The factory has made the following improvements by immediately retrofitting spots that require improvements.

Investment has been made on a priority basis by deciding the advantage order in terms of recovery periods.

(1) Shell-and-tube type coolers have been changed to those of plate type to increase the cooling efficiency.

(2) Installation of automatic blow equipment, and improvement of condensate recovery rate to reduce fuel consumption by 10 kl/ month.

(3) Reinforced insulation. Glass wool has been used.

(4) Processes have been improved to streamline and shorten various pipes wherever possible.

(5) Steam traps have been repaired and replaced.

(6) The chemical used in the cooling tower has been changed to suppress the growth of algae.

(7) Pipes for steam, compressed air, nitrogen, water, etc. have been checked and repaired to prevent leakage.

(8) The number of buses to bring employees to the factory and back has been reduced.

(9) In order to lower the air conditioning load, the room ceiling heights have been lowered to reduce the cubic volume and the roofs of the spinning rooms have been changed to double roofs to increase the insulation efficiency.

The following energy conservation schemes are planned.

(1) To stop in-house manufacture of nitrogen gases and to use purchased liquefied nitrogen to reduce nitrogen comsumption.

(2) To install condensers to improve the power factor. (In order to improve the power factor from 80 to 85%, the total capacity of the condensers to be installed will be approximately 300 kVar, with the cost approx. 65,000 Bt.)

(3) To study the energy conservation effect that can be achieved by installing a boiler economizer.

(4) To study increasing the take-up room humidity from 50 to 60% RH by changing the coating oil.

(5) Remodeling of the processes and design conditions may affect quality and cannot be hastily decided. However, the factory is considering raising the quench air temperature and monomer extraction water concentration.

The management attitude of immediately repairing or remodelling spots for improvement is noteworthy. During our survey, insulation works were being undertaken, and management was positive. Color coding of pipes, repair and maintenance of meters, and arrangement in the factory were good and well-managed control.

4.2. Grasp of Energy Consumption

Grasp of energy consumption has been generally conducted in a satisfactory manner.

Fuel consumption is tabulated for every shift and every month, and steam consumption, by process. Water analysis data are also recorded. This practice is good and should be continued.

Fuel consumption rate has been calculated. Even though a factor analysis is not conducted, it should be conducted to implement carefully through-out control measures. Power statistics such as electric power used and power consumption rate, etc. are well maintained. One suggestion is that the power consumption by process be maintained to further improve data utilizaiton.

4.3. Energy Conservation Committee and Suggestion System

Energy conservation and QC are discussed during overall meetings held every month by managers and supervisors.

The Energy Conservation Committee meetings had been held every month last year, headed by a university professor who had been asked to chair the committee. Reports had been submitted to the committee by the individual sections. However, mutual understanding among the sections was not sufficient, and some suggestions did not meet actual situations. For these reasons, the committee was disbanded three months after its formation as good effects could not be expected and even problems could be anticipated.

The committee chairman should be the factory superintendent, who is the person responsible for all phases of production, or a person next to him. Problems should be carefully sorted out and realistic countermeasures should be produced after hearing the opinions of those who are thoroughly familiar with the actual situations of the individual sections. Such countermeasures should be implemented as directives of the factory superintendent.

At present, countermeasures are implemented by each section at the responsibility of the heads of individual sections. Problems involving more than one section should also receive attention and problems should be discovered systematically.

4.4. Employee Training

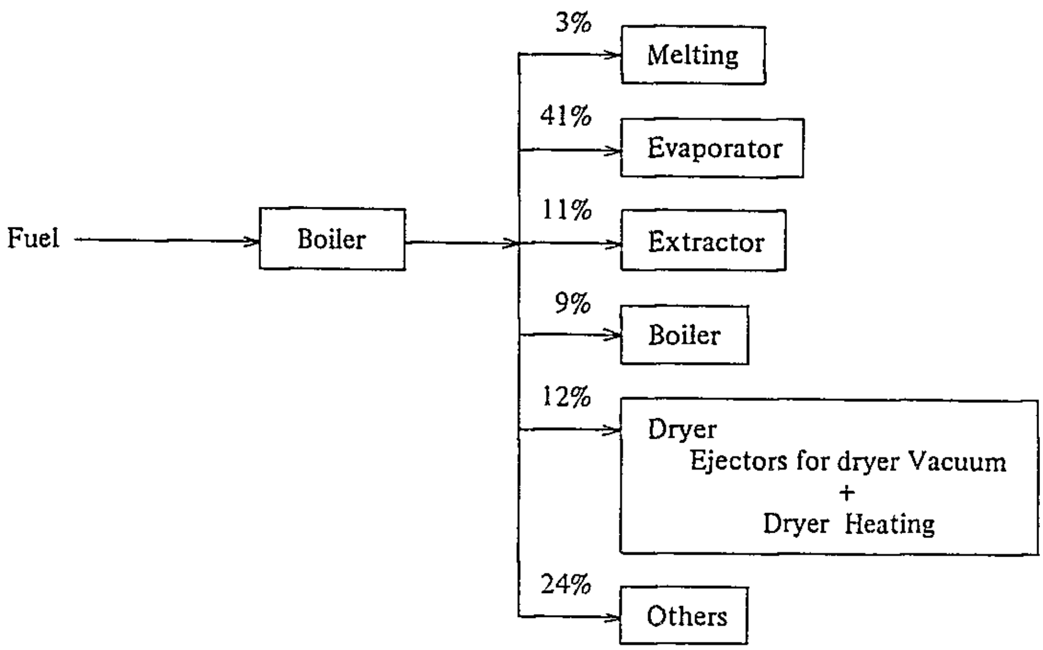
Managers and supervisors of sections such as the boiler and air conditioning sections have been sent to seminars held outside the company. In-house training of employees by those who attended such seminars should be initiated.

4.5. Others

Insulation of facilities and pipes is assigned to each sections which appoint a responsible person to maintain them. The insulation work unit costs are shown to the employees. Stepping on insulation with shoes is prohibited. This is a good method to increase the energy conservation awareness of the employees.

5. State of Fuel Consumption

5.1. Bunker C oil is used only in boilers to generate steam. The consumption is 1800 kl/year. The main steam consuming facilities are listed in the following.



Steam pressure is divided into two lines — high pressure (8 to 9 kg/cm^2) and low pressure (2 kg/cm^2). About 75% of condensate is recovered, and flash steam from the condensate on the high pressure side is utilized on the low pressure side. Through these steps, the system is highly efficient.

5.2. Boiler Heat Balance

The feedwater flow rate could not be measured. However, the heat balance was roughly calculated based on the measurement data of January 16, 1983.

Input			Output		
Item	10^3 Kcal/h	%	Item	10^3 Kcal/h	%
Heat of fuel combustion	1,799.0	99.7	Heat of steam	1,494.7	82.8
Sensible heat of fuel	5.2	0.3	Heat loss in exhaust gas	246.3	13.7
			Heat loss in blow down water	20.5	1.1
			Heat release from boiler body, Others	42.7	2.4
Total	1,804.2	100.0	Total	1,804.2	100.0

Note 1: Data Given for Calculation of Heat Balance

Type of fuel		Bunker C
Fuel consumption	(F)	4,692 l/day – 186.5 kg/h
Heat contents of fuel (Lower)	(Hl)	9,646 kcal/kg
Specific gravity of fuel	(SG)	0.954
Specific heat of fuel	(C_P)	0.45 kcal/kg °C
Temperature of fuel	(T_F)	92°C
Reference temperature	(T_0)	30°C
Oxygen content in exhaust gas	(O_2)	7.2%
Temperature of exhaust gas	(T_G)	280°C
Quantity of blow water	(B)	188 kg/h
Temperature of blow water	(T_B)	179°C
Temperature of feedwater (softened water + condensate recovery water)	($T_{W'}$)	(Estimate) 70°C
Temperature of feedwter after deaerator	($T_{W''}$)	104°C
Steam pressure	(P)	9 kg/cm^2

Note 2: Equation for Calculating the Heat Balance

Input

Heat of fuel combustion (Q_C)

$Q_C = F \times Hl = 1{,}799.0 \times 10^3$ kcal/h

Sensible heat of fuel (Q_S)

$Q_S = F \times C_P (T_F - T_O) = 5.2 \times 10^3$ kcal/h

Output

Heat loss in exhaust gas (Q_E)

Theoretical amount of air (A_O)

$A_O = 0.85\ Hl/1{,}000 + 2.0 = 10.20$ Nm^3/kg

Theoretical amount of exhaust gas (G_O)

$G_O = 1.11\ Hl/1{,}000 = 10.71$ Nm^3/kg

Air ratio (m)

$m = 21/(21 - O_2) = 1.52$

Actual amount of exhaust gas (G)

$G = G_O + A_O(m - 1) = 16.01$ Nm^3/kg

$Q_E = F \times G \times 0.33 (T_G - T_O) = 246.3 \times 10^3$ kcal/h

Heat loss in blow water (Q_B)

$Q_B = B \times (T_B - T_{W'}) = 20.5 \times 10^3$ kcal/h

Heat loss from boiler body and others (Q_R)

Heat loss from boilers (Q_r)

$Q_r = 15.6 \times 10^3$ kcal/h

Other heat losses (Q_O)

$Q_O = \text{Input} \times 1.5\% = 27.1 \times 10^3$ kcal/h

$Q_R = Q_r + Q_O = 42.7 \times 10^3$ kcal/h

Heat of steam (Q_V)

$Q_V = Q_C + Q_S - Q_E + Q_B + Q_R = 1{,}494.7 \times 10^3$ kcal/h

Quantity of evaporation (S)

Enthalpy of steam (E_S) = 662.9 kcal/kg

Enthalpy of feedwater (E_F) = 70 kcal/kg

$S = Q_V \div (E_S - E_F) = 2{,}521$ kg/h

6. Problems in Heat Control and Potential Solutions

6.1. Boiler Control

(1) Combustion control

Black smoke was emitted during load variation, and the oxygen content in exhaust gases was high, 7.2%. It is recommended that the burner nozzles be checked, cleaned, and repaired once a month, that the air-fuel ratio control equipment be readjusted, and thereby the oxygen content be maintained at less than 4% (air ratio 1.3 or less).

The exhaust gas temperature was 280° C and was slightly high. It is also recommended that the exhaust gas temperature be maintained below 230° C by reducing air ratio or by cleaning the heating surfaces through soot blowing measures and other means.

The boiler efficiency would be improved from 82.8 to 86.3% and fuel consumption would be saved 4.1%, or 73.8 kl/year, by lowering the present exhaust gas heat losses from 13.7 to 10%.

(2) Control by Evaporation Ratio

Flowmeters for softened water were installed. However, flowmeters for boiler feedwater including recovered condensate were not installed. Heat-resisting flowmeters should be installed on the discharge side of the feedwater pump to record the feedwater quantity, feed softened water quantity, recovered condensate quantity (feedwater quantity − feed softened water quantity), and fuel consumption every day. By calculating the condensate recovery rate and a simple evaporation ratio to serve as a boiler efficiency criterion based on these values, and by checking them, the level of boiler control can be enhanced.

$$\text{Condensate recovery rate} = \frac{\text{Feedwater quantity} - \text{Feed softened water quantity}}{\text{Feedwater quantity} - \text{Blow quantity}}$$

$$\text{Simple evaporation ratio} = \frac{\text{Feedwater quantity} - \text{Blow quantity}}{\text{Fuel consumption}}$$

(3) Boiler Water Control

The values recorded on January 17, 1983 are as shown in the following:

	Pure water	Softened water (No. 1)	Softened water (No. 2)	Feedwater	Boiler water
PH	6.5	7.0	6.5	9.0	12.0
Dissolved solids	23	532	407	757	4,207
Total hardness	nil	2	10	10	nil
Cl^{-1}	nil	25	21	43	266
PO_4^{-3}			0.1	1.2	12.5

Softened water from the No. 2 softener and recovered condensate were mixed, to which softened water from the No. 1 softener was further mixed for use as boiler feedwater. However, the value of the boiler feedwater was deteriorating. The piping system should be inspected to examine if raw water, etc. is leaking in. The value of the boiler water was generally satisfactory, except that the value for dissolved solids was high.

The standard values for boiler water are shown in the following:

PH	11 to 11.8
Dissolved solids	3,000 ppm
Cl^{-1}	less than 500 mg/l
Electrical conductivity	4,500 μS/cm
PO_4^{-3}	20 to 40 mg/l

The blow quantity can be reduced by increasing the condensate recovery rate, by mixing some pure water obtained in the pure water equipment in the boiler feedwater, by using the No. 1 softener exclusively for the boilers, by preventing non-pure water from entering the feedwater system, and by other means.

The blow rate was 6.9%.

$$\frac{\text{Blow quantity}}{\text{Evaporation quantity} + \text{blow quantity}} = \frac{188}{2,521 + 188} = 6.9\%$$

By lowering the blow rate from 6.9% to 3% through the foregoing measures, 13.3 kl/year of fuel can be conserved.

$$\frac{(188 - 78)\text{kg/h} \times (179 - 70) \times 24 \times 352}{9,600 \times 0.83 \times 0.954} = 13.3 \text{ kl/year}$$

(4) Others

It is preferable to operate boilers alternately every 4 to 6 months in order to prevent their degradation.

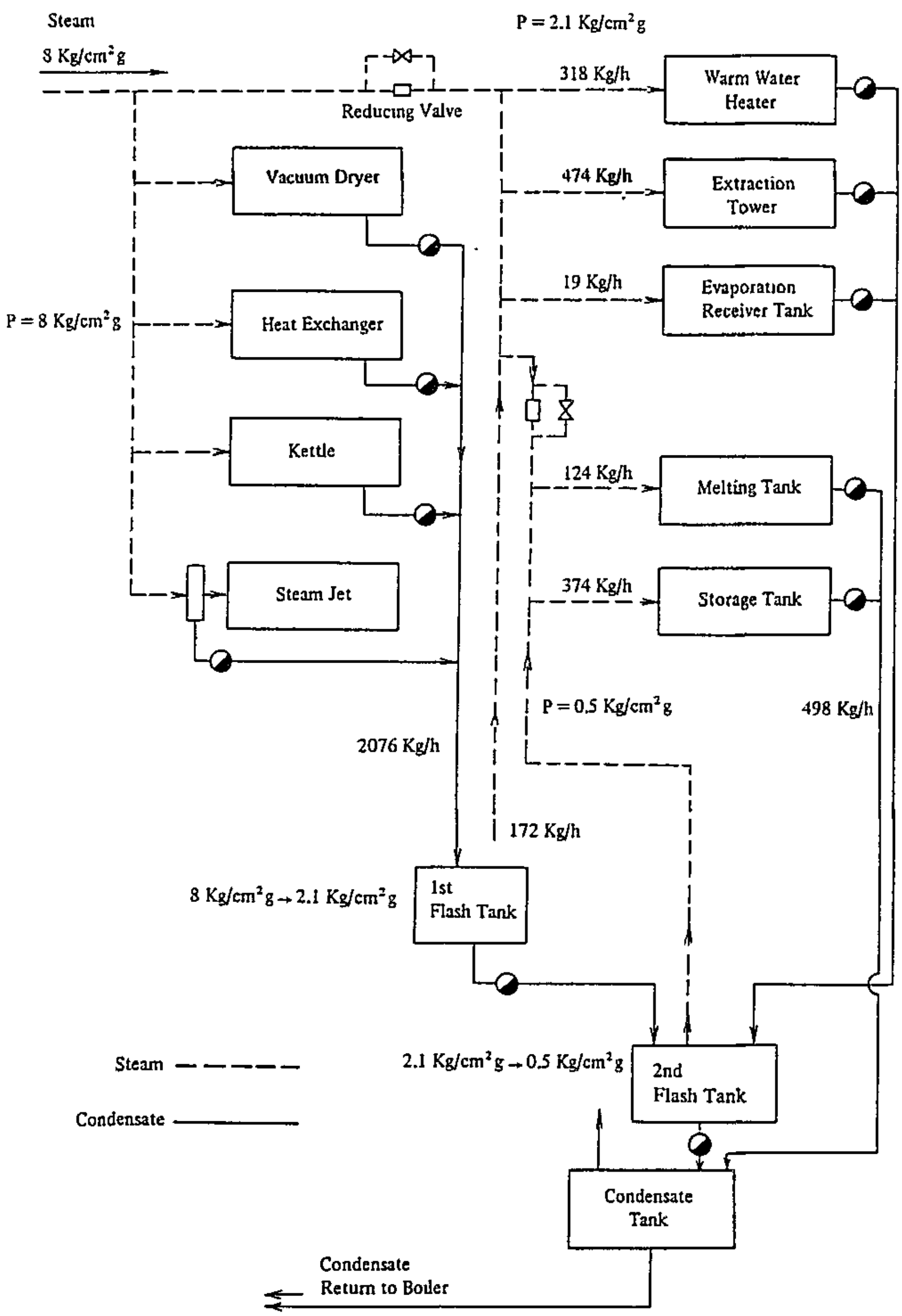
The boiler load was approximately 45%, which is low. Therefore, these boilers should be replaced with ones having smaller capacities.

The fuel oil distribution pipes in the boiler system are complicated and should be streamlined.

6.2. Improved Condensate Recovery Method

At the time of the survey, the condenste recovery rate was 75%. Condenste from much of the equipment using steam such as dryers and dissolver tanks is flashed in two stages (8.0 to 2.1 kg/cm^{2}g and from there to 0.5 kg/cm^{2}g) for effective utilization of steam. Condensate is then recovered.
(See the diagram shown in the following.)

Effective Utilization of Flash Steam



However, the condenste in the dissolver and storage tanks caused condensate locking as the condensate recovery tanks could not be installed in appropriate positions. And condensate from this system had to be discarded. The method of feeding recovered condensate utilizing steam pressure that works on steam traps is limited only to relatively short distance feeding. When they are far apart and when there is no differential pressure between flash tanks, as in this factory, the factory area should be divided into several blocks, installing a condensate tank in each of these blocks, and condensate should be recovered under pressure to boilers by condensate recovery units using a pump or combining a pump and ejector.

The possible amount of fuel conservation when condensate is recovered from this system would be 48.9 kl/year.

Calculations:

Condensate quantity after flashing condensate of 0.5 kg/cm^2 and 498 kg/h at normal pressure:

$$498 \times \{1 - \frac{110 - 100}{539}\} = 489 \text{ kg/h}$$

Assuming heat loss to be 10%, and converting the recovered heat into fuel conservations:

$$\frac{489 \text{ kg/h} \times (100 - 30)\text{kcal/kg} \times 24 \text{ hr} \times 352 \text{ days} \times 0.9}{9{,}600 \text{ kcal/kg} \times 0.83 \times 0.954} = 34.2 \text{ kl/year}$$

6.3. Reinforced Insulation

6.3.1. The bulk of the surface temperature measured in the major manufaturing facilities was less than 60° C, and heat losses through radiation were negligible. (See the list of surface temperatures measured for steam and electric heating equipment).

Areas that seem to require an improvement are shown in the following:

(1) The surface temperature of the lower section of the finishing tower (No. 1) was high, 70 to 73° C.

(2) The surface temperature in some sections of the No. 1 extrusion vaporizer was 82° C, and that of the No. 2 extrusion vaporizer, 81° C, indicating that insulation was not sufficient.

(3) Insulation of the main steam pipes was sufficient, and the insulation work was satisfatory. However, insulation is needed around the small-diameter pipes near the junctions with the equipment which uses steam at the ends of the pipes.

(4) The valves, etc. on the steam pipes, flanges, boiler main valves and condensate pipes require insulation.

(5) Insulation of some dryers and other equipment is superannuated and should be replaced in the near future.

(6) A plan should be made regarding the repairing and shortening of pipes in the boiler system.

6.3.2. Surface Temperatures of Nylon Manufacturing Equipment

(1) Surface temperatures of chemical equipment (tower vessels and dryers)

Name		Surface temperature	Heat release
Low Temperature Distillation Kettle		41 ~ 50°C	
Recovered Lactam Receiver Tank		41°C	
Melting Tank		42~ 49°C	
Blending Tank		38°C	
Monomer Storage Tank		46°C	
Pre-polymerization		48°C	170 Kcal/m²h
Transfer Heater		55°C	
Washwater Collection Tank		73°C	
Finishing Tower Line No. 1	upper part	45°C	115 Kcal/m²h
	lower part	70 ~ 73°C	
Finishing Tower Line No. 2	upper part	61°C	460
	lower part	61°C	410
Vacuum Dryer		40°C	
Extraction Tower	No. 1	48°C	
〃	No. 2	53°C	

(2) Surface temperature of Dowtherm vaporizer heater

No.	Surface temperature °C Equipment name	Measuring position ①	②	③	④
No. 1	Transfer Heater II Dowtherm Vaporized	°C 55	°C 52	°C 62	°C 56
No. 4	Pre Heater I Dowtherm Vaporizer	52	66	54	58
No. 6	Transfer Heater I Dowtherm Vaporizer	55	54	64	58
No. 2	Pre Heater Dowtherm Vaporizer	55	66	55	57
No. 3	Pre Heater II Dowtherm Vaporizer	58	67	57	58
No. 5	Pre Heater I Dowtherm Vaporizer	58	64	57	58

(3) Surface temperature of extrusion vaporizer

No.	Surface temperature °C / Equipment name	Measuring position ①	②	③
		°C	°C	°C
No. 1	Extrusion Vaporizer	73	73	82
No. 2	Extrusion Vaporizer	67	81	67

6.3.3. Insulation Effect

(1) Insulation Effect of No. 1 Finishing Tower

A 0.7 kl/year fuel conservation can be anticipated by reinforcing heat insulation using glass wool 25 mm in thickness.

$$\frac{(487 - 260)\text{kcal/m}^2\text{h} \times 2.8\ \text{m}^2 \times 24 \times 352}{9{,}600 \times 0.83 \times 0.954} = 0.7\ \text{kl/year}$$

Current amount of heat loss	(Q_1)	487 kcal/m²h
Heat loss after improvements	(Q_2)	260 kcal/m²h
Surface temperature after improvements	(T)	55° C
Surface area of improved parts	(A)	2.8 m²
Heat content of fuel	(Hl)	9,600 kcal/kg
Specific gravity of fuel	(S_G)	0.954
Boiler efficiency	(B_E)	83%
Working hours		24 h/day, 352 day/year

Compared with the estimated conservation approximately 3,300 Bt/year, the cost for insulation is about 2,000 Bt, showing that investment can be recovered in a short period of time.

(2) Reinforced Insulation of Extrustion Vaporizer

The power conservation when the surface temperature is lowered from 72 to 42° C by increasing the thickness of the insulation material from the present 100 to 200 mm are shown in the following:

Assuming:

Heat loss 487 kcal/m²h → 111 kcal/m²h

Surface area 5 m²/unit x 2 units

Electric power conservations

$$\frac{(487 - 111) \times 5 \times 2 \times 24 \times 352}{860} = 36{,}900\ \text{kWh/year}$$

Conservation ratio

$$\frac{36{,}900\ \text{kWh/year}}{18\ \text{kW} \times 2 \times 24 \times 352} = 11.7\%$$

Compared with a possible conservations of 55,000 Bt/year, the cost for insulation will be approximately 13,000 Bt, and the investment can be recoverd in a short period of time.

7. State of Electric Power Consumption

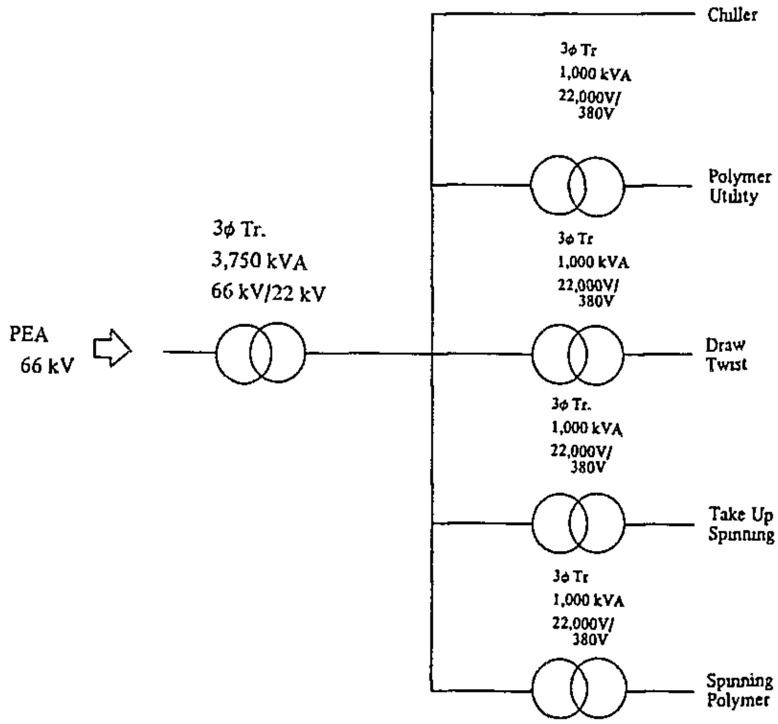
7.1. The Principal Data Relating to Power Consumption

• Power company	PEA
• Peak demand	2,300 kW
• Power consumption	15,991,000 kWh/year
• Load factor	80.5%
• Penalty	None
• Power factor	80%
• Transformer	3,750 kVar (1 unit)
• Power consumption rate	4,351 kWh/kg

7.2. Load Distribution

Motors	57.2%
Air conditioning	15.7%
Lighting	3.4%
Electric heating	16.6%
Compressors and others	7.1%
Total	100 %

7.3. One-line Diagram



8. Problems in Electric Power Control and Potential Solutions

8.1. Transformer

The load factor of the receiving transformer was approximately 77%, indicating it was operated at a high efficiency.

8.2. Motors

(1) The load factor, that is, $\frac{\text{actual load}}{\text{rated capacity}}$, was measured with 16 large-capacity motors exceeding 15 kW. Of these 16 motors, 7 had light loads as shown in the following.

The load factor of the quench circulation water pump (40 HP, 30 kW) was particularly low, 19.6%. It is possible that the measurement was made when the load factor happened to be low. Measurement of the load factor of motors should be continued and motors that always show low load factors should be replaced with ones having optimal capacities on suitable occasions.

Equipment	Capacity	No. of units	Load factor
• Blower	93.8 kW (125 HP)	1	39.7%
• Chiller Compressor	75	1	42.5
• Dryer	15 (20 HP)	4	24.9
• Quench Circulation Water-Pump	30 (40 HP)	1	19.6
• Spinning	22	17	55.9

When the capacities of these motors are optimized, the following energy-conservation effects can be expected.

Motor	Efficiency	Loss	No. of Units	Reduced loss
93.8 kW → 37 kW	91.5% → 92.0%	7.97 kW → 2.96 kW	1	43,914 kWh/year
75 → 37	89.5 92.0	7.88 → 2.96	1	43,055
15 → 3.7	83.5 → 86.0	9.90 → 2.07	4	68,573
30 → 7.5	80.0 → 87.5	6.00 → 0.94	1	44,348
22 → 15	90.5 → 91.0	2.09 → 1.35	17	110,201
			Total	310,091

Electric power conservation 310,090 kWh/year

Conserving ratio 310,091 kWh/year ÷ 15,990,960 kWh/year ≒ 1.9%

(2) The belts used on motors (total capacity 380 kW) in the fine spinning process are one-ply and are made of cloth. Approximately 4% power conservation will be achieved by changing the belts to those of an energy-conservation type. Trial calculations of possible energy-conservation are shown in the following:

Electric power conservations	380 kW x 0.04 = 15.2 kW
Annual conservations	15.2 kW x 24 h x 365 day ≑ 133,150 kWh/year
Conservation ratio	133,150 kWh/year ÷ 15,990,960 kWh/year ≑ 0.8%

(3) The belts on each of the 150-and 40-HP motors for the air compressor and water spray were excessively loose.

The power loss can be reduced by approximatley 3% when the belt tension is properly adjusted. The criterion for belt tension is that the belt lowers by its thickness when pushed down by a thumb applying an ordinary force.

The possible energy conservation that can be attained by this plan can be calculated as shown in the following:

Power conservations	142.5 kW (= 190 HP) x 0.03 = 4.275 kW
Annual conservations	4.275 kW x 24 h x 365 days = 37,450 kWh/year
Conservation ratio	37,450 kWh/year ÷ 15,990,960 kWh/year = 0.2%

8.3. Air Conditioning

(1) Temperature and humidity measurements of the main processes are shown in the following. The values are generally satisfactory for maintianing quality.

Process	Temperature	Humidity
• Twisting	23.18C	63.5%
• Take up	19.0	48.0
• Spinning	21.7	64.3
• Inspection	24.0	68.9
• Control Room	23.0	45.7

In the take-up process, by raising the temperature to 21 or 22°C, which is the temperature range that would not affect the quality during the summer, the electric power consumption can be reduced by approximately 8%. The temperature can be maintained at the value shown above during the winter.

Glass windows in the control room and buildings should be doubled to lower the cooling load.

(2) The total capacity of the major motors related to air conditioning is 548.3 kW broken down as follows:

	For Twist Process	For Spinning Process	Total
• Blowers	93.8 kW (125 HP)	30 kW (40 HP)	123.8 kW
• Water sprays	30 kW (40 HP)	22.5 kW (30 HP)	52.5 kW
• Pumps			372 kW
Total			548.3 kW

Substantial energy conservation will be possible in future by making fine adjustments of the air conditioning settings for individual processes and according to the season, while checking the quality.

There are 584 nozzles (360 in the twisting process, 224 in the spinning process) for water sprays to humidify and cool circulated air. By reducing the pressure drop of water by enlarging the nozzle diameters to reduce the number of nozzles and by other means, electric power consumption can be reduced.

When the amount of air and pressure drop of water is reduced by 10%, the energy conservation can be calculated on a trial basis as follows:

Conservation Ratio	Load of Airconditioning (15.7%) x 0.1 = 1.6%
Power Conservation	15,991,000 kWh/year x 0.016 = 255,900 kWh/year

(3) The ratio of the open air intake has been reduced from 20% as before to 5% to conserve energy. However, this does not have a favorable effect on the working environment in the factory, and the rate should be improved back to the previous 20%, or 15%.

In that case, the energy-conservation can be accomplished by utilizing "total heat exchangers" that can take in fresh open air without letting out the cold heat of the cooled air in the factory.

8.4. Lighting

(1) A measurement of the illuminance in major processs showed that the illuminance was generally satisfactory, as shown in the following:

Process	Illuminance
• Twist	178 lux
• Spinning	105
• Inspection	299
• Control Room	84

The control room is the center for energy control, and an illuminance of about 200 lux is desired to make monitoring and work easier.

(2) The light sources in the factory were fluorescent mercury lamps (total capacity 15.4 kW) and ordinary fluorescent lamps (total capacity 104.52 kW). By replacing these lamps with high-rendition type high-pressure sodium lamps and energy-conservation type fluorescent lamps, the following energy conservation can be expected:

Power conservations	(15.4 kW x 0.5) + (104.52 kW x 0.1)
	= 18,152 kW
Annual conservations	18,152 kW x 24 h x 365 day/year
	≒ 159,000 kWh/year
Conservation ratio	159,000 kWh/year ÷ 15,990,960 kWh/year
	≒ 1.0%

9. Summary

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

	kl/year (equivalent oil)	%
Improvement in boiler combustion	73.8	4.1
Lower blow rate	13.3	0.7
Condensate recovery	34.2	1.9
Reinforced insulation	0.7	—
Subtotal	122.0	6.8

	10^3 kWh/year	%
Reinforced insulation	36.9	0.2
Changes in motor capacities	310.1	1.9
Improvement in motor belt material	133.2	0.8
Adjustments of motor belt tension	37.4	0.2
Control of air conditioning load	255.9	1.6
Replacement of lamps	159.0	1.0
Subtotal	932.5	5.7

Report No. 8: Textile

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

— Toray Nylon Thai Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Toray Nylon Thai Ltd. —

1. Outline of the Factory

Address	112 Soi Wadladplakao, Ramintra Rd. Bangkhen, Bangkok	
Capital	120 million Bt	
Type of industry	Textile	
Major products	Nylon fiber, Polyester fiber	
Annual product	12,000 t	
No. of employees	740	
Annual energy consumption	Electric Power	42,000,000 kWh
	Fuel	Fuel Oil 6,726 kℓ Diesel Oil 1,389 kℓ
Interviewees	Director, Factory Manager, Michio Niwa Deputy Factory Manager, L. Adisorn Senior Advisor N. Tomoshige	
Date of diagnosis Diagnosers	Jan. 20 ~ 21, 1983 Y. Ohno, K. Nakao, M. Matsuo	

The factory started operations in 1967, as a synthetic fiber factory formed by joint venture using Thai and Japanese capital.

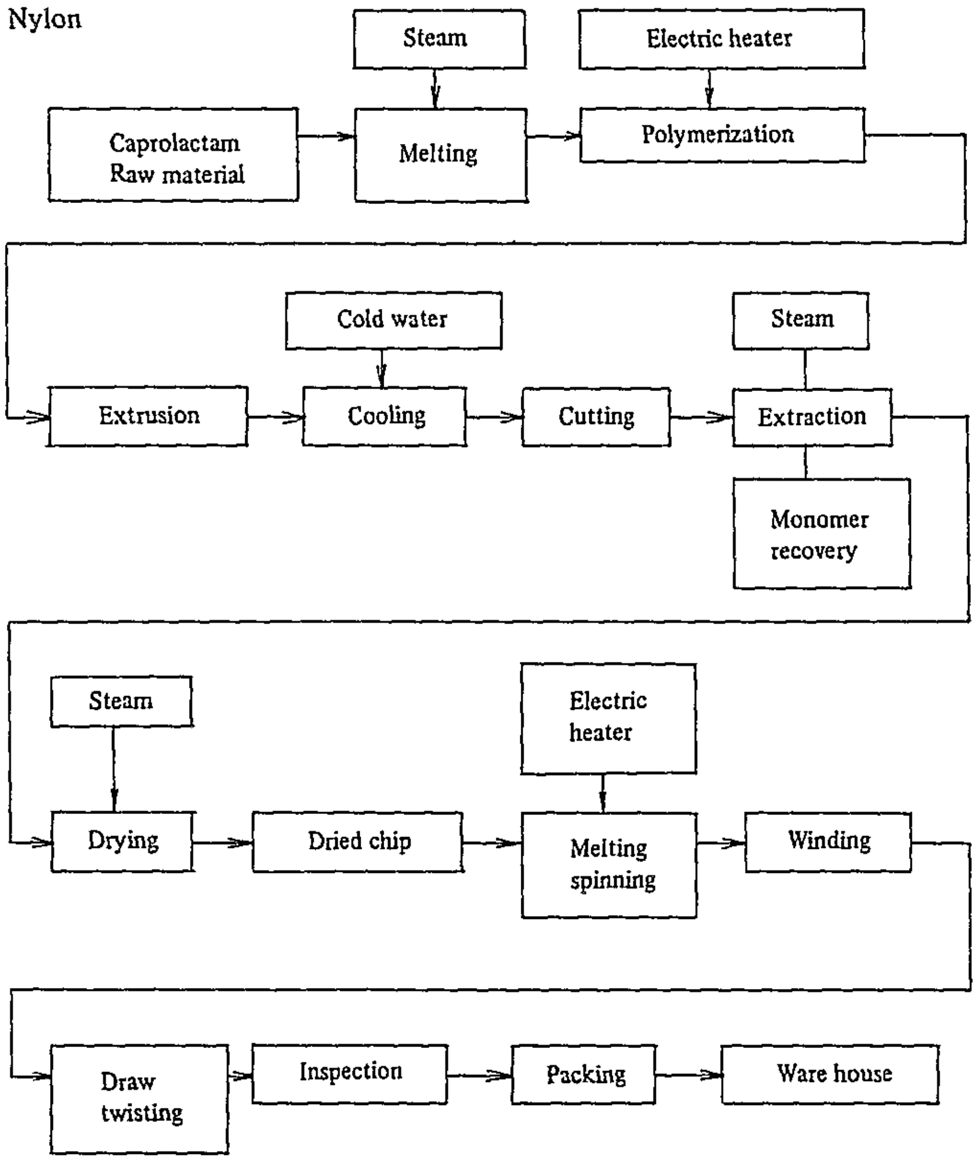
In the beginning, the factory produced only Nylon-6. However, from about 10 years ago, the factory started to produce polyester fibers as well.

The production capacity of the factory is 600 tons/month each for nylon and polyester. The factory is the largest producer of nylon of Thailand's three nylon manufacturing plants. It is operating at full capacity at present.

The factory's motto is to make daily advances based on quality improvement, energy conservation, and smooth human relations. The factory is well maintained, is tidy, and has a high level of management.

2. Manufacturing Process

Nylon

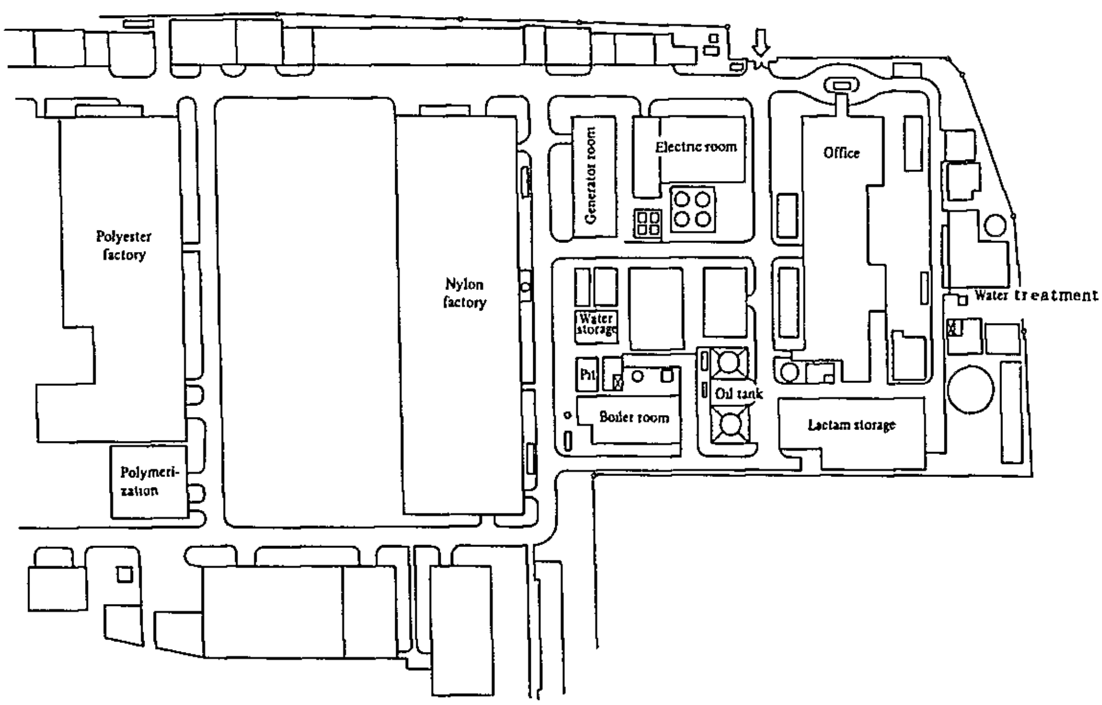


3. Major Equipment

3.1. Major Equipment

Name	No. of units installed	Type, etc.
Boiler	2	Water tube type 15 t/h, 11 ~ 11.5 kg/cm^2G
Boiler	2	Water tube type 7.1 t/h, 55 ~ 56 kg/cm^2G
Polymerzation tower	12	
Extractor	9	
Dryer	6	Vacuum conical type, jacket heating
Melting tank	1 set	
Diesel generator	5	1,500 kVA x 3, 1,250 kVA x 1, 350 kVA x 1
Chiller	5	1,900 kW (total)
Large size pump	10	1,300 kW (total)

3.2. Layout



4. State of Energy Management

4.1 Energy Conservation Target

The factory has set consumption rates for both fuel and power and is vigorously promoting an energy conservation drive.

Energy conservation target (%)

1981	10% saving
1982	8 〃
1983	10 〃

4.2 Energy Saving Investment

Energy savings investments have also been made positively. Investments have been made under a policy of depreciating on a 5-year basis in contrast with 8 years for ordinary depreciation and recovering funds in two years for energy conservation equipment.

Recent investments are shown in the following.

1981	2,500	10^3 Bt
1982	500	〃
1983	3,500	〃

4.3 Cases of Improvement

As shown in the diagram, the factory achieved energy conservation of approximately 20% until 1981, using 1977 as a base. The major improvments in recent years are shown in the following.

(1) Reinforced Insulation

Reinforced insulation of nylon polymerization towers, polyester Dowtherm boilers, boiler feedwater tanks, etc.

(2) Review of Air Conditioning

The motive power cost has been reduced by reducing the air quantities and dropping pressures of blowers for air conditioning.

Compared with the 10,000 Bt invested, the factory has been saving as much as 370,000 Bt per year.

One example is given in the following.

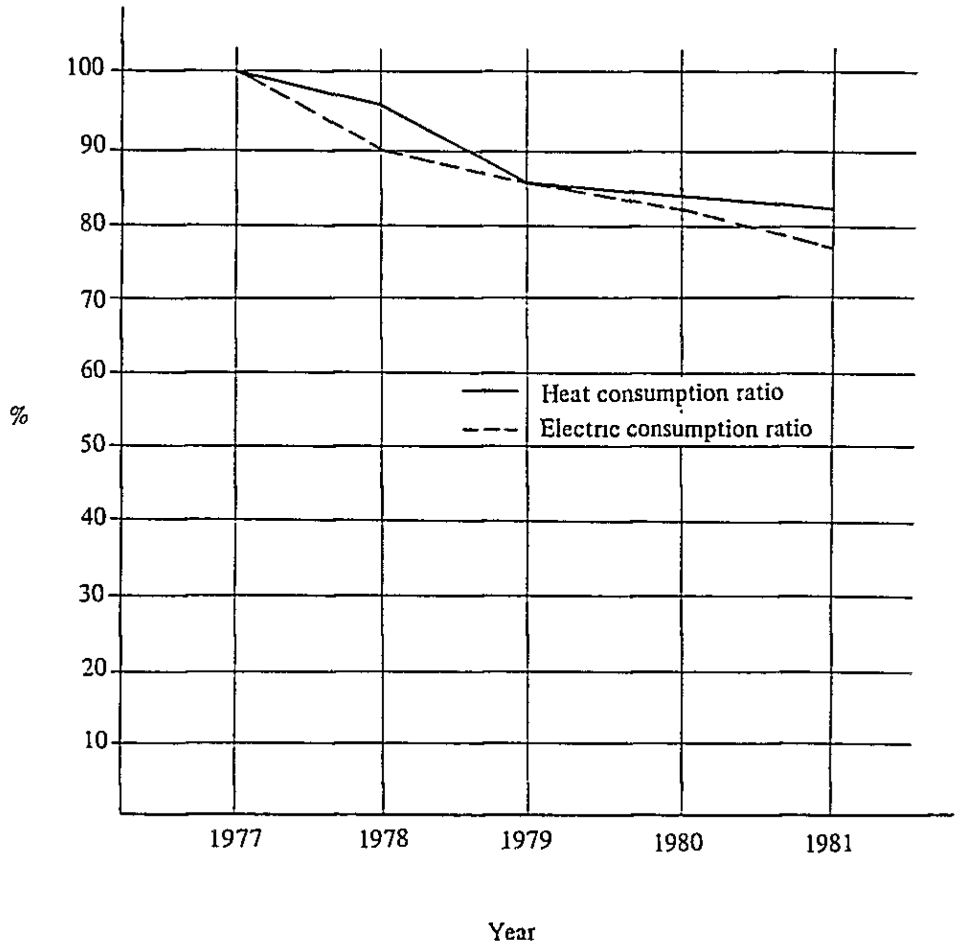
	Before	After Improvement
Room temperature	24 °C	26°C
Relative humidity	70%	60%

(3) Efficient Cooling Tower Operation and Pump Head

By partially remodeling the piping system, water can be evenly fed to several cooling towers, thereby increasing effiency.

The number of cooling tower fans operated during the night has been reduced.

Decrease of energy consumption ratio by rationalization



Of cooling towers installed on the roof of the factory building 20 m above the ground, 70% have been moved down to ground level to save pumping power.

Compared with the 2.4 million Bt investment, 3 million Bt per year, has been saved with 10-month recovery period.

(4) Recovery of Condensate from Vacuum Dryers, etc.

(5) Fewer Pumps Operated and Optimal Pump Capacities

The three colling water pumps operated for air conditioning have been reduced to two. The pump to feed softened water has been reduced in size.

(6) Efficient Chiller Operation by Overhaul and Purchase of High Efficiency Turbo Chiller

(7) Lower Boiler Air Ratio

The oxygen content in boiler exhaust gas has been reduced from 6 to 3%.

4.4 Grasp of Energy Consumption

Factory consumables, as well as energy consumption, are recorded, and data is filed appropriately as monthly and annual statistical data. Fuel quantities and electric energy are recorded daily, broken down by process and equipment. Some automatic recorders are also installed.

Consumption rates are calculated every month on power, fuel, steam, and nitrogen. Control charts are prepared and are listed in monthly reports. These charts are also posted in offices and other conspicuous places.

Variation factor analysis is conducted on a case-by-case basis when large fluctuations are noted. Energy cost (for power and steam) is calculated monthly and is distributed to the nylon and polyester processes.

4.5 Energy Conservation Committee and Suggestion System

The Energy Conservation Committee is headed by the factory manager as the chairman, and committee meetings attended by technical department section managers and staff are held every other month. Technical meetings are also attended by process foremen to discuss routine matters.

A suggestion system was implemented in the past. However, because its purpose was not sufficiently understood by the employees and PR was inadequate, as well as problems in the distribution of prizes, the suggestion system was reorganized into an incentive award system in 1982. Prizes are awarded on the basis of actual performance of group activities. The prizes are approximately 1500 to 2,000 Bt per award or 200 Bt per head.

4.6 Employee Training

Employees above the foremen level are sent to lectures sponsored by TPA. In-house training meeting are held to show slides on steam traps, etc.

The appeal to employees is made by the factory manager during regular department meetings or through posters. Process specifications are well prepared and are posted by major equipment.

The factory is clean and well maintained. Employees wear uniforms, and general discipline could be observed.

The factory received an outstanding commendation by MOI for its excellent waste-water treatment operation and a high level of management could be observed.

5. State of Fuel Consumption

Bunker C oil was used entirely for boiler steam generation, and 6,726 kl was consumed in 1982. About 1,500 kl of diesel oil is consumed per year by an emergency diesel generator.

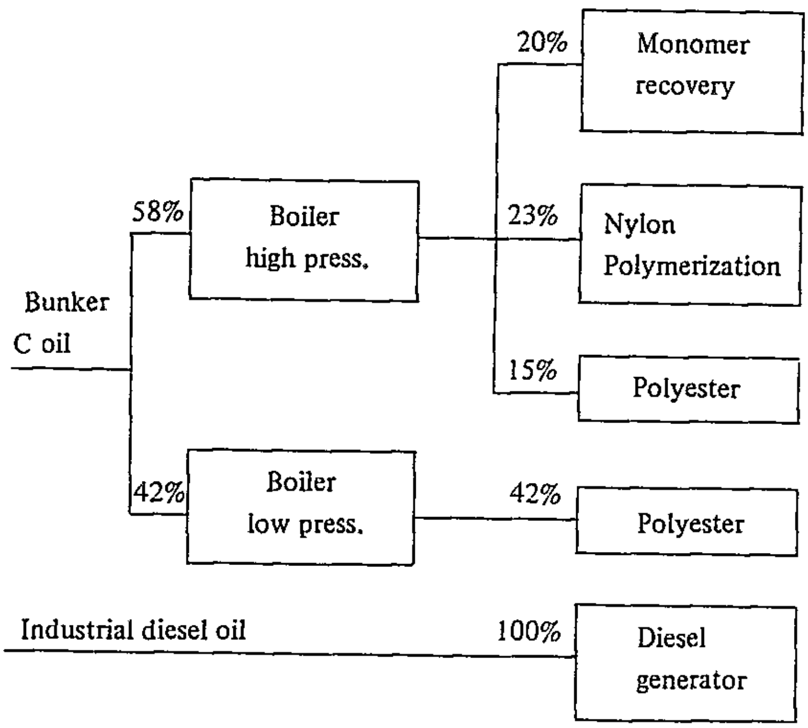
Regarding working steam, 55 to 56 kg/cm^2 steam from the high pressure boiler is used in the polyester process, and 11 kg/cm^2 steam from the low pressure boiler, in the nylon process.

The steam consumption distribution is as follows:

- High pressure steam 42% ..... Polyester
- Low pressure steam 58% ..... 40% Nylon polymerization
  35% Monomer recovery
  25% Polyester

The following quantities of high and low pressure steam were used in 1982.

	t/month		Bt/t
• High pressure steam	3100	Steam unit cost	338.5
• Low pressure	4500	Steam unit cost	338.4



5.1 Heat Balance in the High Pressure Boiler

Heat balance was calculated based on the values contained in the daily boiler report for January 10, 1983.

Input			Output		
Item	10^3 Kcal/h	%	Item	10^3 Kcal/h	%
Heat of fuel combustion	3,052.6	99.7	Heat of steam	2,568.8	83.9
Sensible heat of fuel	8.7	0.3	Heat loss in exhaust gas	367.2	12.0
			Heat loss in blow water	6.3	0.2
			Heat release from furnace body and others	119.0	3.9
Total	3,061.3	100.0	Total	3,061.3	100.0

Note 1: Data given for determination of the Heat Balance

Type of fuel		Bunker C oil
Consumption of fuel	(F)	8,030 l/day = 316.2 kg/h
Heat content of fuel (Low level) (Hl)		9654 kcal/kg
Specific gravity of fuel	(S_G)	0.945
Specific heat of fuel	(C_p)	0.45 kcal/kg
Fuel temperature	(T_F)	91°C
Reference temperature	(T_O)	30°C
Oxygen content in exhaust gas	(O_2)	4.3%
Temperature of exhaust gas	(T_G)	293°C
Specific heat of exhaust gas	(C_G)	0.33 kcal/Nm^3°C
Quantity of blow water	(B)	7,920kg/day = 330 kg/h
Blow water temperature	(T_B)	271°C
Water temperature at the outlet of continuous blow equipment	(T_B')	95°C
Feedwater quantity	(W)	112,400kg/day =4,683 kg/h
Feedwater temperature	(T_W)	76°C
(Softend water + recoverd condensate)		
Steam pressure	(P)	56 kg/cm^2

Note 2: Amount of Steam Evaporation (S)

$$S = W - B = 4{,}353 \text{ kg/h}$$

Steam enthalpy	(E_S)	666.1 Kcal/kg
Feedwater enthalpy	(E_F)	76 Kcal/kg
Continuous blow equipment outlet blow water enthalpy	(E_B)	88 Kcal/kg

Note 3: Equations for calculating the heat balance

Input

Heat of fuel combustion (Q_C)

$Q_C = F \times Hl = 3052.6 \times 10^3$ Kcal/h

Sensible heat of fuel (Q_S)

$Q_S = F \times C_P (T_F - T_O) = 8.4 \times 10^3$ Kcal/kg

Output

Heat content of steam (Q_V)

$Q_V = (W - B)(E_S - E_F) = 2568.7 \times 10^3$ Kcal/h

Heat loss in exhaust gas (Q_E)

Theoretical amount of air (A_O)

$A_O = 0.85\ Hl/1000 + 2 = 10.2\ Nm^3/kg$

Theoretical amount of exhaust gas (G_O)

$G_O = 1.11\ Hl/1000 = 10.72\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 1.26$

Actual amount of exhaust (G)

$G = G_O + A_O (m - 1) = 13{,}38\ Nm^3/kg$

$Q_E = F \times G \times 0.33 (T_G - T_O) = 367.2 \times 10^3$ Kcal/h

Heat loss in blow water (Q_B)

$Q_B = B \times (T_B' - T_W) = 6.3 \times 10^3$ Kcal/h

Heat loss radiated by furnace body and other heat losses (Q_R)

Heat loss radiated by furnace body (Q_r)

$Q_r = 53.4 \times 10^3$ Kcal/h

Other heat losses (Q_O) (balance)

$Q_O = 65.6 \times 10^3$ Kcal/h

$Q_R + Q_r - Q_O = 119.0 \times 10^3$ Kcal/h

5.2 Heat Balance in the Low Pressure Boiler

Input			Output		
Item	10^3 Kcal/h	%	Item	10^3 Kcal/h	%
Heat of fuel combustion	4,679.3	99.7	Heat of steam	3,967.0	84.5
Sensible heat of fuel	13.5	0.3	Heat loss in exhaust gas	599.9	12.8
			Heat loss in blow water	24.3	0.5
			Heat release from furnace body and others	101.6	2.2
Total	4,692.8	100.0	Total	4,692.8	100.0

Note 1: Data given for calculation of the Heat Balance

Type of fuel		Bunker C oil
Consumption of fuel	(F)	12,310 l/day = 484.7 kg/h
Heat content of fuel (low level)	(Hl)	9,654 kcal/kg
Specific gravity of fuel	(S_G)	0.945
Specific heat of fuel	(C_P)	0.45 kcal/kg
Fuel temperature	(T_F)	92°C
Reference temperature	(T_O)	30°C
Oxygen content in exhaust gas	(O_2)	7.5%
Temperature of exhaust gas	(T_G)	260°C
Specific heat of exhaust gas	(C_G)	0.33 kcal/Nm^3°C
Quantity of blow water	(B)	21,600 kg/day = 900 kg/h
Water temperature at the outlet of continuous blow equipment	(T_B')	93°C
Feedwater quantity	(W)	180,600 kg/day = 7525 kg/h
Feedwater temperature	(T_W)	66°C
(Softend water + recovered condensate)		
Steam pressure	(P)	11.5 kg/cm^2

Note 2: Amount of steam evaporation (S)

$S = W - B = 6625$ kg/h

Steam enthalpy	(E_S)	664.8 kcal/kg
Feedwater enthalpy	(E_F)	66 kcal/kg
Continuous blow water	(E_B')	93 kcal/kg

Note 3: Equations for calculating the heat balance

Input

Heat of fuel combustion (Q_C)

$Q_C = F \times Hl = 4679.3 \times 10^3$ kcal/h

Sensible heat of fuel (Q_S)

$Q_S = F \times C_P (T_F - T_O) = 13.5 \times 10^3$ kcal/kg

Output

Heat loss in steam (Q_V)

$Q_V = (W - B)(E_S - E_F) = 3967.0 \times 10^3$ kcal/h

Heat loss in exhaust gas (Q_E)

Theoretical amount of air (A_O)

$A_O = 0.85\ Hl/1{,}000 + 2.0 = 10.21$ Nm^3/kg

Theoretical amount of exhaust gas (G_O)

$G_O = 1.11\ Hl/1{,}000 = 10.72$ Nm^3/kg

Air ratio (m)

$m = 21/(21 - O_2) = 1.56$

Actual amount of exhaust gas (G)

$G = G_O + A_O (m - 1) = 16.44$ Nm^3/kg

$Q_E = F \times G \times 0.33 (T_G - T_O) = 599.9 \times 10^3$ kcal/h

Heat loss in blow water (Q_B)

$Q_B = B \times (T_B' - T_W) = 24.3 \times 10^3$ kcal/h

Heat loss radiated by furnace body and other heat losses (Q_R)

Heat loss radiated by furnace body (Q_r)

$Q_r = 60.3 \times 10^3$ kcal/h

Other heat losses (Q_O) (balance)

$Q_O = 41.3 \times 10^3$ kcal/h

$Q_R = Q_r + Q_O = 101.6 \times 10^3$ kcal/h

6 Problems in Heat Control and Potential Solutions

6.1 Insulation

6.1.1 Insulation of Equipment in the Nylon Factory

Measurements of surface temperatures of production equipment in the nylon factory are shown in the attached tables. Except for the flanges, the areas near manholes, polymerization tower tops, and some other sections, the surface temperatures were low, indicating effective insulation. Heat loss from the equipment was very low.

Attached tables:

- Surface Temperature Records of Towers, Tanks, etc. in Nylon Factory
- Surface Temperatures of Lactam Storage Tanks

6.1.2 Improved Insulation on DW Head Tank

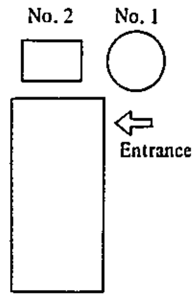
The evaporater of the distilled water equipment was sufficiently insulated, and its surface temperature was approximately 50° C. However, the temperature was high near the bottom and at the flanges.

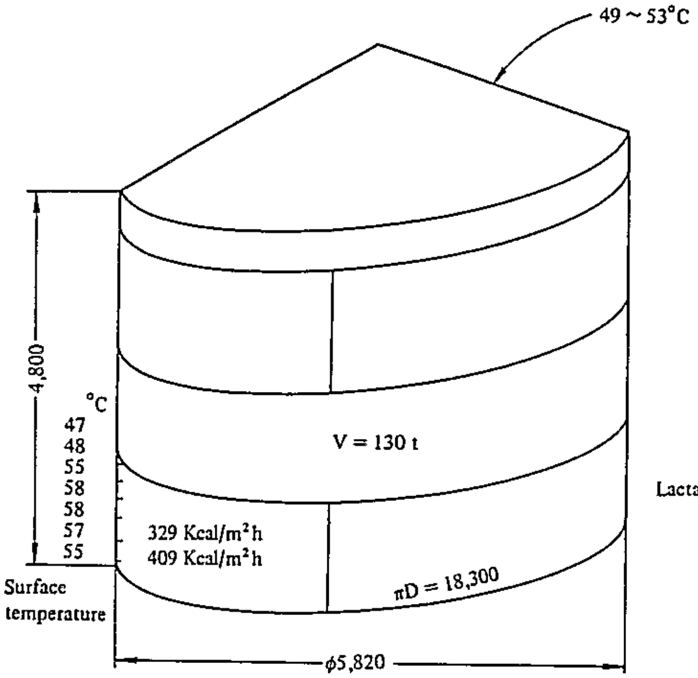
The following trial calculations can be made on energy savings that would be achieved by reinforcing insulation of these sections to lower their surface temperatures to 60° C. (Insulation material: Glass wool, thickness 25 mm)

	Bottom dished Plate		Flanges	
Surface Area	0.41 m^2		0.65 m^2	
	Now	After	Now	After
Surface Temperature °C	97	60	91	60
Convection Heat loss kcal/h	111	56	226	87
Radiant Heat loss kcal/h	180	64	197	101
Total kcal/h	291	120	423	188
Decrease of Heat loss kcal/h	171		235	

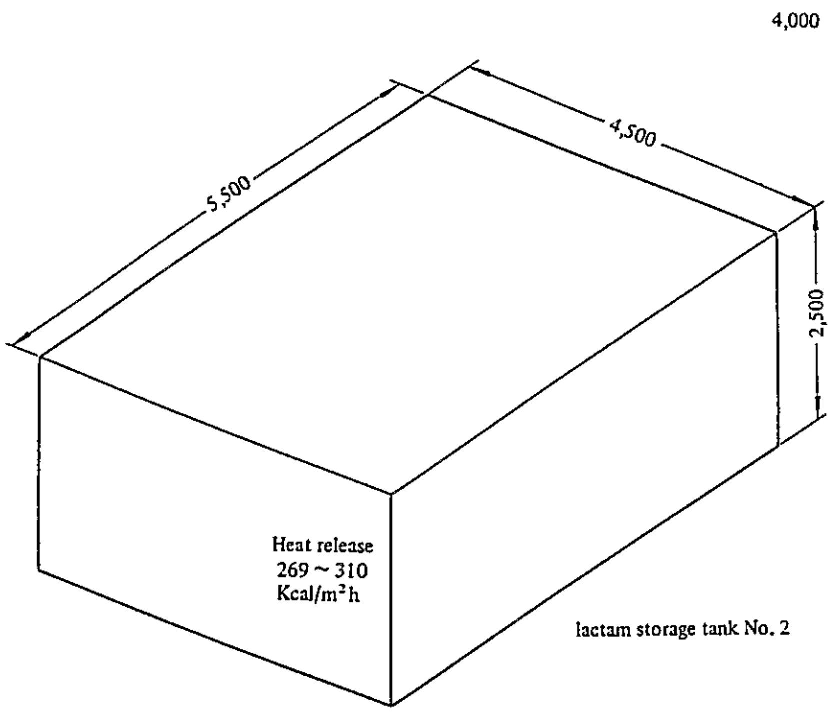
Recording List of Surface Temperature of Nylon Factory's Towers and Tanks

No.	Equipment			Surface temperature °C	Remarks	
(1)	Lactam head tank No. 1	T–100		40		5F
(2)	Lactam head tank No. 2	T–200		47		"
(3)	Lactam head tank No. 3	T–700		54		"
(4)	Slurry setting tank	TA–500		39		"
(5)	Re-slurry tank	TA–100		37		"
(6)	Diluted water head tank	Evaporator	at surface of insulation on body	53		"
		"	at flange	91		"
		"	at bottom	97		"
(7)	Polymerization tower	T–700 Surface of insulation	No. 1	81		4F
(8)	"		No. 2	75		"
(9)	"		No. 3	83		"
(10)	"		No. 4	73		"
(11)	"		No. 5	98		"
(12)	"		No. 6	85		"
(13)	"		No. 7	78		"
(14)	"		No. 8	61		"
(15)	"		No. 9	56		"
(16)	"		No. 10	74		"
(17)	Preparation tank	No. 1~4		40 ~ 57		"
(18)	Polymerization tower			42	Surface of insulation	3F
(19)	Lactam circulation tank	T–100		47		"
(20)	"	T–200		47		"
(21)	"	T–700		54		"
(22)	Lactam storage tank	Steam jacket		40	Surface of insulation	2F
	"	Top		44		
(23)	Spinneret preheater	Side		48 ~ 67		"
	"	Top		62 ~ 96		
(24)	Extractor tank No. 8	Side		145	(98°C)	"
	"	Manhole (top)		84		
	"	Top head plate		48		
	" No. 5	Side		43		"
	"	Manhole (top)		82		
	"	Top head plate		52		
(25)	Vacuum dryer	Side		47	(149~166°C)	1F
	"	Manhole		65		
(26)	Hot water tank No. 4			35		





Lactam storage tank No. 1



lactam storage tank No. 2

$$\text{Electric Energy Savings} = \frac{(171 + 235)\ \text{kcal/h} \times 24\ \text{h/day} \times 365\ \text{day/year}}{860\ \text{kcal/kWh}}$$

$$= 4{,}150\ \text{kWh/year}$$

Saved Power Charges 1.45 Bt/kWh x 4,150 kWh/year = 6,000 Bt

The cost for this plan is estimated at about 800 Bt

6.1.3 Heat Loss Reduction of Lactam Recovery Tanks

Two outdoor tanks at the entrance to the lactam recovery plant store liquids which are heated by steam to a fixed temperature.

As shown in the diagram, their surface temperatures are not so high. However, the tanks are large, and insulation could greatly reduce the heat loss.

(1) Heat Loss of Cylindrical Tank

		Now	After
Convective heat loss	kcal/h	11,357	3,057
Radiant heat loss	kcal/h	8,547	4,182
Total		19,904	7,239

Annual Fuel Saving

$$\frac{(19{,}904 - 7{,}239) \times 24\ \text{h} \times 365\ \text{days}}{(9{,}654 + 28) \times 0.84 \times 0.954} = 14.4\ \text{kl/year}$$

Fuel Savings

$14.4 \times 10^3 \times 4.5 = 64{,}600$ Bt/year

Approximate cost for insulation is: 80,000 Bt

Specifications

Tanks Dimensions	5,820 mm outside diameter 4,800 mm height
Insulation Material	Glass Wool
Thickness of insulation	25 mm
Surface temperature	53°C
Atmospheric temperature	30°C
Boiler efficiency	84%

(2) Heat Loss of Square Tank

		Now	After
Convective heat loss	Kcal/h	16,824	2,403
Radiant heat loss	Kcal/h	5,130	2,727
Total		11,694	5,130

Annual Fuel Savings

$$\frac{(11{,}694 - 5{,}130)\ \text{kcal/h} \times 24\ \text{h} \times 365\ \text{days}}{(9{,}654 + 28) \times 0.84 \times 0.945} = 7.3\ \text{kl/year}$$

Fuel Savings 33,300 Bt/year

Approximate cost for insulation is: 49,000 Bt

Specifications

Tank dimensions 4,500 width x 5,500 length x 2,500 height mm

Insulation material	Glass wool
Thickness of Insulation	25 mm
Surface temperature	Now: 54°C After: 40°C

6.1.4 Electric Heating

The surface temperatures of the electric heaters were generally lower than 65° C. However, the following units had high temperatures.

Equipment	Capacity x No. of units	Average surface temperature
Lower Heater	20 KW x 10 sets	140 ~ 165°C
Extraction	40 x 3	81
Depolymerization Heater	40 x 5	211
Upper Heater	15 x 10	160 ~ 220
Nylon		
Spinning (old type)	2 x 2	70
Spinning (new type)	10 x 5	90
Polyester		
Spinning	12 x 6	100
Total	796	

Assuming that 30% of the power is lost by radiation, the following energy savings could be anticipated by reducing this heat loss by 10%.

Power savings 7.96 KW x 0.3 x 0.1 = 23.9 KW

23.9 KW x 24 x 365 days = 209,200KWH/year

6.1.5 Piping for Boiler System

The insulation on steam pipes was generally safisfactory. However, insulation and shortening of boiler feed water pipe are necessary. The following sections were not insulated on the low-pressure boiler feedwater lines: Approx. 8m of 3" pipe from the feedwater tank to the feedwater pump, approx. 4m of 2" pipe on the pump discharge side, approx. 11m of 3" pipe on the pump discharge side, continuous blow equipment body, and approx. 25m of 3" pipe (surface temperature 72°C) after the continuous blow equipment.

The same situation exists with the high pressure boiler. The pipe lengths are long from the feedwater tank to the continuous blow equipment, and these pipes are installed outdoors. Heat losses are large particularly on rainy days.

Energy savings when the feedwater temperature raises 5° C will be as follows:

High pressure boiler

Amount of feedwater 4,683 kg/h

Boiler efficiency 83.9 %

$$\frac{4{,}683 \text{ kg/h} \times 5 \text{ kcal/kg} \times 24 \text{ h/day} \times 365 \text{ day/year}}{(9{,}654 + 28) \text{ kcal/kg} \times 0.839 \times 0.945} = 26.7 \text{ kl/year}$$

Low pressure boiler

Amount of feedwater 7,525 kg/h

Boiler efficiency 84.5 %

$$\frac{7{,}525 \text{ kg/h} \times 5 \text{ kcal/kg} \times 24 \text{ h/day} \times 365 \text{ day/year}}{(9{,}654 + 28) \text{ kcal/kg} \times 0.845 \times 0.945} = 42.6 \text{ kl/year}$$

In general, heat loss from all boilers was great. Some sections near the burners in the front were hot, with the surface temperature reaching 135° C. Internal burner tiles should be checked, or asbestos insulation added to the surfaces. Insulation is required also from the standpoint of safety.

6.2 Boiler Control

The operating states was properly recorded in a daily report. It is recommended that evaporation multiples (ratio between amounts of feedwater and fuel) be calculated periodically and entered in the daily report.

The air ratio for the low-pressure boiler was slightly high at 1.56, and this level should be reduced below 1.3. An attempt should be made to reduce the oxygen content in exhaust gas below 4% by periodically checking and maintaining burner nozzles and by adjusting dampers. By using low oxygen burners, the oxygen content can be lowered to 1.5~2.0%. The percentage of carbon dioxide in exhaust gases was measured. However, values for oxygen content were more sensitive.

The temperature of exhaust gas was slightly high. The air ratio should be reduced, and blow-cleaning of soot should be regularly conducted.

By reducing the air ratio from 1.56 to 1.3, exhaust gas losses will decrease 16%, and fuel can be saved by approximately 2.3%.

4,493 kl/year x 0.023 = 103.3 kl/year

The exhaust gas thermometer for the low-pressure boiler was damaged and should be replaced.

6.3 Boiler Water Control

The blow rate of the high-pressure boiler is 7% and that of the low pressure boiler, 12%. According to the records, the amount of water in the high-pressure boiler was slightly higher than the reference value, and water control seems to require more attention.

The pH level should be 9.2 to 10.8; total evaporation residues, less than 300 mg/l; electrical conductivity, less than 500 μS/cm; Cl^-, below 50 mg/l and PO_4^{-3}, approximately 3 to 10 mg/l.

The amount of impurity in the low-pressure boiler water was at a particularly high level. The boiler water should be controlled to attain a pH of 10.8 to 11.3; M alkalinity, less than 600 $CaCo_3$ mg/l; total evaporation residues, less than 2,000 mg/l; electrical conductivity, less than 3,000 μS/cm; Cl^- less than 300 mg/l and PO_4^{-3}, 20 to 40 mg/l.

In the low-pressure boiler, feed water was softened water. The quality of boiler feedwater improves when the mixing ratio of recovered condensate which is close to pure water, is increased, and the blow rate can be reduced. By reducing the blow rate of the low-pressure boiler to 8%, the following fuel savings will be possible.

Feedwater quantity per day	180,600 kg/day
Blow rate of 12%	21,600 kg/day
Boiler efficiency	84%,
Blow rate of 8%	14,450 kg/day

$$\frac{(21{,}600 - 14{,}450)\text{kg/day} \times (93^\circ C - 66^\circ C) \times 365 \text{ day/year}}{(9654 \text{ kcal/kg} + 28 \text{ kcal/kg}) \times 0.84 \times 0.945} = 9.1 \text{ kl/year}$$

6.4 Effective Utilization of Flash Steam

The heating temperatures of equipment using steam in a nylon manufacturing process are not equal. A vacuum dryer is heated to 149—166° C, and an extractor, to 98° C. It will be effective to utilize flash steam generated to the low-pressure line by leading the high-pressure condensate to a flash tank.

Using condensate at a pressure of 8 kg/cm^2 as an example, the amount of steam generated when the steam pressure on the secondary side is 2.0 kg/cm^2, will be 8.4% of the condensate.

Calculations:

(f)	Flash ratio	
(h_1')	Enthalpy of saturated condensate at steam pressure 8 kg/cm^2 before flashing	176.7 kcal/kg
(h_2')	Enthalpy of saturated condensate at steam pressure 2 kg/cm^2 after flashing	133.4 kcal/kg
(r)	Latent heat of evaporation at steam pressure after flashing	517.1 kcal/kg

Amount of flash evaporation

$$f = \frac{h_1' - h_2'}{r} \times 100 = 8.4\%$$

Of the amount of potential heat in condensate the proportion transferred to flash steam will be:

$$\frac{650.6 \times 0.084}{176.7} = 30.9\%$$

as the steam enthalpy at 2 kg/cm^2 is 650.6 kcal/kg.

This flash steam can be utilized to warm tanks, etc., and the remaining low-pressure condensate can be utilized as boiler feed water.

Assuming flash steam is utilized for about half of the low-pressure line condensate, the fuel savings can be calculated as follows. (when flashing 8 kg/cm^2

condensate to 2 kg/cm^2)

Amount of reduced heat loss

$$7{,}000 \text{ kg/h} \times 0.5 \times \{176.7 \text{ kcal/kg} - (1 - 0.084) \times 133.4 \text{ kcal/kg}\}$$
$$= 190.8 \times 10^3 \text{ kcal/h}$$

Fuel savings

$$\frac{190.8 \times 10^3 \times 24 \text{ hrs} \times 365 \text{ days}}{(9{,}654 + 28) \text{ kcal/kg} \times 0.84 \times 0.945} = 216.2 \text{ kl/year}$$

6.5 Recovery of Condensate

Some condensate is recovered from both high- and low-pressure lines. However, the recovery rate appears low. Demineralized water and softend water supplied to the feedwater tanks should be measured, calculating and recording the amount of condensate recovered based on the measured amount and the reading of the feedwater meter.By increasing the recovery rate, the feedwater temperature goes up, and the blow rate can be reduced by improving feedwater quality.

About 35% of the amount of evaporation in the low-pressure boiler is used in the nylon recovery process and 10% of this is recoverd. The following amount of condensate is discarded at present:

$$191 \text{ t/day} \times 0.35 \times 365 \text{ day} \times (1 - 0.1) = 22{,}000 \text{ t/year}$$

Assuming that 80% of condensate is recovered at atomospheric pressure, the heat recovered is,

$$\frac{22{,}000 \text{ t/year} \times (100 - 30)\text{kcal/kg} \times 0.8}{(9{,}654 + 28)\text{kcal/kg} \times 0.84 \times 0.945} = 159.4 \text{ kl/year}$$

7. State of Electric Power Consumption

7.1 Principal Data Relating to Power Consumption

- Power company : MEA
- Peak demand : 5,700 kW
- Electric energy used : 3,500,000 kWh/month
- Load factor : 85.0%
- Penalty : None
- Power factor : 98%
- Transformers : 12,500 kVA (4,000 kVA x 3 + 500 kVA x 1)
- Fuel consumption rate : 3,435 kWh/kg

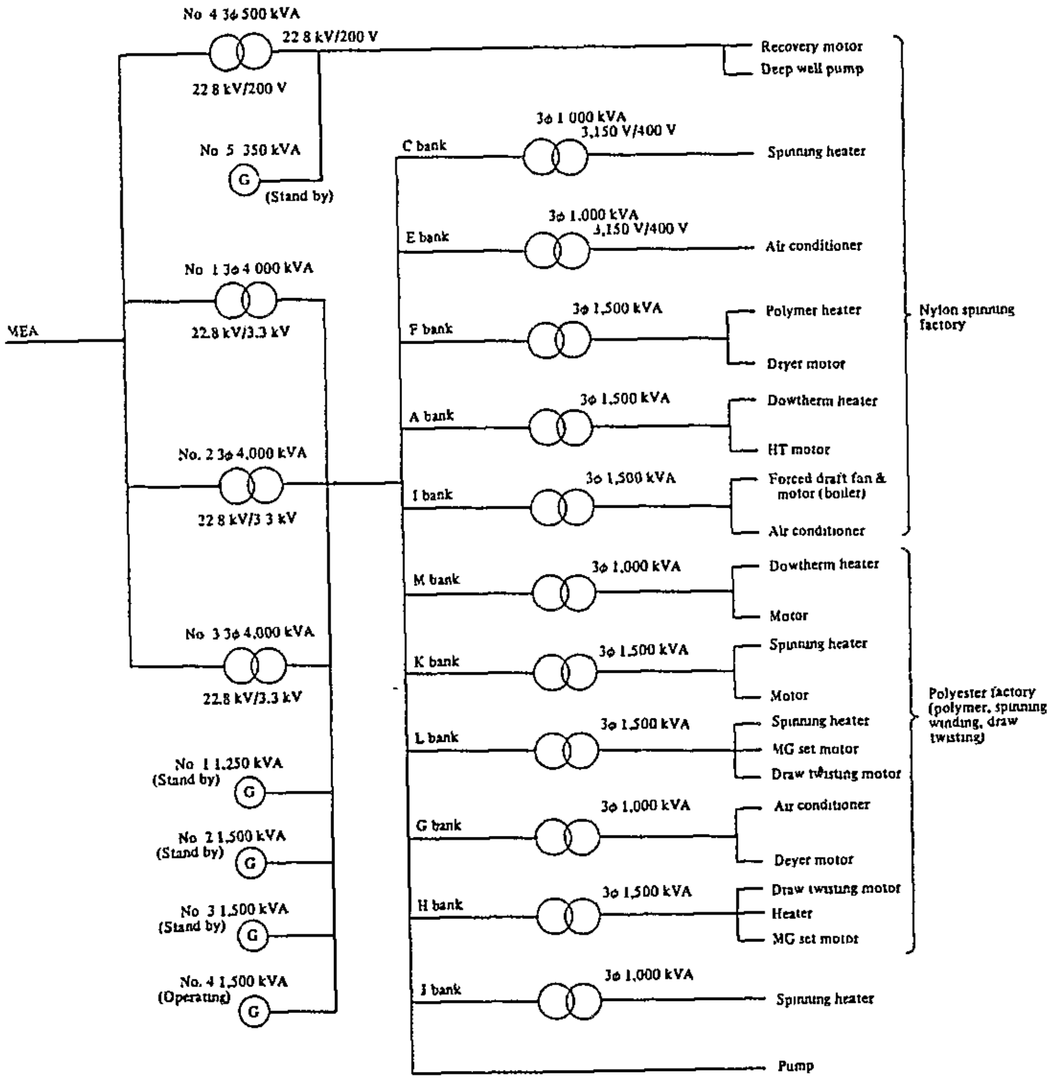
7.2 Load Distribution

- Motor : 47.4%
- Air conditioning : 18.0%
- Lighting : 0.9%
- Electric heating : 30.6%

- Compressor : 3.1%

Total 100 %

7.3 One Line Diagram



7.4 Proportion of Electric Power Consumption

Approximately 90% of the electric power consumed by the factory is received from MEA. The most critical production processes are connected to diesel generators to depress the production loss minimum in the event of a utility power failure.

A total of five diesel generators capable of generating 6,100 kVA are installed: 1,500 kVA x 3 units, 1,250 kVA x 1 unit, and 350 kVA x 1 unit. Of these five diesel generators, one 1,500 kVA generater is in operation at present.

8. Problems in Electric Power Control and Potential Solutions

8.1 Significant Achievements

There were very few problems found at this factory. Control at the factory achieved the following:

8.1.1 Improvement of Power Factor

The factory has an extremely high power factor of 98% achieved by installing phase advancing capacitors, indicating that the factory is making a great effort to effectively utilize power.

8.1.2 Air Conditioning

The spinning process requires control of constant temperature and humidity, and air conditioning is used at optimal set values.

Efforts have been made to effectively insulate buildings to save energy.

The heads of the four cooling towers (37 kW x 4 units) on the roof of the nylon process building were large and consumed much electric power. The use of these cooling towers was discontinued, and four 11-kW cooling towers have been installed on the ground, achieving substantial energy savings of 104 kW.

8.1.3 Transformers

The factory has three 4,000-kVA receiving transformers and one 500-kVA unit. Because the load has been reduced, one of the three 4,000-kVA transformers is disconnected, and the remaining transformers are operated at high efficiency.

Eleven distribution transformers are installed. The transformers with light loads are cut off. The load is combined with that of other transformers on the secondary side, and the distribution transformers are operated at high efficiency in load factors of 60 to 100%.

8.2 Problems and Potential Solutions

(1) Power Control

a. Hourly records in the daily report for power received should be utilized for energy conservation control, for example, multiplying by a multiplication factor to the reading of meters and recording the differences of them or by determining the trends by preparing control charts recording differences in "readings" of energy meters.

b. A load curve for the day should be prepared at least once a week based on records of hourly electric power consumed to make the load more even.

(2) Equipment Control

a. Motors

- The factory has been continually expanded, and it is essential to closely examine whether the present water and air piping routes, pressures and amounts of water and air are appropriate.

The load factors, namely, $\frac{\text{Actual loads}}{\text{Rated capacities}}$, of 19 large-capacity motors in the nylon, polyester, and service processes were measured. Most of them were being operated at high efficiency of load factor 80 to 100%. However, some were operated at low loads of approximately 30%.

Process	Capacity	Units	Load Factor
Nylon Process			
• Draw twist	22 kW	16	32.7%
• Draw twist	11	16	37.3
• Winding	15	5	35.3
• Melting-Spinning	15	5	30.7
Polyester Process			
• Synchronous	60	6	25.6

It is possible that these motors were being operated at low loads only when the measurements were made. Therefore, data should be continually gathered, and the motors should be replaced with those having optimal capacities at an opportune time. A trial calculation of energy savings using this plan is shown in the following.

(Motor capacity)	(Efficiency)	(Loss)	(Number of units)	(Reduction of loss)
kW	%	kW		kWh/year
22→7.5	81.5→82.0	4.07→1.35	16	381,235
11→5.5	86.5→86.0	1.48→0.77	16	100,214
15→5.5	87.0→86.0	1.95→0.77	5	51,684
15→5.5	86.0→86.0	2.10→0.77	5	58,254
60→18.5	88.0→91.5	7.20→1.57	6	295,781
			Total	887,168

Electric power savings 887,170 kWh/year

Saving ratio 887,170 kWh/year ÷ 42,000,000 kWh/year ≒ 2.1%

• The belts on the transmission shafts of the motors in the spinning process (total 420 kW; nylon process, 198 kW; polyester process, 222 kW) are single-ply belts made of rubber. By replacing them with energy conservation belts, transmission losses will be reduced, and approximately 4% of the energy can be saved.

Power savings 420 kW x 0.04 = 16.8 kW

electric power savings 16.8 kW x 24 h x 365 day = 147,200 kWh/year

Saving ratio 147,200 kWh/year ÷ 42,000,000 kWh/year ≒ 0.4%

b. Illumination

- The illumination in each process was measured with the following results.

	N Process	P Process
Draw twist	123 lux	264 lux
Draw C.R	90	80
Winding	181	309
Winding C.R	52	231
Spinning	78	148
Spinning C.R	64	310
Keep to draw twisting	90	105
Main C.R	35	—

The CR (Control Room) is the center for energy conservation and some degree of illumination is required for work and monitoring. The illuminante in the CR should be about 200 lux.

Note: "N Process" and "P Process" denote the nylon and polyester processes.

- By changing 2,500 40-W ordinary fluorescent lamps to energy conservation types and by exchanging 44 150-W outdoor fluorescent mercury lamps to high-rendition, high pressure sodium lamps, the following energy savings can be achieved:

Electric power savings {(40 w x 2,500 x 0.1 x 24 h) + (150 w x 44 x 1/2 x 12 h)}
x 365 day ≑ 102,050 kWh/year

Saving ratio 102,050 kWh/year ÷ 42,000,000 kWh/year
≑ 0.2%

c. Air Conditioning

- Temperature and humidity are finely adjusted for adequate industrial air conditioning. The results of measurements generally endorsed these efforts, showing that air conditioning is appropriate.

	Setting		Measurements	
Nylon Process				
Draw twist	28°C	60 ~ 70%	27°C	81%
Winding	19	58 ~ 61	20	46
Spinning	30	50 ~ 59	34	48
Keep to D.T	26	60 ~ 62	26	64
Polyester Process				
Draw twist	27°C	40 ~ 45%	29°C	55%
Winding	30	60 ~ 65	30	75
Spinning	35	38 ~ 40	35	37
Keep to D.T	29	70 ~ 75	29	67

- The number of water washers to humidify and cool the circulating air in each process is shown in the following. The nozzle diameters are 4 mm.

	Nylon Process			Polyester Process		
Room	Installed	In use	Number of nozzles	Installed	In use	Number of nozzles
Q	1	1	360	1	1	312
TU	2	1	510	1	1	130
C_1	1	1	168	1	1	276
C_2	1	—	96	1	—	130
D_1	1	1	700	1	1	660
D_2	1	1	200			
Total			2,034			1,508

We understand that studies are being made to save water, which means electric power, without affecting product quality, by changing the nozzle diameters or by other means, after analyzing whether or not the current amount of washer water is optimal. This plan is encouraged.

d. Diesel power generators are used for critical processes when utility power fails. If trouble caused by power failures can be prevented by appropriate utilization of delay relays, etc., the diesel power generators should normally be idle from the standpoint of power generation cost. When the generator is used continuously, waste heat recovery should be studied to improve total energy efficiency.

e. Elimination of Head Tanks, etc.

A study should be made to reduce the number of head tanks for hot water, etc. in the processes whenever possible to save power consumption.

9. Summary

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

	kl/year	%
Reinforced insulation	91.1	1.3
Lower air ratio	103.3	1.5
Improved feedwater quality	9.1	0.1
Utilization of flash steam	216.2	3.2
Recovery of condensate	159.4	2.4
Sub Total	579.1	8.6

	10^3 kWh/year	%
Changes of motor capacity	887.2	2.1
Change of motor belt mateiral	147.2	0.4
Reinforced insulation of electric heating equipment		
D.W. head tanks	4.2	0.5
Heaters	209.2	
Higher efficiency lamps	102.0	0.2
Sub Total	1,349.8	3.2

Report No. 9: Textile

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

— The Bangkok Nylon Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Bangkok Nylon Company —

1. Outline of the Factory

Address	113 Ramintra Road Umphur Bangkhen	
Capital	40 million Bt	
Type of industry	Manufacture of nylon socks	
Major products	Stocks and underwear	
Annual products	1,200,000 dozens	
No. of employees	550	
Annual energy consumption	Electric Power	2,112,000 kWh
	Fuel	Fuel oil 320 kℓ
Interviewees	Mr. Sersh. Factory Manager and one other person	
Date of diagnosis	February 8 ~ 9, 1983	
Diagnosers	K. Nakao, Y. Ohno and M. Matsuo	

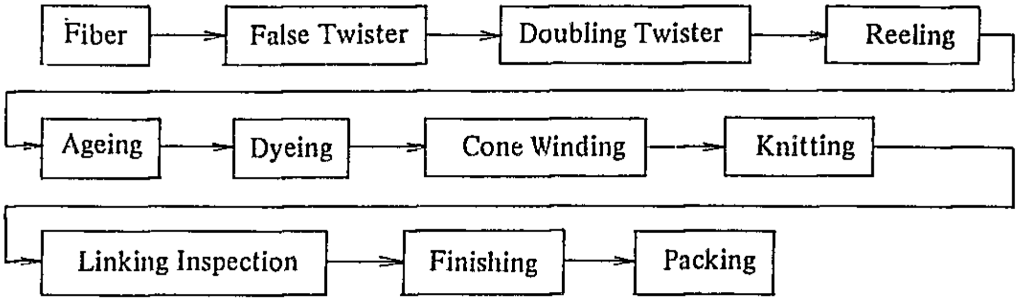
Bangkok Nylon Company was established as a joint venture with Toray Industries, Inc., Mitsui & Co. and Nichinan of Japan in 1965. It embarked upon the domestic production of socks, the import of which was growing at that time.

The number of knitting machines in use has increased from 70 in 1965 to 347, the biggest level among socks manufacturing factories in Southeast Asia. The products of the factory are sold in the domestic market under a variety of brands, and 20% of them are exported to Japan, Southeast Asia and the rest of the world. A subsidiary company, established on a basis of a joint venture with Japan, manufactures elastic yarns and other products.

The ratio of energy costs against sales proceeds is as low as 3%. Still, the company is studying the possibility of replacing the fuel source with natural gas.

New models of knitting machines have been installed in the factory. The rate of defective products is only around 3%.

2. Manufacturing Process

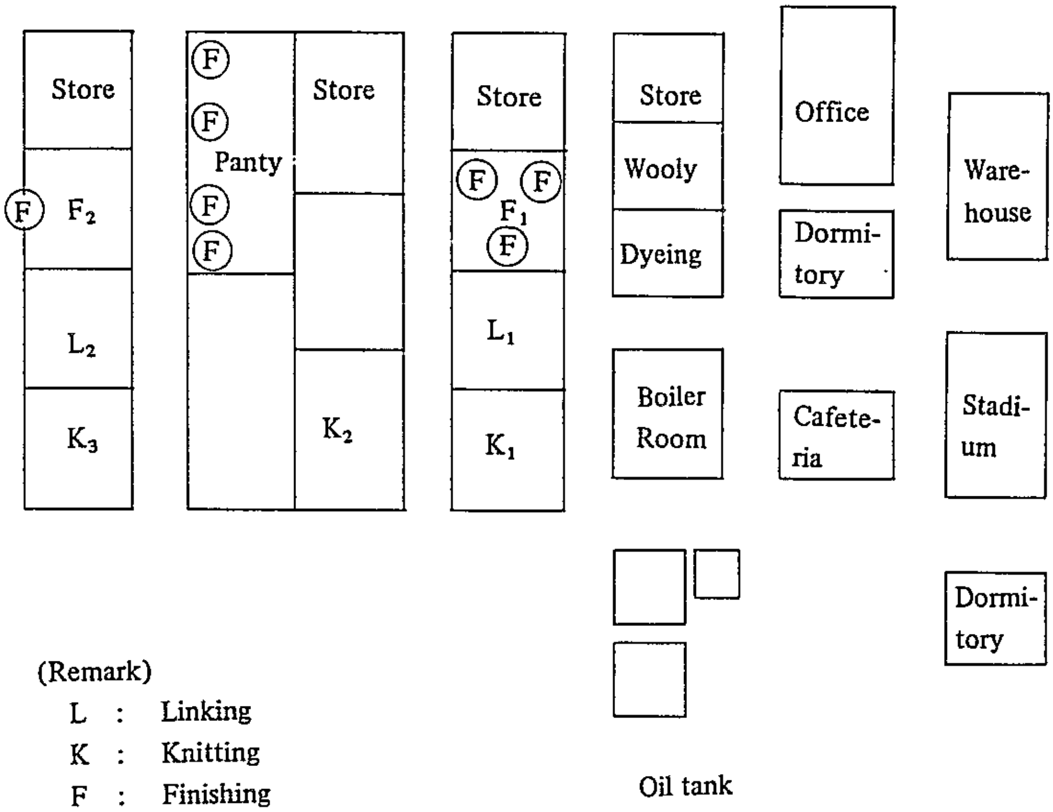


3. Major Equipment

3.1 Major Equipment

Name	No. of units installed	Type, etc.
Boiler	2	3 t/h (6.6 kg/cm^2)
Ageing chamber	1	
Dyeing machine	5	1 unit for normal pressure 4 units for increased pressure (50 kg/cm^2)
Finishing machine (heat setter)	4	
Knitting machine	347	150 kW
Twisting machine	4 lines	32 kW
Air conditioner		
Central type	3	55 kW
Package type	9	65 kW
Total	12	120 kW

3.2 Layout



(Remark)

L : Linking

K : Knitting

F : Finishing

4. State of Energy Management

4.1 Investment in Energy Conservation and Cases of Improvement

Although the company has no systematic energy conservation program with specific targets, cases of improvement achieved heretofore are witnessed in;

- Insulation of steam pipes,
- Replacement of steam traps,
- Moving fluorescent lights to a lower position,
- Division of circuits to enable unnecessary lights to be turned off easily,
- Reduction in the number of fluorescent lights.
- Air conditioners are installed only in areas where high products are manufactured. The ceilings of the new factory are built higher in order to alleviate the stuffy heat.

The company has not spent much money on energy conservation measures so far, but said that it was going to make positive investment in any measures which could recover funds within two years.

4.2 Grasp of Energy Consumption

(1) A record of electric power consumption is not kept in the factory, but is handled in the Main Office. For the purpose of promoting energy conservation programs, it is necessary to determine the power consumption at the factory level and to utilize the data as follows.

a. Hourly electric power consumption be recorded in a logsheet for this purpose.

b. As the load factor is as low as 57%, it should be elevated to a higher level and the peak load should be reduced through load analysis of major processes based on the daily load curve.

c. Power consumption rate should be calculated and its change be determined.

(2) Presently the peak demand is calculated from the slips of the Main Office. A reduction in demand should be studied through an analysis of load based on the detailed records filed by the factory. An attempt should be made to avoid starting too many machines at the same time.

(3) Presently, ammeters and voltmeters are equipped in the substations of the new factories A and B. In addition to them, wattmeters, watt-hour meters, power factor indicators, etc. should be installed to promote the energy conservation program.

4.3. Energy Conservation Committee and Suggestion System

The company does not have an organization functioning as an Energy Conservation Committee at present, but meetings on production, safety, quality, welfare, etc. are held from time to time, and energy issues are discussed in such meetings. A suggestion system has been implemented, and most suggestions are related to the improvement of safety and production processes.

4.4. Employee Training

The training of employees in the Sales Division is conducted through such means as video tapes. Managers may participate in various seminars held by TPA, and have the opportunity to visit Japan. Workers are encouraged to conserve steam and water verbally or by posters.

All employees should be involved in the effective implementation of the forthcoming energy conservation program. It will be necessary to organize pertinent groups such as an Energy Conservation Committee including foremans and to encourage small circle activities.

5. State of Fuel Consumption

The annual consumption of Bunker A, which is used for generating steam in boilers, is 320 kl. The steam is used as the heating source for the processes of ageing, dyeing and finishing. The boiler operates 16 hours per day.

5.1. Heat Balance in the Gebrüder Wagner Boiler

The evaporating amount could not be obtained because the feedwater flowmeter was not working. Therefore the heat balance depended partly on estimation.

Input			Output		
Item	10^3 Kcal/h	%	Item	10^3 Kcal/h	%
Heat of fuel combustion	1,045.0	99.6	Heat of steam	896.3	85.4
Sensible heat of fuel	4.5	0.4	Loss of heat in exhaust gas	115.4	11.0
			Heat release from boiler body, Others	37.8	3.6
Total	1,049.5	100.0	Total	1,049.5	100.0

5.2. Data Given for Calculation of the Heat Balance

Type of Fuel		Bunker A
Consumption of fuel	(F)	110 kg/h
Heat content of fuel (low level)	(Hl)	9,500 kcal/kg
Specific heat of fuel	(C_P	0.45 kcal/kg°C
Temperature of fuel	(T_F)	120°C
Reference temperature	(T_0)	30°C
Oxygen content in exhaust gas	(O_2)	7.3%

Temperature of exhaust gas	(T_G)	230°C
Temperature of feedwater	(T_W)	40°C
Steam pressure	(P)	6.6 kg/cm^{2}g
Loss of heat through the outer walls of boilers		
Longitudinal direction	(Q_L)	86 kcal/m^{2}h
Burner side wall	(Q_F)	127 kcal/m^{2}h
Rear side wall	(Q_B)	1036 kcal/m^{2}h
Boiler dimensions (outer dimensions)		ϕ2100 x 4170L
Test time		1.2 h

Equations for Calculating the Heat Balance

Input

Heat of fuel combusiton (Q_c) $Q_c = F \times Hl = 1{,}045.0 \times 10$ kcal/h

Sensible heat of fuel (Q_s) $Q_s = F \times C_P (T_F - T_o) = 4.5 \times 10^3$ kcal/h

Output

Heat loss in exhaust gas (Q_z)

Theoretical amount of air (A_o) $= (0.85\ Hl/1000) + 2.0 = 10.08$ Nm^3/kg

Theoretical amount of exhaust gas (G_o) $= 1.11\ Hl/1000 = 10.55$ Nm^3/kg

Air ratio (m) $= 21/(21 - O_2) = 1.53$

Actual amount of exhaust gas (G) $= G_o + (m - 1)A_o = 15.89$ Nm^3/kg

$$QE = F \times G \times 0.33(T_G - T_0) = 115.4 \times 10^3 \text{ kcal/h}$$

Heat loss from furnace (Q_R)

$$Q_R = 2.1\ \pi \times 4.17 Q_L + (2.1/2)^2 \pi Q_F + (2.1/2)^2 \pi Q_B = 6.4 \times 10^3 \text{ kcal/h}$$

Other heat loss (Q_o) . . . 3% of input heat

$$Q_o = 0.03\ (Q_c + Q_s) = 31.4 \times 10^3 \text{ kcal/h}$$

Heat of steam (Q_v)

$$Q_V = Q_C + Q_S - Q_E - Q_R - Q_O = 896.3 \times 10^3 \text{ kcal/h}$$

Amount of steam evaporation (S)

Steam enthalpy (E_s) = 660.3 kcal/kg

Feedwater enthalpy (E_F) = 40.0 kcal/kg

$$S = Q_v \div (E_s - E_F) = 1{,}445 \text{ kg/h}$$

5.3. Calculation of Heat Efficiency

Heat efficiency was calculated using the factory data of Oekonom-Kessel (Sabel & Scheurer) boiler in November, 1982.

Type of Fuel		Bunker A
Fuel consumption	(F)	32,870 l/mon. = 95.4 kg/h
Heat content of fuel (low level)	(Hl)	9,500 kcal/kg

Specific heat of fuel	(C_F)	0.45 kcal/kg°C
Specific group of fuel		0.975
Fuel temperature	(T_F)	120°C
Reference temperature	(T_o)	30°C
Quantity of feedwater	(W)	425,000 l/mon. = 1,265 kg/h
Feedwater temperature	(T_w)	33°C
Steam pressure	(P)	6.6 kg/cm^{2}g
Quantity of blow water	(B)	13 kg/h (assuming 1% of feedwater)
Blow water temperature		167°C
Working days		21 day
Working hours		16 h/day

Evaporation ratio = (W − B)/F = 13.1

Conversion factor = (E_s − E_F)/538.8 = 1.16

(E_s) Steam enthalpy = 660.3 kcal/kg

(E_F) Feedwater enthalphy = 33 kcal/kg

Conversion evaporation ratio = (W − B)/F x (E_s − E_F)/538.8 = 15.20

$$\text{Boiler efficiency} = \frac{(W - B)(E_s - E_F)}{F \times Hl + F \times C_p \times (T_F - T_o)} = 86.3\%$$

6. Problems in Heat Contorl and Potential Solutions

6.1. Boiler Control

One of the two boilers has just been replaced. The older boiler is being maintained adequately and boiler room is in good order. The boiler logbook is updated regularly. Proper heat control with the knowledge of heat efficiency change for each boiler requires data on daily fuel consumption and quantity of feedwater. Currently, the fuel consumption for each boiler can be obtained, but there is only one feedwater flowmeter available exclusively for the older boiler. It is recommended that the position of the flowmeter be shifted so that the figures for the new boiler may also be obtained or that a new feedwater flowmeter be installed for the new boiler.

6.2. Insulation for Boilers and Related Equipment

As the steam trap equipped to a 3,000 kl bunker oil service tank is not working well, the steam leaks into the feedwater tank. If the oil is bunker A, preheating is not needed and steam can be stopped. The heat released from the steam header is limited because it is well insulated, even as far as the valves equipped at the top.

Temperatures measured are as follows:

Side wall of the steam header: 54°C

Flange of the steam header: 63°C

Upper valve of the steam header:52°C

Measurement of the surface temperature of the new boiler which was in operation on that day, showed that the temperature of the side wall was 44°C, but that the temperature at the rear access door of cleaning was as high as 103°C.

6.3. Temperature of Boiler Exhaust Gas

Measurement of the exhaust gas pointed to 170°C during low combustion and 230°C during high combustion. These figures are reasonable for a bunker firing boiler.

6.4. Air Ratio

There is charged too much air during high combustion. The damper at the air inlet of the oil burner should be adjusted to the point just before black smoke comes out of the chimney so that the oxygen content can be reduced to 4.5%.

Oxygen content in exhaust gas: 7.3%

Air ratio: $m = 21/(21 - O_2) = 1.53$

If the air ratio is improved to the level of m = 1.3, there will be a 2% fuel savings, which is equivalent to about 30,000 Bt/year (320 kl/y x 0.02 = 6.4 kl/y). The effects would be impressive.

6.5 Insulation of Steam Equipment

(1) The steam pipes are generally well insulated. However, the reducing valves, solenoid valves, bypass pipes, joints, etc. at the inlet of the ageing chamber should also be insulated.

The heat loss from major valves and reducing valves is as follows:

As to one 3/4" reducing valve, seven 3/4" valves, (equivalent pipe length is 5.91 m) and 3/4" pipe 1.5 m in length, when steam pressure is 2.5 kg/cm^2 the released heat would come to 138 kcal/mh x (5.91 m + 1.5 m) = 1,023 kcal/h. Assuming that the boiler efficiency is 85% and the insulation efficiency is 75%, heat saving by insulatoin, as converted into fuel consumption is as follows:

$$\frac{1{,}023 \text{ kcal/h} \times 16 \text{ h} \times 300 \times 0.75}{9{,}500 \times 0.85 \times 0.945} = 0.5 \text{ kl/year}$$

This figure would be larger if other 1/2" pipes and joints, etc. is also insulated.

(2) As to the four setting machines, the pipe between the steam inlet value and the machine and the steam trap bypass pipe on the side of exhaust should also be insulated. The length of the steam pipes to the setting machines should be shortened as much as possible. Consideration should also be given to the out door pipe so that rainwater cannot leak into the insulating materials.

(3) Insulation for Water Tank in the Dyeing Room

Much heat is lost from the side and bottom of the tank which makes up warm water by direct steam blow into it, as well as from the surface of the warm water. It is necessary to insulate the side and bottom of the tank and to use insulation floats to cover the surface of the warm water. The reduced heat loss by these measures as converted into the fuel consumption is as follows:

- Surface area of warm water tank: 4.4 m^2,
  Surface area of warm water: 1.04 m^2
- Heat released from warm water tank: 820 kcal/m^2h x 4.4 m^2 = 3,608 kcal/h
- Insulation efficiency: 75%
- Heat released from the surface of the warm water: 7,400 kcal/m^2h
- Heat released from the surface of the warm water when insulation floats are used: 2,100 kcal/m^2h

Thus,

$$(7400 \text{ kcal/m}^2\text{h} - 2100 \text{ kcal/m}^2\text{h}) \times 1.04 \text{ m}^2 = 5512 \text{ kcal/h}$$

$$\frac{5{,}512 \text{ kcal/h} \times 16 \text{ h/day} \times 300 \text{ day/year}}{9{,}500 \text{ kcal/kg} \times 0.85 \times 0.945} + \frac{3{,}608 \text{ kcal/h} \times 16 \text{ h/day} \times 300 \text{ day/year} \times 0.75}{9{,}500 \text{ kcal/kg} \times 0.85 \times 0.945} = 5.2 \text{ kl/year}$$

The pipes blowing steam into the warm water tank, which are about 7 meters in length, are bare. Assuming steam pressure is 5.5 kg/m^2, the released heat from the pipes would be 174 kcal/mh.

The reduced heat loss by insulating these pipes as converted into the fuel consumption is as follows:

$$\frac{174 \text{ kcal/mh} \times 7 \text{ m} \times 16 \text{ h/day} \times 300 \text{ day/year} \times 0.75}{9{,}500 \text{ kcal/kg} \times 0.85 \times 0.945} = 0.6 \text{ kl/year}$$

(4) Hank Dyeing Machine

Not withstanding the relatively high surface temperature, the hank dyeing machine is not insulated enough. If the insulation efficiency is 75%, the volume of fuel saving after insulation is estimated as follows:

- Surface area: 10 m^2
- Average surface temperature: 75°C
- Released heat: 560 kcal/m^2h

Thus,

$$\frac{560 \text{ kcal/m}^2\text{h} \times 10 \text{ m}^2 \times 16 \text{ h} \times 300 \text{ days} \times 0.75}{9{,}500 \text{ kcal/kg} \times 0.85 \times 0.945} = 2.6 \text{ kl/year}$$

(5) Pressure-type Dyeing Machine

If the shell and bottom of the 50 kg/cycle dyeing machine is insulated the reduction of heat loss as converted into fuel consumption is as follows:

- Surface area of the tank shell and bottom: about 3.7 m^2
- Released heat: 427 kcal/m^2h
- Average heating time: 160 minutes
- Number of charge: 4 per day

Thus,

$$\frac{427\ kcal/m^2h \times 3.7\ m^2 \times 10.67\ h/day \times 300\ day/year \times 0.75}{9{,}500 \times 0.85 \times 0.945} = 0.5\ kl/year$$

If three other dyeing machines is also insulated, reduction of heat loss would be much greater.

6.6. Utilization of Heat of Dyeing Cooling Water and Dyeing Solution

As the temperature of the cooling water rises through the dyeing machine, it can be used as the warm water for dyeing if kept in a insulated tank. The temperature would rise higher through the heat exchange with the dyeing solution.

The volume of steam may be reduced by reutilizing the dyeing cooling water stored in the insulated tank as the warm water for dyeing through the newly installed heat exchanger.

a. Manufacturer's Data for 50 kg/cycle Dyeing Machine

Weight of dye stuff: 50 kg

Capacity of dyeing solution: 750 l (wet ratio 1:15)

Quantity of cooling water: 67 l/min

b. Cooling Conditions

Dyeing solution are cooled from 130°C to 90°C and discharged.

Cooling time: 20 minutes

Quantity of cooling water: 1,340 l/20 min

Cooling water is warmed from 31°C to 53°C and discharged.

Heating area: 1.9 m^2

c. Heat Exchange with Dyeing Solution

The dyeing solution is cooled from 90°C to 75°C.

The warmed cooling water is raised from 53°C to 61°C.

Assuming that the heat exchange time is 20 minutes, the heat exchange area should be 3 m^2 (equivalent to about 20 m of the 1-1/2" pipe), allowing for the fouling during operation.

Consequently, if the daily average treatment is 200 kg/4 cycle, and average wet ratio is 1:15, the amount of dyeing solution to be discharged would be 200 kg x 15 = 3,000 l/day.

Thus, by heat exchange,

$$3000\ l \times \frac{1340\ l}{750\ l} = 5360\ l/day$$

The 5360 l/day warm water of 63°C can be made available. A part of such warm water can be used for dyeing process, and the rest can be used in scouring, reduction, cleaning, and oiling processes as supplement. Full utilization of such warm water would result in the following full oil saving:

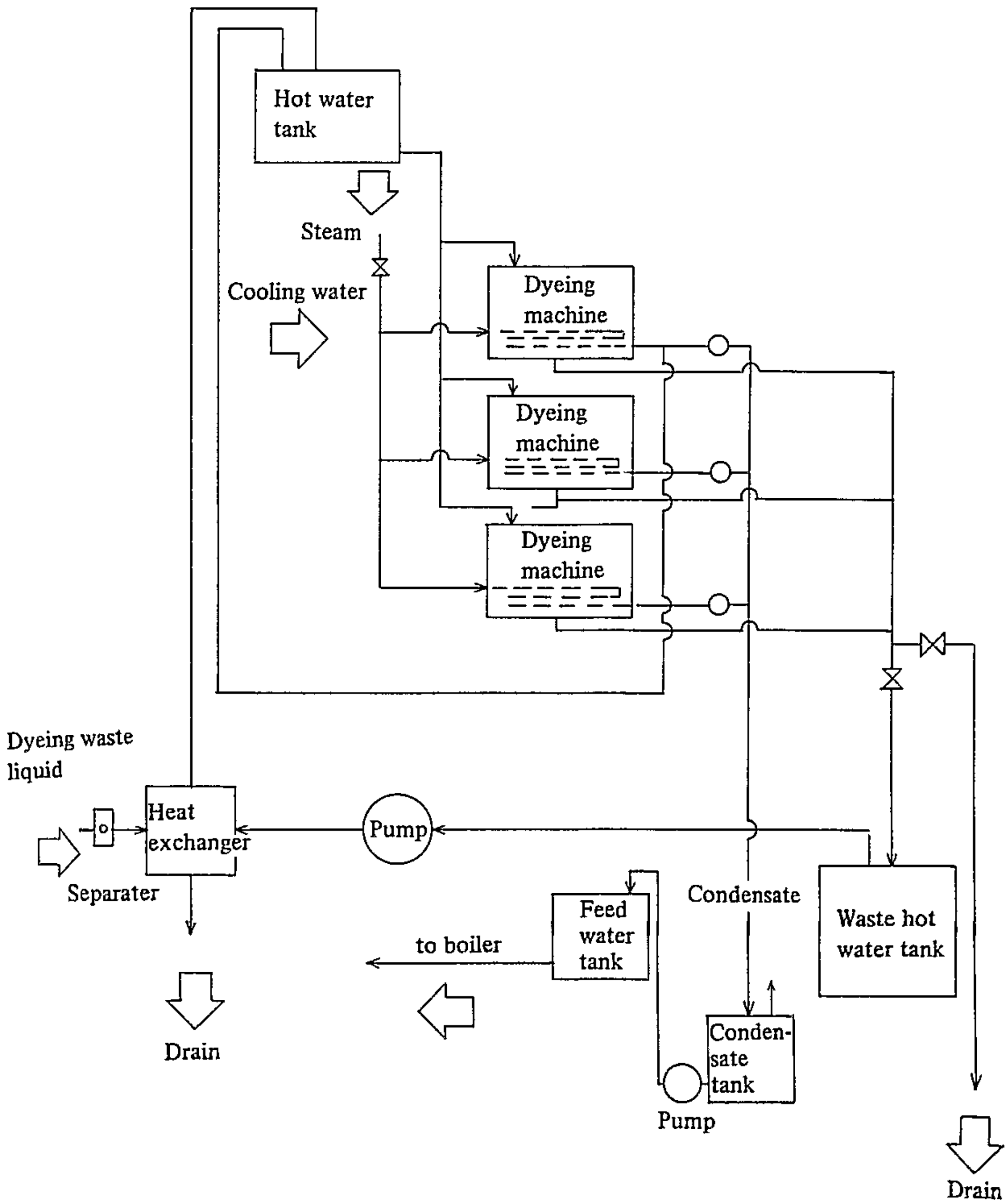
(provided that the rate of temperature drop of the recovered heat is 10%)

$$\frac{[\{5{,}360\ l/day \times (61°C - 31°C)\} \times (1 - 0.1)] \times 300\ day}{9{,}500 \times 0.85 \times 0.945} = 5.7\ kl/year$$

If such measured are taken for three other pressure-type dyeing machines, the saving would be much larger.

In cases implemented in Japan, it is reported that the investment for these improvement was recovered in three glass.

Heat recovery flowsheet of dyeing waste liquid



6.7. Inspection and Maintenance of Steam Trap

Malfunctioning steam traps tend to cause greater leakage of steam. Two traps in the ageing chamber, three traps in setting machine No. 1, one trap in setting machine No. 2, three traps in setting machine No. 4 were found to be malfuncitoning. They should be properly repaired after inspection.

6.8. Recovery of Condensate

The recovery of condensate is not carried out at present. This should be carried out. It was pointed out that the setting machines are located too far apart. However, considering that the distance to the nearest setting machine and the ageing machine is about 80 m, it seems that the recovery of condensate would be economically rewarding. If the temperature of the feedwater is raised 30°C by the recovery of condensate fuel consumption would be reduced by 4.7%, i.e. 320 kl/year x 4.7% = 15.0 kl/year. The recovery of condensate will also improve the quality of the feedwater in the boiler, and will be effective in decreasing the load of the water softener and in reducing the quantity of boiler compound as well as the amount of blow water.

7. State of Electric Power Consumption

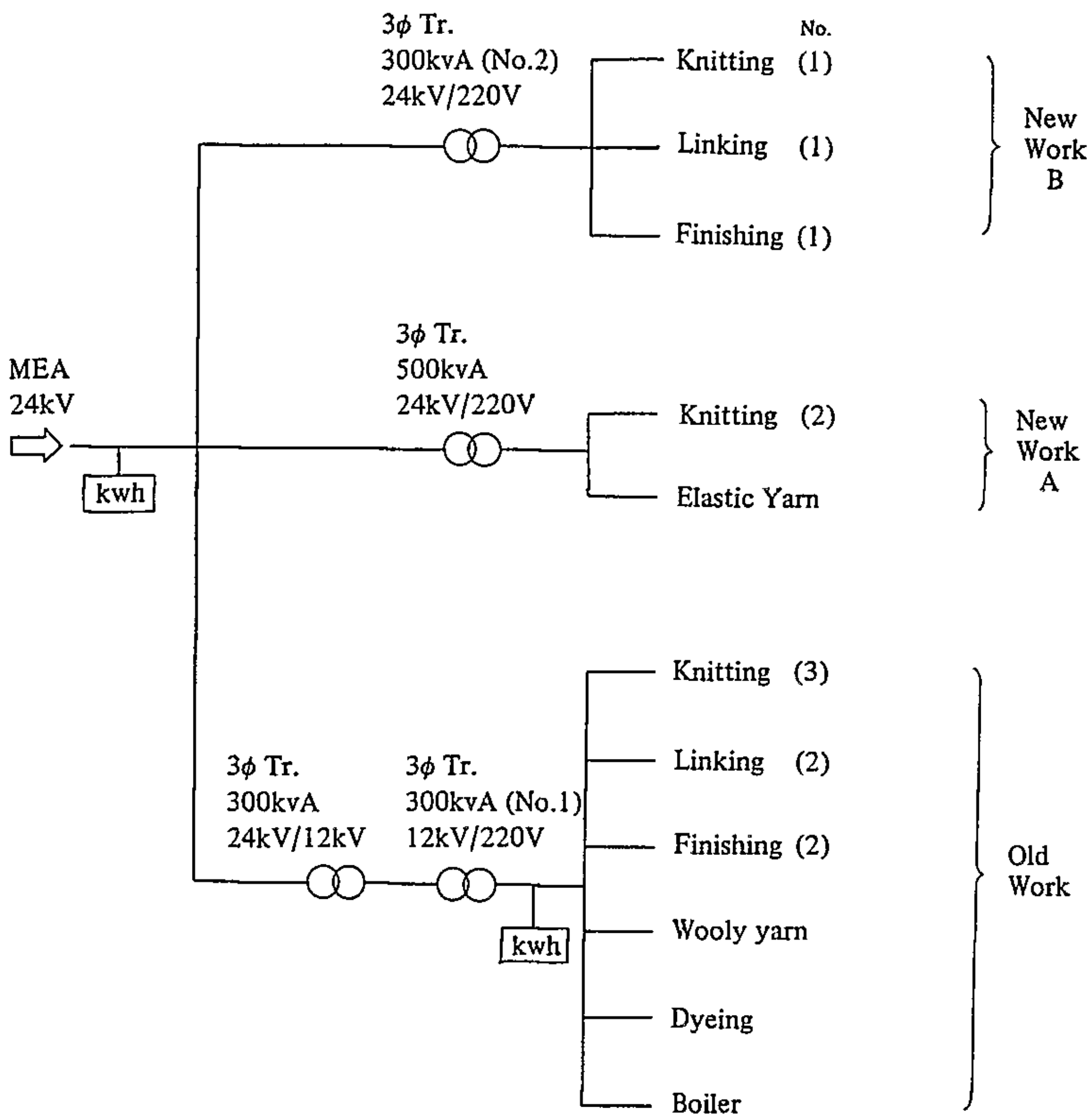
7.1. The Principal Data Relating to Power Consumption

- Power company: MEA
- Peak demand: 430 kW
- Electric energy used: 176,000 kWh/month
- Load factor: 56.9%
- Penalty: 4,035 bahts/month
- Power factor: 72%
- Transformers: Four 1,100 kVA
- Consumption rate of electric power: 1,760 kWh/dozen

7.2. Load Distribution

Motor	76.6 %
Air conditioning	14.1 %
Lighting	5.5 %
Electric heating	3.8 %
Total	100 %

7.3. One-line Diagram



8. Problems in Electric Power Control and Potential Solutions

8.1. Improvement of Power Factor

As the power factor is as low as 72% at present, it should be improved by using condensers for the purpose of utilizing electric power effectively. To raise the power factor from 72% to 85% requires condensers having a capacity of approximately 150 kVar (estimated cost 36,000 Bt). Such condensers should be installed in each of the three substations.

8.2. Transformer

(1) Presently the peak demand is 430 kW and the power factor is 72%, while the gross capacity of the transformer is 1,100 kVA. The transformer is fairly efficiently operated with a load factor of about 54%.

(2) There are plans for additional production facilities being installed particularly in the new plants. Taking this into consideration, the capacity of the transformer may be adequate.

8.3. Motor

(1) Five motors each with 3.7 kW to 22 kW were selected from the motors of each process in order to obtain the load factor, i.e. (actual load/rated capacity). The load factors turned out to be in the lower range of 30% to 60%.

(2) Motors operate very effectively when the load factor is 80 to 100%. Therefore the motors with a low load factor should be replaced at an opportune time.

Power saving effect by replacement in estimated as follows.

Motor capacity	Efficiency	Loss	Quantity	Reduced loss
kW	%	kW		kWh/year
11 → 5.5	86.5 → 86.0	1.48 → 0.77	1	5,148
3.7 → 2.2	84.0 → 82.0	0.59 → 0.40	2	2,822
5.5 → 2.2	79.5 → 82.0	1.13 → 0.40	2	10,534
5.5 → 3.7	84.0 → 86.5	0.88 → 0.50	1	2,740
5.5 → 2.2	81.5 → 82.0	1.02 → 0.40	1	4,475
22 → 15	90.5 → 91.5	2.09 → 1.28	1	5,868
			Total	31,587

Electric power savings: 31,590 kWh/year

Savings rate: 31,587 kWh/year ÷ 2,112,000 kWh/year ≒ 1.5%

(3) As the following motors, show sharp fluctuation of load, substantial energy savings may be achieved by carrying out speed control via frequency conversion or pulley exchange.

Blower: 12 kW
Pump: 28 kW
Total: 40kW

If each of these motors is given a speed contorl of 10%, the resulting energy savings would be:

Electricity savings: $40\ kW \times \{(1 - 0.9^3) - 0.03\} = 9.64\ kW$

Annual power savings: 9.64 kW x 24 h x 300 day = 69,400 kWh/year

Saving rate: 69,400 kWh/year ÷ 2,112,000 kWh/year ≒ 3.3%

(4) The motor belt tension in each process was generally good:

Old factory: Good in five of eight processes (including 96 knitting machines)*

New factory: Good in six of nine processes (including 69 knitting machines)*

Note: The motor belt tension for a total of 165 knitting machines was fairly good. However consideration should be given to the replacement of the flat belt with the V belt at an opportune time. Pulley centers which might be a bit off should be inspected.

(5) Most of the motor belts are flat belts, but energy-saving type belts are used for twisters and other major equipment to reduce the loss of electric power due to poor conduciton.

8.4. Air Conditioning

The industrial air conditioning were found to have generally met the requirements of quality maintenance.

Old factory:	False Twisting:	26°C, 50%
	Knitting:	26.5°C, 53%
New factory:	Double Twisting and Reeling:	
		27°C, 38%

8.5. Lighting

(1) Illumination photometry indicated that it was in the range of 100 to 300 Lux, as befitting the operating conditions.

(2) It was found that an appropriate level of illuminance was obtained by lowering the position of the fluorescent lights in the process where the ceiling was high.

(3) Energy saving of about 10% would be obtained by replacing the conventional fluorescent light lamps with energy-saving type ones while keeping the same level of illuminance.

Electricity savings: 47 kW x 0.1 = 4.7 kW

Annual power savings: 4.7 kW x 24 h x 300 day = 33,840 kWh/year

Saving rate: 33,840 kWh/year ÷ 2,112,000 kWh/year ≑ 1.6%

(4) Sunlight should be positively used in Bangkok from the viewpoint of energy conservation. However, as improved utilization may sometimes lower labor efficiency or degrade the working environment due to glare or excessive luminance, consideration should be given to the following points.

a) If vinyl chlorides are used for transparent material, ultraviolets may deteriorate the surface, resulting in cracking and accumulation of dust which will lead to the significant reduction of illuminance unless replaced every year. It is recommended that polycarbonates, acrylate and others less vulnerable to ultraviolets be used as transparent materials.

b) Blinds powered by a small motor which open or close automatically depending upon the changing outer luminence from the sun should be added to the transparent materials to adjust the illuminance in the factory.

c) The ratio of illuminance in the area receiving exterior light entering through the transparent materials to the illuminance in its neighboring area should be 10:1 or lower.

8.6. Electric Heating

In the factories, electric heating is mostly used for the heating of Dowtherm oil for the twisting machines. From the fact that the surface temperature of the heated area is not so high, it seems that there is good insulation with little release of heat.

9. Summary

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

	kl/year (oil equivalent)	%
Improvement of air ratio,	6.4	2.0
Insulation of ageing chamber pipe	0.5	0.2
Insulation of warm water tank	5.2	1.6
Insulation of steam pipe of warm water tank	0.6	0.2
Insulation of dyeing machine (Hang)	2.6	0.8
Insulation of dyeing machine (Pressure-type)	0.5	0.2
Utilization of heat in cooling water and dyeing solution liquid for heating purposes	5.7	1.8
Recovery of condensate	15.0	4.7
Subtotal	21.5	6.8

	10^3 kWh/year	%
Optimizing motor capacity	31.6	1.5
Speed control of motors	69.4	3.3
Replacement of lamps	33.8	1.6
Subtotal	134.8	6.4

Report No. 10: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Bangkok Steel Industry Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Bangkok Steel Industry Co., Ltd. —

1. Outline of the Factory

Address	27 Poochaosamingprai Road, Phrapradeang, Samuthprakarn	
Capital		
Type of industry	Steel Making	
Major products	Reformed bar, Round bar	
Annual Product	60,000 t/year	
No. of employees	500	
Annual energy consumption	Electric Power	44,280,000 kWh/year
	Fuel	Bunker C Oil 2,533 kℓ/year Diesel Oil 379 kℓ/year
Interviewees	Executive Director Mr. Praphan Plant Director Mr. Srinakorn Phoonphiphatana Asst. Plant Manager Mr. Boriphant Sritrai	
Date of diagnosis	Jan. 20 ~ 21, 1983	
Diagnosers	Mr. Nakagawa, Mr. Noda, Mr. Kurita	

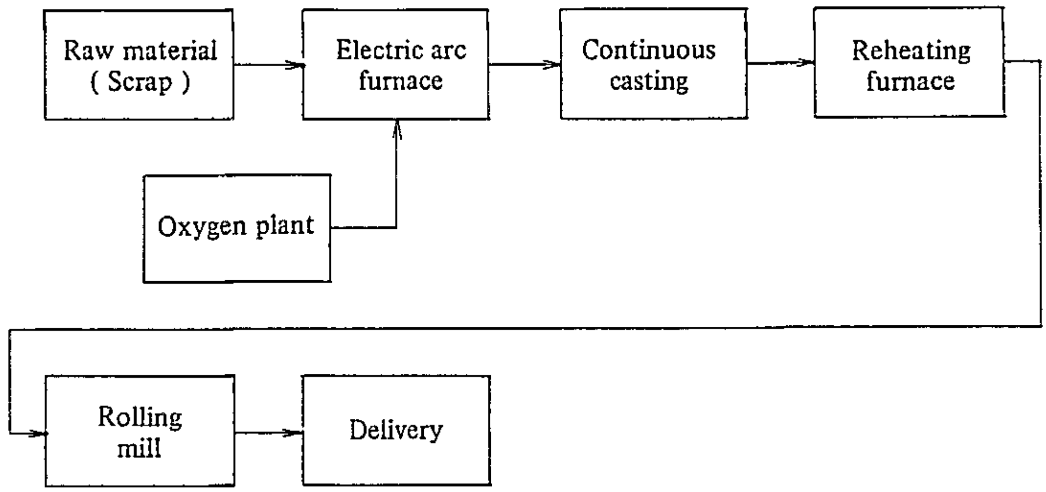
The company started its business in 1970 and is entirely financed by Thai capital. In its early days, the factory received technical assistance from Daitetsu Kogyo Co., Ltd. of Japan. However, this relationship has been discontinued. The company is a member of the Metro Group. Of its 500 employees, there are 30 engineer. These engineers are responsible for electrical, mechanical, and production activities.

In the factory, scrap iron is melted in an electric-arc furnace and is made into billets by continuous casting, to be rolled into bar steel for concrete reinforcement. The factory is an approved factory under the Thailand Industrial Standards.

The factory is being operated at approximately 50% of capacity. Of the six manufacturers of electric furnace steel in Thailand, the factory has the second largest capacity. The factory ranked first as a bar steel manufacturer in the Thai market.

For the factory's scrap iron requirements, 30% is imported, 60% comes from domestic supply, and the remaining 10% is recycled scrap within the company.

2. Manufacturing Process

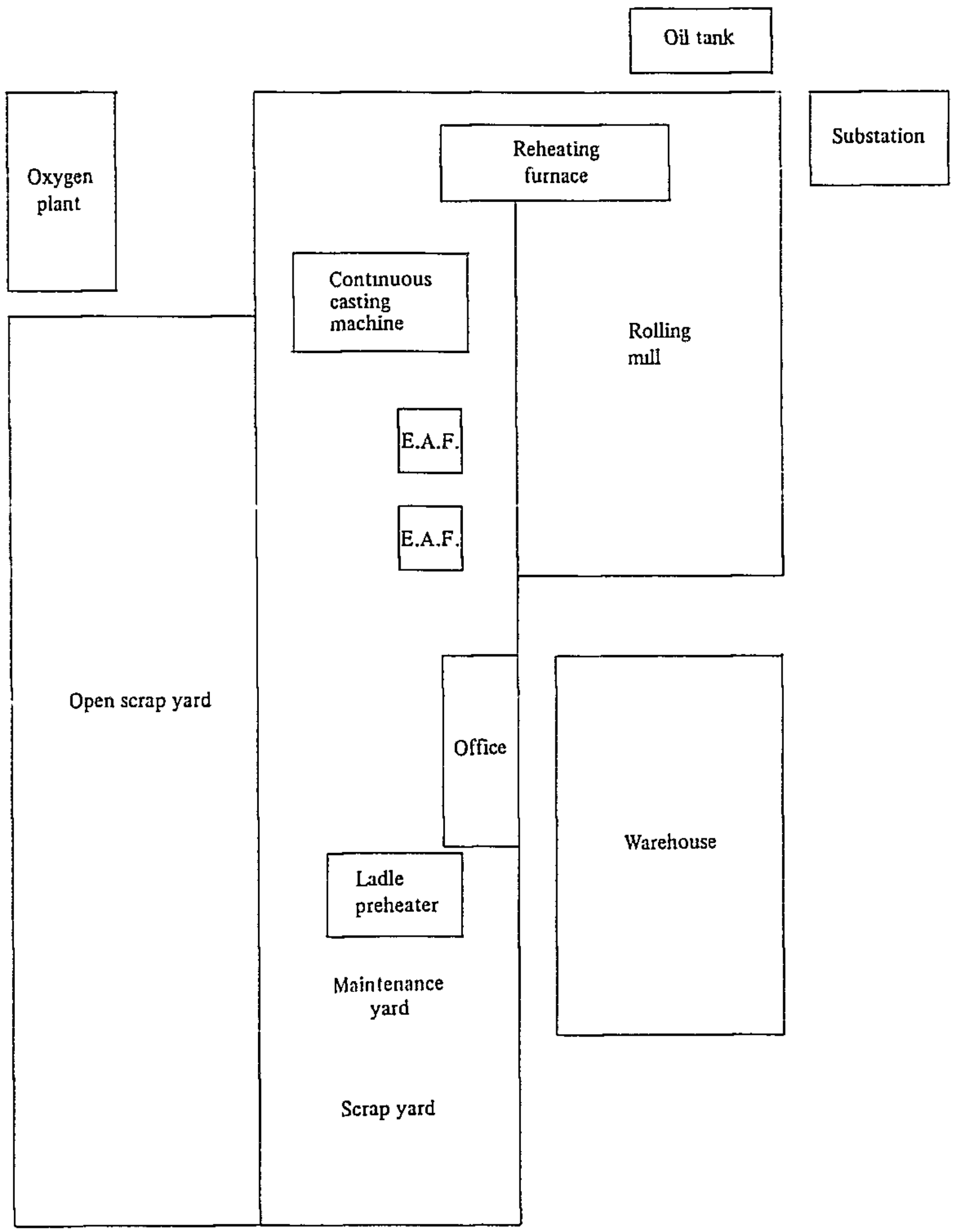


3. Major Equipment

3.1 Major Equipment

Name	No. of units installed	Type, etc.
Electric arc furnace	1 unit	20 t/ch : Demag
Electric arc furnace	1 unit	20 t/ch : Centroad
Continuous casting machine	1 unit	2 strand Billet size 100 x 100 : Concast
Reheating furnace	1 unit	24 t/h, 2 Zone type
Rolling mill	11 stands	
Oxygen plant		Compresser power : 900 kW Pressure : 130 kg/cm^2

3.2 Layout


Oil tank
Oxygen plant
Reheating furnace
Substation
Continuous casting machine
Rolling mill
E.A.F.
E.A.F.
Open scrap yard
Office
Warehouse
Ladle preheater
Maintenance yard
Scrap yard

4. State of Energy Management

4.1 Investment in Energy Conservation and Cases of Improvement

The company is undertaking activities in an organized manner, and has approximately 30 engineers in the mechanical, electrical, and production processes. No major investments have been made since the factory replaced its heating furnaces about three years ago. The company makes investments in equipment only on the condition that the investments will be recovered within one year.

The present energy conservation target of the company is to reduce the power consumption rate of electric-arc furnaces from 600 to 550 kWh/t within one year.

4.2 Grasp of Energy Consumption

The company measures power consumption on a monthly basis and fuels daily. Energy cost management is conducted by calculating energy consumption rates. However, heat balances are not calculated.

A voltmeter, ammeter, wattmeter, power factor meter, reactive power meter, integrating watt meter etc. are installed on the 69 kV side of a switchboard in the receiving substation. Except for the voltmeter, all other meters are inaccurate. The attendants in the substation did not know the multiplication rates for the integrating watt meter very well, and these rates should be clearly indicated.

The defective meters should be repaired. By gathering data on the hourly conditions of the primary side, that is, voltage, current, power factor, and reactive power and by preparing graphs based on these data, variations in the peak demand and power factor can be managed. All the electrical meters in the electric-arc furnace control room should also be repaired.

A One-line diagram is provided in the factory. However, some errors could be found as to condenser capacities, etc., and the diagram should be reexamined.

4.3 Energy Conservation Committee and Suggestion System

Energy conservation activities are mainly conducted by section managers, and there is no special committee for energy conservation. Circle activities involving staff members began four years ago and are being continued.

The factory has an improvement suggestion system. Prizes were awarded to good suggestion however, this is not being done at present.

4.4 Employee Training

As part of employee training, the company sent its staff to training seminars outside the company four times last year. Its staff are expected to participate in similar seminars every month this year.

Staff members have been sent on inspection tours of facilities in Singapore, Japan, Korea, the United States, Europe, and other countries.

an appeal for energy conservation is made to employees at monthly meetings.

5. State of Fuel Consumption

5.1 Fuel Consumption Data

Data on fuel consumption in 1982 are shown in the following.

Fuel oil C 2,533 kl/year

Diesel oil 379 kl/year

The entire amount of fuel oil C is used in reheating furnaces. Diesel oil is used to preheat electric furnace ladles and continuous casting tundishes at a rate of 50:50.

5.2 Fuel Consumption Rate

Assuming that last year's production was 60,000 tons in terms of crude steel, the annual average fuel consumption rates of the individual sections can be calculated as shown in the following.

Reheating furnaces (fuel oil C)

2,533 x 10^3 l/year/(60,000 t/year x 0.98) = 43.1 l/t billets

Note: The yields for continuously casted billets was estimated to be 98%.

Electric furnace ladles (diesel oil)

(379 x 10^3 l/t x 0.5)/60,000 t/year = 3.2 l/t

Continuous casting tundishes (diesel oil)

(379 x 10^3 l/t x 0.5)/60,000 t/year = 3.2 l/t

5.3 Simple Heat Balance of Reheating Furnace

The simple heat balance of the reheating furnace including air preheaters is shown in the following.

5.4. Heat Balance Table

Input			Output		
Item	10^3 Kcal/t	%	Item	10^3 Kcal/t	%
(1) Heat of fuel combustion	437.8	97.0	(4) Heat of discharging billet	173.8	38.5
(2) Oxdation heat of scale	13.4	3.0	(5) Heat loss in scale	3.0	0.7
(3) Recovery heat by recuperator	(41.1)	(9.1)	(6) Head loss in exhaust gas	159.3	35.3
			(7) Others	115.1	25.5
			(8) Recovery heat by recuperator	(41.1)	(9.1)
Total (1) + (2)	451.2	100.0	Total (4) + (5) + (6) + (7)	451.2	100.0

Note : For one ton of charging billet

referece temperature is 35°C.

5.5. Data Given for the Calculation of the Heat Balance

Weight of charged billets

100 t/shift ÷ 8 h/shift = 12.5 t/h

Note: The figure of 100 t/shift was based on amounts reported at the factory

Fuel oil consumption

Consumption of upper-stage burners in the soaking zone and heating zones

485 l/h x 0.95 kg/l = 461 kg/h

(values indicated by meters on the instrumentation panel)

Consumption of lower-stage burners in the soaking zone

40 kg/h.burner x 5 burners/2 = 100 kg/h

(Consumption is set at 1/2 the rated burner value of a 40 kg/h burner)

Fuel oil consumption

461 + 100 = 561 kg/h

Fuel oil consumption per ton of billet

561 kg/h/12.5 t/h = 44.9 kg/t

Specific gravity of fuel oil:	0.95
Low heating value of fuel oil:	9.750 kcal/kg
Theoretical air amount of fuel oil:	10.29 Nm^3/kg
Theoretical wet exhaust gas amount of fuel oil:	10.82 Nm^3/kg
Combustion loss:	1%
Scale formation heat:	1,355 kcal/kg Fe
Billet charging temperature:	35°C
Billet extraction temperature:	1,100°C

(Value measured by radiation thermometer)

Heat content of billet:

Calculated from the following table

Temperature (°C)	50	100	1,000	1,050	1,100	1,150	1,200	1,250
Heat capacity (Kcal/kg)	5.8	11.6	163.7	171.6	179.5	187.4	195.3	203.2

Iron content in scale:	95%
Average specific heat of scale:	0.215 kcal/kg°C
Oxygen content in exhaust gas (after air preheater): (measured value)	12.5%
Exhaust gas temperature (after air preheater): (measured value)	415°C
Average specific heat of wet exhaust gas:	0.33 kcal/Nm^3°C
Consumption of preheated air: (on instrumentation panel flowmeter)	5,100 Nm^3/h

Preheated air temperature: 350° C

Average specific heat of preheated air: 0.32 kcal/Nm^3° C

5.6. Equations for Calculating the Het Balance

Input

Heat of fuel combustion:

Fuel oil consumption per ton of billets (44.9 kg/t) x heating value of fuel oil (9,750 kcal/kg) = 437,775 kcal/t

Scale formation heat

Scaling loss of Fe per ton of billets (10 kg/t) x scale formation heat (1,335 kcal/kg.Fe) = 13,350 kcal/t

Sensible heats of fuel and primary air were negligible and were omitted.

Output

{1,000 kg − Scaling loss of Fe (10 kg)} x {heat content of billets at extraction temperature (179.5 kcal/kg) − heat content of billets at ambient temperature (4.0 kcal/kg)} = 173,745 kcal/t

Heat of scale:

Scaling loss per ton of billets (10 kg/t) x $\frac{75.5}{100}$ average specific heat of scale x {extraction temperature (1,100° C) − ambient temperature (35° C)} = 3,033 kcal/t Heat loss in exhaust gas:

- Air ratio = 21/{(21 − oxygen content in exhaust gas (12.5)} = 2.47
- Wet exhaust gas amount = theoretical wet exhaust gas amount (10.82 Nm^3/kg) + {air ratio (2.47) − 1} x theoretical air amount (10.29 Nm^3/kg) = 25.95 Nm^3/kg
- Heat loss in exhaust gas

Fuel oil consumption per ton of billets (44.9 kg/t) x wet exhaust gas amount per kg of fuel oil (25.95 Nm^3/kg) x average specific heat of wet exhaust gas (0.33 kcal/Nm^3° C) x {exhaust gas temperature (450° C) − ambient temperature (35° C)} = 159,261 kcal/t

Other heat losses:

Total input (451,125 kcal/t) − outpu {(173,745 kcal/t) + (3,033 kcal/t) + (159,261 kcal/t)} = 115,086 kcal/t

Heat recovered by air preheaters:

- Preheated air consumption per ton of billets = 5,100 Nm^3/h ÷ 12.5 t/h = 408 Nm^3/t
- Heat recovered by air preheaters:

Preheated air consumption per ton of billets (408 Nm^3/t) x average specific heat of preheated air (0.32 kcal/Nm^3° C) x {preheated air temperature (350° C) − ambient temperature (35° C)} = 41,126 kcal/t

6. Problems in Heat Control and Potential Solutions

6.1 Hot Charge

6.1.1 Problems

Though there was no sign of grinding off flaws in the billet storage yard, the explanation by the factory is that hot charge could not be done because of a problem with flaws in continuously cast billets.

6.1.2 Potential Solutions

The continuous casting machine and charging machine of the reheating furnaces in the rolling mill were close to each other and were very convenient for hot charging in their layout. It is hoped that hot charging will be employed as soon as is practical to lower the fuel consumption rate.

High-temperature continuous cast billets should preferably be charged directly into reheating furnaces. However, it is very difficult to process the entire amount due to the difference in production capacities of the continuos casting machine and rolling line. Therefore, generally, a heat insulation box is installed to temporarily store high-temperature continuous cast billets as a buffer function. The heat insulation box is made of steel plate lined with an insulation material and has a movable cover for loading and unloading billets.

The storage capacity of a heat insulation box, the number of boxes to be installed, and other considerations are decided by the capability of the continuous casting machine, planned billet storage amount, and other factors.

Energy savings by hot charging will be 20×10^3 Kcal/t per 100° C of the charging temperature (2.2 l/t when converted into fuel oil C). assuming that 50% of the charged quantity is hot-charged and the temperature to be 500° C, the savings will be $60{,}000 \times 0.5 \times 5 \times 2.2 = 330$ kl/year.

6.2 Burner Combustion

6.2.1 Problems

The upper-stage burners in the soaking zones and heating zone burners are controlled by temperature and air ratio. The lower-stage burners of the soaking zones are regulated manually.

When the load fluctuates, variations of combustion are great, depending on time, possibly because the air flow is not appropriately controlled, even though the oil flow of the lower-stage burners of the soaking zones is regulated whenever necessary. As an example, measurements of the oxygen content of furnace combustion gases in the soaking, heating, and preheating zones are shown in the following.

Position \ Date	Jan. 12	Jan. 13
Soaking zone	9.0%	0.3%
Heating zone	9.5%	0.3%
Preheating zone	2.8%	3.4%

The oxygen content in the soaking and heating zones varies greatly while that in the preheating zones does not. In the preheating zones, combustion gases produced by individual burners in individual zones are mixed and are nearly uniform. Therefore, generally satisfactory air ratio control is carried out on the whole, judging from the foregoing results of oxygen content analysis. Nevertheless, it shows that air ratio control is not done optimally in some sections. The lower-stage burners in the soaking zones seem to be the real cause. Short flames could be observed at times, while long flames mixing black smoke, extending near the edge of the heating zones. could also be observed at other times. The difference in fuel oil consumption is great among the five burners, and no constant trend could be seen for this unbalance in fuel oil amounts.

6.2.2. Potential Solutions

The capacity of the upper-stage burners in the soaking zone still has a considerable margin, and the lower-stage burners do not have to be used. The flames of the lower-stage are very close to the upper surfaces of the billets with a high possibility of causing overheating and local heating of the billets.

A study should be made to stop using the lower-stage burners in the soaking zone because of these considerations.

6.3. Furnace Pressure

6.3.1. Problems

(1) Furnace pressure was negative most of the time.

When furnace pressure is negative, open air is suctioned into the furnace through the furnace opening, cooling billets that have been heated and lowering the combustion gas temperature, thereby deteriorating the furnace heat transmission effect. Exhaust gas losses are increased as the exhaust gas quantity is increased. Therefore, negative furnace pressure has very large disadvantages.

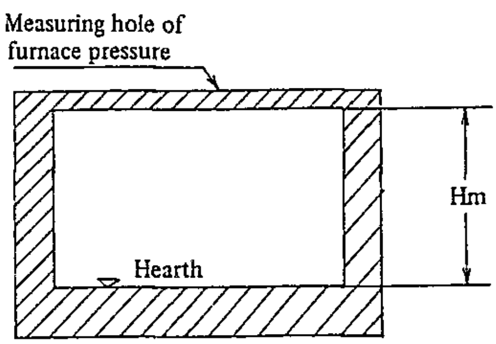
(2) The two pressure lead pipes installed on the soaking- and heating-zone ceilings were connected to a common lead pipe at a midpoint. The common lead pipe was connected to a furnace pressure gauge and a furnace pressure controler. Therefore, the reading was considered to show an average furnace pressure in the

soaking and heating zones, making the purpose of measuring and controling the furnace pressure considerably ambiguous. The purpose of controling reheating furnace pressure is to absolutely prevent cold air of the atmosphere from infiltrating the furnace, that is, to maintain even a slight positive pressure, even though high temperature gases in the furnace blow out in small quantities from door gaps, inspection hole gaps, and other openings on the furnace in its high temperature region (normally a soaking zone). In this sense, average pressure control is not desirable.

6.3.2. Potential Solutions

(1) Set the furnace pressure to 0.2~0.4 mm H_2O on the hearth. The furnace has an opening on the furnace ceiling to measure furnace pressure. The controler set pressure should be set as shown in the following considering the effect of furnace gas buoyancy.

Furnace pressure set value = (0.2~0.4) + H(m) mmH_2O



(2) Furnace pressure should be controlled and measured only in the soaking zone, and the lead pipe between the heating-zone ceiling measurement port and common lead pipe should be removed.

(3) The following advantages can be derived by optimizing furnace pressure.

- Prevention of billet cooling. It is extremely difficult to quantify. However, provided cooling can be minimized by 10° C, saving of 5,000 Kcal/t (0.5 l/t when converted into fuel oil) will be possible.

60,000 t/year x 0.5 l/t = 30.0 kl/year

6.4. Fuel Oil Temperature

6.4.1. Problems

Fuel temperatures in front of the burners are shown in the following. The temperature is extremely low except in the lower-stage burners of the soaking zone.

Upper-stage burner of soaking zone	48°C
Lower-stage burner of soaking zone	100°C
Heating zone	42°C

Fuel oil viscosity increases when the temperature is low, adversely affecting the atomizing of fuel oil, and flames become long or have black smoke at low flame temperatures.

6.4.2. Potential Solutions

(1) Heat fuel oil C to its optimal temperature of 100~110°C by increasing the fuel oil heater capacity.

(2) Fuel oil consumption increases 3% when exhaust gas contains 1% of CO. The furnace sometimes emitted black smoke from its end, indicating that CO was present. However, no CO analysis was made, and an evaluation of advantages by implementing potential solutions could not be made.

6.5. Ceramic Fiber Insulation

6.5.1. Problems

The entire inner walls of the furnaces were lined with 20 mm thick ceramic fiber. This has proved to be a very good energy conservation countermeasure.

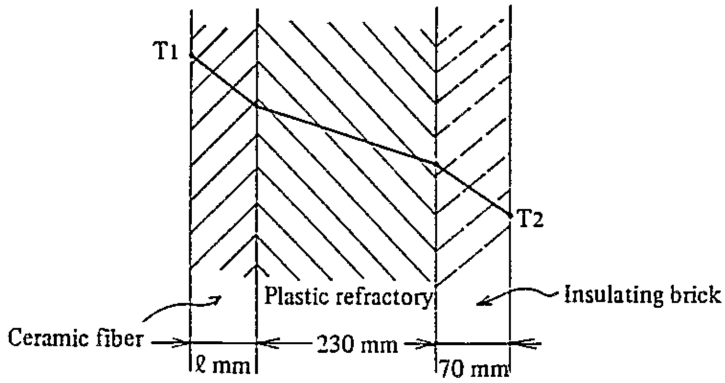
The durability of ceramic fiber insulation has been extended considerably due to improved quality and installation method. Its investment effects have been recently evaluated highly. In Japan, veneering to 50~70 mm has become the norm.

6.5.2. Potential Solutions

(1) The thickness of ceramic fiber insulation should be increased to 50~75 mm at oppotune time. Mounting new ceramic fibers on top of the existing fiber to increase insulation will cause a bonding failure or a peeling-off of the new ceramic fiber in a short time due to a degradation of the existing fiber. Therefore, the existing ceramic fiber should be removed before new ceramic fiber is applied to increase the insulation thickness.

(2) The optimal thickness of insulation materials should be decided after weighing the calculation examples in the following table, ceramic fiber prices, and other factors.

(a) Furnace Wall Composition (Ceilings)



(b) Calculation Examples (Heat Loss Q: $Kcal/m^2h$, External Temperature T_2: °C)

ℓ / T1	20 mm (existing state)			50 mm			70 mm		
	T2	Q (A)	%	T2	Q (B)	% (B/A)	T2	Q (C)	% (C/A)
1,200°C	128	1,554	100	116	1,322	85	110	1,170	75
1,000	110	1,164	100	98	932	80	92	816	70
800	92	822	100	80	611	74	75	528	64

(c) Calculation Conditions

- Steady state
- Room temperature 35°C
- Emissivity 0.9
- Thermal conductivity of refractories:

  Ceramic fiber $0.07^{21 \times 10^{-3(t-400)}}$ Kcal/mh°C

  Plastic refractories $0.75 + 3.9 \times 10^{-4}t$ Kcal/mh°C

  Insulating brick $0.105 (1 + 1.22 \times 10^{-3}t)$ Kcal/mh°C

  t: average temperature of refractories °C

(d) Energy Conservation Effects

Compared with the current ceramic fiber insulation thickness of 20 mm, heat loss will decrease an average of 20% when the insulation thickness is increased to 50 mm.

Assuming the area of furnace inner walls to be 120 m^2, the amount of released heat will be (1164 − 932) x 120 = 27,840 Kcal/h, saving fuel oil by

$$\frac{27{,}840}{9{,}750 \times 1{,}000} \times 7{,}200 = 20.6 \text{ kl/year}$$

at an energy savings of 0.8%.

Cost of lining with 50 mm thick ceramic fiber is approx. 75,000 Bt., incl. material and work. This cot can be recovered in approx. 10 months.

6.6. Billet Extraction Temperature

6.6.1. Problems

It was reported during the hearing that the billet extraction temperature would be 1,230~1,250° C. When measurements of temperature were made, the value on the radiation thermometer was 1,100° C (emissivity $\varepsilon = 0.85$).

6.6.2. Potential Solutions

(1) Measurements were made on the spot, and surface temperatures of billets are difficult to measure. It cannot be asserted that low temperature extraction was always made only because a billet temperature of 1,100° C was measured. Nevertheless, it can be said that billets were being extracted and rolled at temperatures considerably below 1,230~1,250° C for some time. This fact is very important. By intentionally expanding this state, extraction at low temperature, offering great energy savings can be established.

Measurements of billet extraction temperatures are essential to stabilize and improve low-temperature extraction operations. Radiation thermometers should be installed and trials of lowering temperatures as low as possible without affecting quality and rolling machine power based on the data obtained from these radiation thermometers are strongly recommended.

(2) Energy conservation by low temperature extraction.

The fuel consumption rate decreases 50×10^3 Kcal/t by lowering the extraction temperature by 100° C (5 l/t when converted into fuel oil C).

6.7. Maintenance and Adjustment of Meters

6.7.1. Problems

Equipment for controlling furnace temperature, air ratio, and furnace pressure was installed. Furnace temperature was controlled at a low range of 10~30% of the full scale. Only a very brief observation was made. However, measurement values of furnace pressure varied greatly within a range of 0~+5 mm during each measurement.

6.7.2. Potential Solutions

(1) Measurement accuracy of low range is not good, and it follows that control based on such bad measurement values becomes low in quality. The fuel oil and air flow rates under various loads should be studied, and the capacities of the transmitters and control valves should be changed optimally.

(2) The controllability of the furnace pressure seemed very bad, and the furnace pressure controler should be adjusted and calibrated.

6.8. Air Preheaters

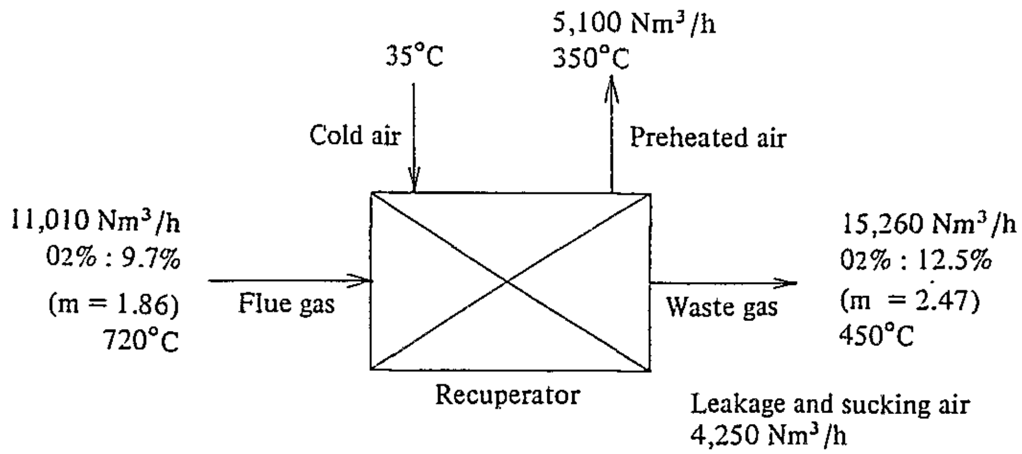
6.8.1. Problems

(1) The heat balance and a flow diagram are shown in the following. The air ratio after the air preheater increases against before.

(a) Heat Balance Chart

Input			Output		
Item	10^3 Kcal/h	%	Item	10^3 Kcal/h	%
(1) Heat in flue gas at recuperator inlet	2,564.9	100.0	(2) Heat in preheated air	514.1	20.0
			(3) Heat in waste gas at recuperator outlet	1,993.7	77.7
			(4) Heat release Others	57.1	2.3
Total	2,564.9	100.0	Total (2) + (3) + (4)	2,564.9	100.0

(b) Flow Diagram



(c) Data given for calculation of the heat balance

Fuel oil consumption	561 kg/h
Theoretical amount of air	10.29 Nm^3/kg
Theoretical amount of exhaust gas	10.82 Nm^3/kg
Actual amount of exhaust gas outlet of the preheater	25.95 Nm^3/kg
Temperature of exhaust gas	
before air preheater	720° C
after air preheater	450° C
(Both are measured values)	
Specific heat of exhaust gas	
before air preheater	0.34 kcal/Nm^{3}°C

after air preheater 0.33 kcal/Nm^{3}°C

Preheated air amount 5,100 Nm^3/h (meter indication value)

Temperature of preheated air 350°C

Specific heat of preheated air 0.32 kcal/Nm^{3}°C

Room temperature 35°C

(d) Equation for Calculating the Heat Balance

Input

Heat of exhaust gas inlet

Fuel oil consumption (561 kg/h) x wet exhaust gas per kg of fuel oil (X Nm^3/kg) x specific heat of wet exhaust gas (0.34 kcal/Nm^{3}°C) x {temperature of exhaust gas inlet (720°C) − room temperature (35°C)} = 130,657 X kcal/h

Note: The oxygen content in exhaust gas inlet was not known. In this calculation, wet exhaust gas per kg of fuel oil was assumed to be X Nm^3/kg to after obtaining the heat balance of the air preheater.

Output

Heat of preheated air

Preheated air amount (5,100 Nm^3/h) x specific heat of preheated air (0.32 kcal/Nm^{3}°C) x {preheated air temperature (350°) − room temperature (35°C)} = 514,080 kcal/h

Heat of exhaust gas outlet

Fuel oil consumption (561 kg/h) x wet exhaust gas per kg of fuel oil (25.95 Nm^3/kg) x specific heat of exhaust gas (0.33 kcal/Nm^{3}°C) x {Temperature of exhaust outlet (450°C) − room tempeerature (35°C)} = 1,993,711 kcal/h

Heat loss and others

Heat of preheated air (514,080 kcal/h)/0.9 x 0.1 = 57,120 kcal/h

Note: Heat efficiency of the air preheater was assumed to be 90%.

Estimation of wet exhaust gas quantity X Nm^3/kg air ratio and oxygen content in exhaust gas at the preheater inlet

Estimation of X

130,657 X kcal/h = total heat output (2,564,911 kcal/h)

Estimation of air ratio

19.63 Nm^3/kg = Theoretical amount of wet exhaust gas (10.82 Nm^3/kg) + (air ratio − 1) x theoretical amount of air (10.29 Nm^3/kg)

Air ratio = 1.86

Estimation of oxygen content in exhaust gases

Air ratio (1.86) = 21/(21 − O_2% in exhaust gases)

Oxygen content in exhaust gases = 9.71%

(2) The allowable temperature of exhaust gas at the air preheater inlet was 780°C, and the exhaust gas temperature was adjusted by using dilution air.

(3) The flows of exhaust gases and preheating air were parallel and crossflow.

6.8.2. Potential Solutions

(1) According to the heat balance calculations, the oxygen content in exhaust gas increased after the air preheater. Air leakage from the heat transfer pipes in the air preheater or the infiltration of open air is suspected. Depending on where it occurs, air leakage and open air infiltration greatly affect the hot air temperature due to lower exhaust gas temperatures. A composition analysis of exhaust gas before and after the air preheater should be made to check air leakage and open air infiltration.

When there are leaks from the heat transfer pipes, the required amount of air cannot be supplied to the burners when the amount of leaking air is great, and efficiency of heat recovery decreases. The heat balance should be checked periodically and leakage locations repaired urgently when the leakage increases.

The heat exchanger should be changed to a counter flow type that can obtain high temperature air when the next equipment replacement is scheduled.

At that time, high temperature corrosion of the exhaust gas inlet, low temperature corrosion of the outlet, and heat resistance of the burners and air duct should be studied.

7. State of Electric Power Consumption

Of the metal factories surveyed, the factory had the largest power consumption and electric equipment capacity. Therefore, its receiving voltage was high. The factory was the only one that was receiving power at 69 kV.

7.1. The Principal Data Relating to Power Consumption

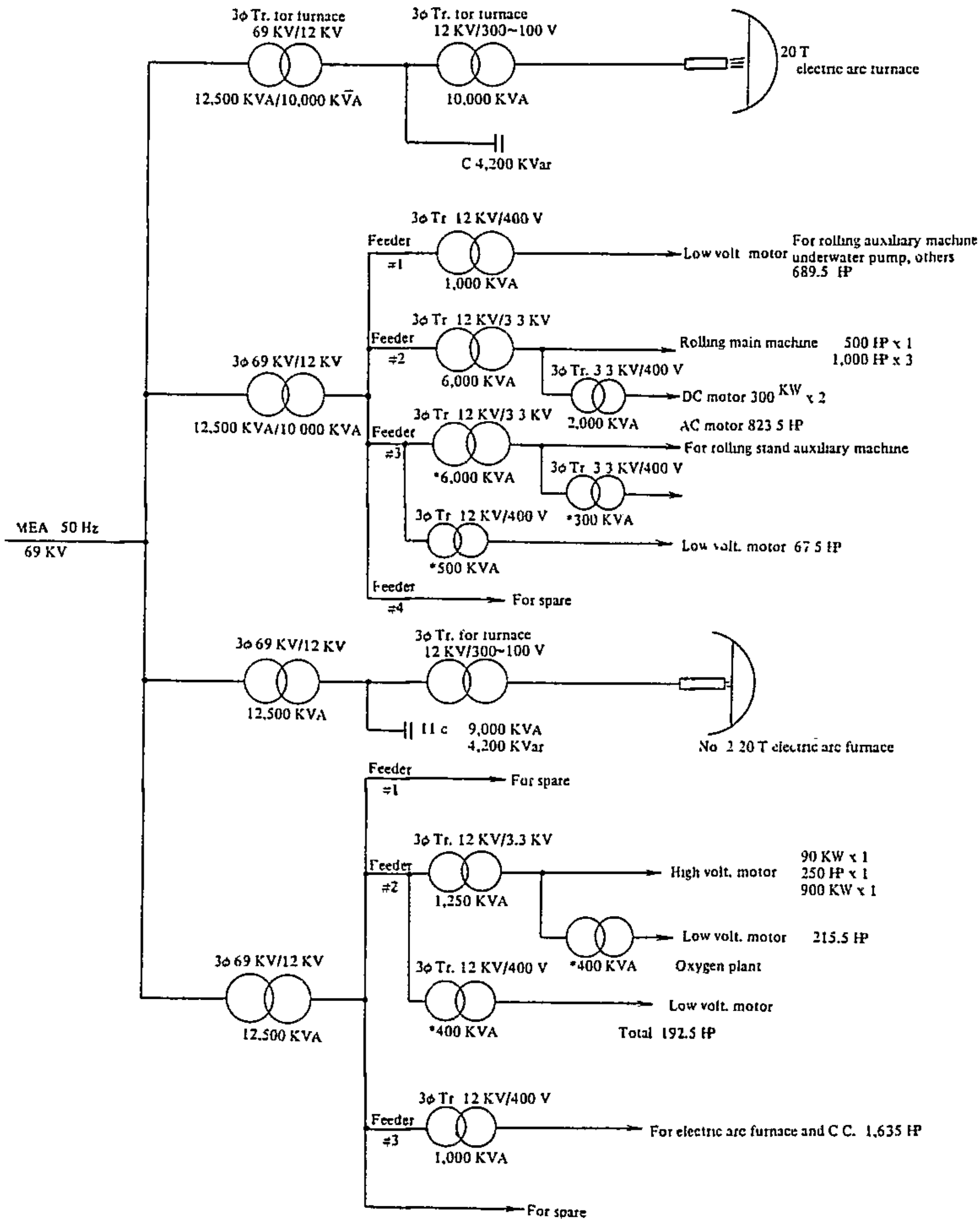
- Power company : MEA
- Peak demand : 10,538 kW
- Power consumption : 44,280,000 kWh/year
- Load factor : 58.4%
- Penalty : Maximum 48,180 Bt/month
- Power factor : 72.5%
- Transformers :

The transformers for the No.1 electric-arc furnace and mill stand had a double rating of 10 MVA/12.5 MVA. The capacities for the No.2 electric-arc furnace and oxygen plant were both 12.5 MVA. The total capacity of the transformers in continuous rating was 10 + 10 + 12.5 + 12.5 = 45 MVA (the substation capacity, 50,000 kVA).

- Power consumption rate

  The rate was 738 kWh/t for a total annual output of 60,000 t/year.

7.2. One-line Diagram



8. Problems in Electric Power Control and Potential Solutions

8.1 Maintenance and Adjustments of Electrical Meters

The watt-hour meters in the individual production processes were assumed to be well-maintained and adjusted as the factory was calculating the monthly power consumption rates of all processes. However, the ammeters, wattmeters, power factor meters, watt-hour meters, reactive wattmeters, etc. on the 69 kV side of the receiving substation were defective. The load of the entire factory could have been determined if these meters were operating accurately, and this is regrettable. The meters should be repaired and adjusted as soon as possible.

8.2 Peak Demand, Maximum Reacting Power, and Load Factor

The peak demand and maximum reactive power recorded in September and December, 1982, are shown in the following.

December	10,538 kW	8,531 kVar
September	10,037 kW	9,535 kVar

Therefore, the penalty becomes:

(8531 − 19538 x 0.63) x 15 = 28380 Bt

(9535 − 10037 x 0.63) x 15 = 48180 Bt

The average peak demand was understood to be 9,484 kW according to information given by the factory.

The annual electric energy consumed was 44,280,000 kWh, and the annual working hours were 7,200 hours (24 x 300). Therefore, the average power was 6,150 kW, with a load factor of 58.4%:

$$\frac{6,150}{10,538} = 0.584$$

The rate is not low for a load factor in the steel industry. However, there is room for improvement as indicated in the following.

(1) The electric energy consumption is large. The peak demand can be suppressed by minimizing variations of electric energy consumption for each hour by improving the operating method.

(2) There is a difference of 1,000 kW between the maximum and average values (9,484 kW) of the peak demand throughout the year, and the maximum peak demand can be minimized further. (By improving the operating method and sequence) By minimizing the peak demand, the demand fee can be lowered. In order to implement this, the actual conditions of load variations should be determined. Based on the current records, five daily load curves are drawn on electric energy on the 69 kV receiving side and on main transformers in the four banks on the 12 kV side every hour. By this, the causes can be determined and improvements in operating methods can be studied when the receiving electric power significantly increases. (100 kW can be lowered on average) Particular attention should be paid to the starting of large motors such as 900-kW

synchronous motors for the compressors in the oxygen plant.

It is also effective to install demand controllers to attempt to suppress the maximum power by forecast, and the cost of the controllers can be recovered in two years.

8.3. Transformers

As shown in the one-line diagram, there are four banks of main transformers as detailed in the table in the following.

Major load	Capacity MVA	Volt KV	Condenser capacity KVar	Remarks
No. 1 electric arc furnace	10/12.5	69/12	4,200	Double rated
Rolling mill	10/12.5	69/12	–	Double rated
No. 2 electric arc furnace	12.5	69/12	4,200	
Oxygen plant	12.5	69/12	–	

The following values were measured on indicators in the factory substation on January 21 immediately after supplying power to the No.1 electric-arc furnace.

Measuring time	Recieving (income)					No. 1 electric arc furnace			KVA Transformer rolling auxiliary machine, pump	KVA Transformer rolling main machine	KVA Transformer rolling auxiliary machine	Oxygen plant EAF auxiliary machine of CC
	Volt	Amp.	Power	Factor	Reactive power	Volt	Amp.	Power	Amp.	Amp.	Amp.	Amp.
	KV	A	MW		MVar	KV	A	MW	A	A	A	A
AM 11.40'	64.5	80 ~100	6~9	0.9~ 0.95	3~5	11.3 ~11.5	200 ~500	9.5 ~10.5	18~20	80~ 100	10	120
PM 2.05'	64.5	90 ~110	9~11	0.9~ 0.92	5~10	10.8 ~11.2	200 ~500	7~9	20	80~ 120	10	120

Based on the foregoing data, the apparent power is approximately as shown in the following.

Receiving power (income)	Transformer for No. 1 electric arc furnace KVA 10,000/12,500	Transformer of rolling mill 10,000/12,500 KVA			Transformer for auxiliary machine of oxygen plant, EAF and CC 12,500 KVA
		For auxiliary machine 1,000 KVA	For main machine 6,000 KVA	For auxiliary machine 6,000 KVA + 500 KVA	
9,000 KVA ~12,000	4,000 KVA ~9,500	340 KVA ~400	1,500 KVA ~2,300	190 KVA ~200	2,250 KVA ~2,400

Records kept by the factory during the day showed the following values.

Measuring time	Transformer for No. 1 electric arc furnace KVA 10,000/12,500		Transformer for rolling mill 10,000/12,500 KVA					Transformer for auxiliary machine of oxygen plant EAF and CC 12,500 KVA		
			Main circuit		Amp. of branch			Volt.	Amp. of branch	
	Volt	Amp.	Volt.	Amp.	Primary of 1,000 KVA Tr.	Primary of 6,000 KVA for rolling main machine	Primary of 6,000 KVA for rolling auxiliary machine		Primary of 1,250 KVA, 4,000 KVA Tr.	For auxiliary machine of EAF, CC
8 AM ~2 PM	KV 10.8 ~11	A 480 ~500	KV 11.8 ~11.9	A 160 ~180	A 16 ~20	A 110 ~130	A 6	KV 11.9	A 10	A 10~38
	KVA 9,100~10,200		KVA 3,300~3,700		KVA 330 ~410	KVA 2,250 ~2,680	KVA 120		KVA 200	KVA 200 ~780

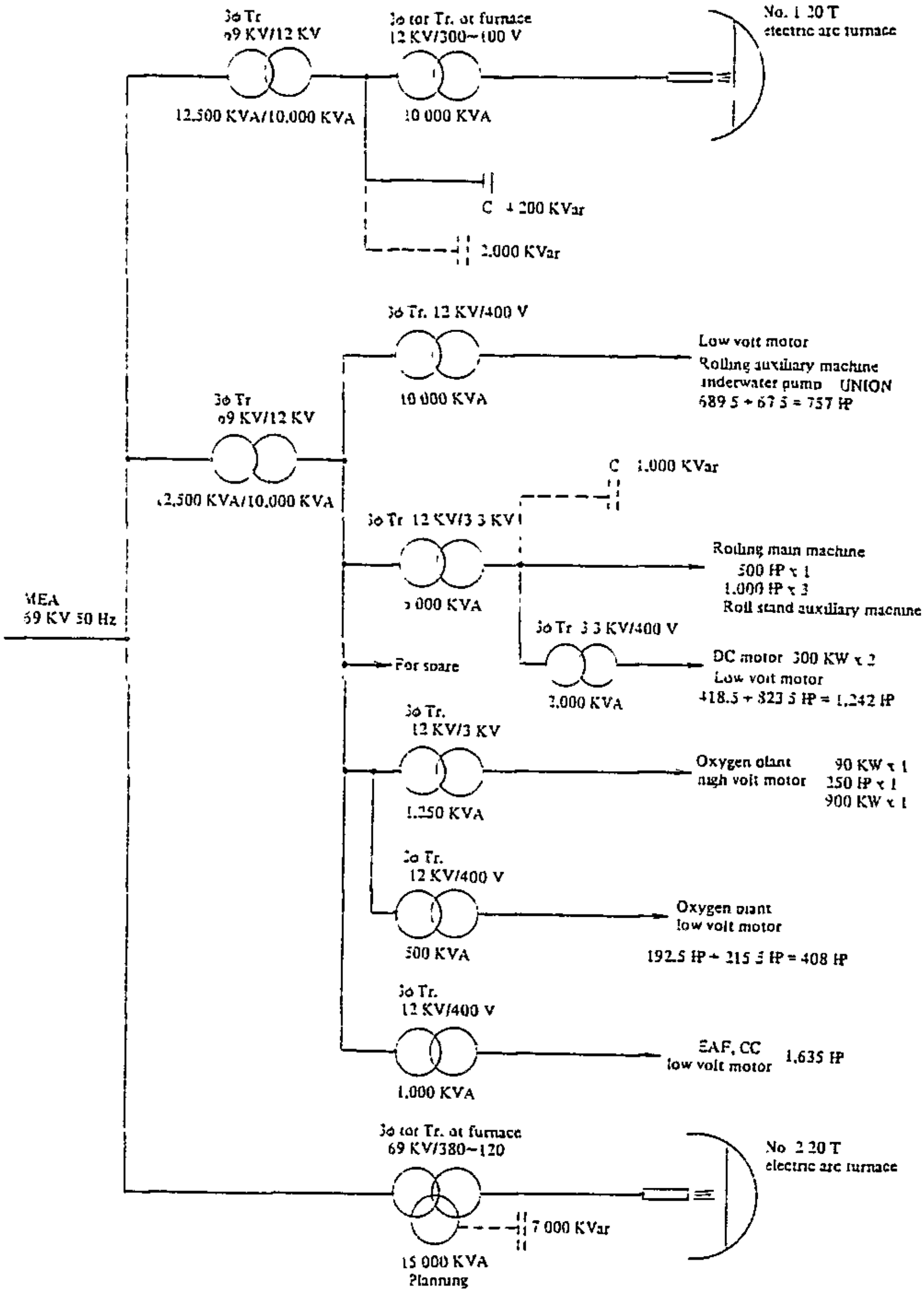
The tap voltage and current flowing of the electric-arc furnace transformer (10,000 kVA) during the melting time are shown in the following.

Time	No. of scrap charging	Tapping voltage	Amp. of electrode (amp. of arc)			
			Electrole 1	Electrode 2	Electrode 3	Remarks
11.35' AM	1	V 12,000/246	KA 12~20	KA 15~25	KA 15~23	
0.15' PM	2	12,000/246	15~25	15~25	15~25	
0.40' PM	3	12.000/246	15~25	15~25	15~25	
1.10' PM	4	12,000/279	15~25	15~25	15~25	

(1) The present capacity of the electric-arc furnace transformer is sufficient when there are eight charges per day. However, receiving is for 69 kV, and a direct voltage drop is desired, instead of a two-stage drop as at present, in terms of power losses and equipment cost.

The factory has a plan to increase the capacity of the No. 2 electric-arc furnace to 15,000 kVA. When increasing the capacity, the transformer should be of a type that allows direct dropping of the voltage from 69 kV to the furnace voltage.

(2) The loads of the transformers, 69/12 kV and 10,000/12,000 kVA, for the rolling mill are low. The load of another transformer (12,500 kVA for the oxygen plant, electric-arc furnace, the CC auxiliary equipment) is also extremely low. This transformer should be removed, and the four 12-kV branches including a spare unit, should be reconnected to the 69/12 kV, 10,000/12,500 kVA transformer for the rolling mill.



(3) In the three feeders, three transformers are used to step down from 69 kV to 400 V (69 kV/12 kV, 12 kV/3.3 kV, and 3.3 kV/400 V), involving too many steps. Therefore, transformers for less than 3.3 kV should be rearranged as shown in the following:

Load	Existing state	Improvement plan
Auxiliary machine of rolling stand	* Transformer for rolling mill #3 feeder, 6,000 KVA transformer	The same as left to #2 feeder 6,000 KVA transformer
Low voltage motor (418.5 HP)	* The same as above #3 feeder, 300 KVA transformer	The same as left to #2 feeder 2,000 KVA transformer
Low voltage motor (67.5 HP)	The same as above #3 feeder, 500 KVA transformer	The same as left to #1 feeder
Low voltage motor (215.5 HP) (192.5 HP)	Transformer for oxygen plant * #2 feeder, 400 KVA transformer	The same as left 500 KVA transformer

As a result, the transformers marked with * in the foregoing table and one-line diagram can be removed, and a wiring system as shown in the diagram in the following can be established.

Load	Existing state	Improvement plan
Auxiliary machine of rolling stand	* Transformer for rolling mill #3 feeder, 6,000 KVA transformer	The same as left to #2 feeder 6,000 KVA transformer
Low voltage motor (418.5 HP)	* The same as above #3 feeder, 300 KVA transformer	The same as left to #2 feeder 2,000 KVA transformer
Low voltage motor (67.5 HP)	The same as above #3 feeder, 500 KVA transformer	The same as left to #1 feeder
Low voltage motor (215.5 HP) (192.5 HP)	Transformer for oxygen plant * #2 feeder, 400 KVA transformer	The same as left 500 KVA transformer

Of 14 transformers, the new system will be reduced five, excluding the No. 2 electric arc furnace transformer, which has a plan to increase the transformer capacity, and losses for these five transformers will decrease.

The reduction in losses can be calculated as shown in the following.

(1) No-Load Loss (based on a plant construction manual)

69 kV/12 kV 12,500 kVA transformer	12 kV/3.3 kV 6,000 kVA transformer	12 kV/400V 400 kVA transformer	3.3 kV/400V 400 kVA transformer	3.3 kV/400V 300 kVA transformer
25 kW	12 kW	2.5 kW	2.4 kW	1.8 kW

A total of 43.7 kW will be saved.

(2) Load Loss

Assuming the apparent power impressed to the 12,500 kVA transformer for the arc furnace, CC auxiliary equipment and the oxygen plant to be 2,200 kVA on average, the load applied to the 6,000 kVA transformer for the auxiliary rolling equipment to be 150 kVA on average, 30 kVA, 30 kVA, and 50 kVA apparent power is applied to the 12 kV/400 V transformers, to the 3.3 kV/400 V, and 400 kVA transformers, respectively. Assuming the load losses during rated operations to be 85, 48, 4.2, 4.5, and 3.2 kW in order of transformer capacities,

$$85 \times \left(\frac{2,200}{12,500}\right)^2 + 48 \times \left(\frac{150}{6,000}\right)^2 + 4.2 \times \left(\frac{30}{400}\right)^2 + 45 \times \left(\frac{30}{400}\right)^2 + 3.2 \times \left(\frac{50}{400}\right)^2 = 2.6 \text{ kW}.$$

The values of transformers of less than 6,000 kVA are negligible. Therefore, assuming the load of 12,500 kVA transformer for the rolling mill is 3,600 kVA before making the change, and 5,600 kVA after making the system change, the increase in the load loss will be

$$85 \times \{(\frac{5,800}{12,500})^2 - (\frac{3,600}{12,500})^2\} = 85\{0.21 - 0.03\} = 11 \text{ kW}.$$

Therefore, copper losses will increase $11 - 2.6 = 8.4$ kW.

(3) Energy Saving

The rolling mill operates 16 hours per day. Assuming 300 working days per year, $43.7 \times 24 \times 365 - 8.4 \times 16 \times 300 = 342{,}492$ kWh/year. Assumig that there is no change in the number of about 60 holidays during the year, 342,492 kWh electric power can be saved (496,613 Bt/year).

8.4. Opening of the Furnace Cover During Electric Furnace Repair

The furnace covers are fully opened to spary furnace materials during repair after tapping. The opening area should be made smaller, as long as it does not affect the gunning work, to decrease heat loss from the furnace.

Data show that the heat loss of a 40-ton furnace is approximately 490 kWh when the furnace cover is opened for 4 minutes. Assuming that the inner furnace diameter of a 40-t furnace is 4,500 mm and that the heat loss varies in proportion to the opening area, heat loss with a 20-t furnace (inner furnace diameter 3,150 mm) will be 240 kWh/4 min.

8.5. Shorter Production Time

The Tap to Tap time is a somewhat long 180 minutes. A shorter production time is one of the principal factors of energy saving in electric furnaces, and steel production time should be shortened by a quicker charging of charging materials by press by faster melting, by shortening idle time by set-up procedures, and by other means.

8.6. Advantage of Improved Power Factor

In September last year, the factory paid the highest penalty, when the peak

demand was	10,037 kW
penalty was	48,180 Bt

Therefore, the total reactive power was:

$$10{,}037 \times 0.63 + \frac{48{,}180}{15} = 9{,}535 \text{ kVar}$$

The power factor at that time was an extremely low

$$\frac{10{,}037}{\sqrt{10{,}037^2 + 9{,}535^2}} = 0.725.$$

Connecting a 2,000 kVar condenser to the electric-arc furnace circuit and 1,000 kVar condenser to the 3.3 kV side of the 6,000 kVA transformer as mentioned before, the penalty of approximately 200,000 Bt will be almost completely eliminated. The load losses of the 6,000 and 12,500 kVA transformers will decrease automatically as shown in the following.

After the transformers are integrated as mentioned previously, the loads of the 6,000-kVA transformers, oxygen mill, and electric-arc auxiliary equipment will be as shown in the follwing.

<table>
<tr><th colspan="2">Transformer capacity</th><th>Name of load</th><th colspan="2">Apparent power</th><th>Apparent power after installed 1,000 KVar condenser</th><th>Power</th></tr>
<tr><td rowspan="3">12,500/ KVA 10,000</td><td>KVA 1,000</td><td>Auxiliary machine of rolling
Underwater pump</td><td>296+j222= 370 KVA</td><td rowspan="3">KVA
4,227+ j2,044 = 5,342</td><td></td><td rowspan="3">97.1%</td></tr>
<tr><td>KVA 6,000</td><td>Main machine of rolling
DC motor</td><td>1,676+ j1,257=2,095</td><td>1,676+j(1,257 −1,000)=1,676 +j257=1,690 KVA</td></tr>
<tr><td>KVA 1,250
KVA 500
KVA 1,000</td><td>Oxygen plant
High voltage motor
Oxygen plant
Low voltage motor
electric arc furnace
Auxiliary machine of C.C.</td><td>2,255+j565 =52,325</td><td>4,227+j (2,044− 1,000)= 4,227+ j1,044= 4,354</td></tr>
<tr><td colspan="2">12,500/10,000 KVA</td><td>No. 1 electric arc furnace</td><td colspan="2">9,484+j7,113−(4,227+ j2,044)=5,257+j5,069= 7,303 KVA</td><td>5,257+j(5,069−2,000) =5,257+j3,069= 6,087 KVA</td><td>86.4</td></tr>
<tr><td colspan="3">Receiving power (income)</td><td colspan="2">Annual average peak demand 9,484+j7,113=11,855</td><td>9,484+j4,113= 10,332 KVA</td><td>91.8</td></tr>
</table>

By inserting a 1,000 kVar condenser on the secondary side of the 6,000-kVA transformer and by inserting a 2,000 kVar condenser on the secondary side of the 12,500/10,000 kVA transformer for an electric-arc furnace, the load losses of the transformers will be reduced by:

$$48 \times \{(\frac{2,095}{6,000})^2 - (\frac{1,690}{6,000})^2\} + 85 \times \{(\frac{7,303}{10,000})^2 - (\frac{6,087}{10,000})^2\} = 2 + 13.8 \text{ kW}$$

The energy saving by inserting these condensers will be 2 kW x 16 h x 300 + 13.8 x 24 x 300 = 108,960 kWh, 157,992 Bt.

* The cost for installing two condensers is estimated to be 700,000 Bt including the cost of auxiliary equipment, and this cost can be depreciated in 4 years and 4 months.

8.7. Motor Operating States

The operating states of motors larger than 15 kW is shown in the table of next page. Those motors with particularly low loads are shown in the table in the following. Losses can be reduced by changing to those with low rated output.

Use	Before improvement					After improvement					Energy conservation KWh/year
	Rated output	Load	Efficiency	Loss	Power factor	Rated output	Load	Efficiency	Loss	Power factor	
Rolling mill, shear	22	11	89.9	1.24	74.5	15	11	89.5	1.15	83	393
Rolling mill, cutter	15	3.75	83.7	0.73	47	5.5	3.75	85.2	0.65	71	349
Rolling mill, shear	37	9.25	86.3	1.47	56	11	9.25	89	1.14	76	1,440

The real load (kW) in the above table was calculated by finding a load factor — current curve based on the measured current.

Because of steel cutting and shearing time, the loss differences will become narrower and were divided by using a correction coefficient of 1.1.

Realload (kW) $\times \frac{1}{\eta} \times (1 - \eta) \times 16 \times 300 \times \frac{1}{1.1}$, η is the efficiency at the load factor during that time.

Use	Capacity	No. of unit	Volt	Amp. Rated (A)	Amp. Measured (B)	Amp. (B)/(A)	Rotation speed	Speed control	Power factor	Remarks
			AC V	A	A	%	r.p.m.		%	
Rolling mill No. 1 STD	1,000 HP (750 KW)	1	3,300	158	Average 100	63.3	485	Second control	86	
No. 2 STD No. 3	"	1	3,300	158	Average 100	63 3	485	"	86	
No. 4~7 STD	"	1	"	160	Average 60	37.5	365	"	78	
No. 10~11 STD	500 HP (375 KW)	1	"	80	90	113	480	"	90	
No. 8 STD	300	1	DC 440	745				Volt control by SCR		Cannot measure
No. 9 STD	"	1	DC 440	745				"		
Air-compressor	75HP (56 KW)	1	AC 380	107	81.2	75.9	1,460	None	87.5	
"	"	1	"	102	85.8	84.1	1,460	"	89	
Pinch roll	15 KW	1	"	29	10	34.5		"	28	No load supposed 4P
(horizontal)	"	1	"	29	33	113.8	1,460	"	90	
Shear	22 KW	1	"	43.5	25	57.5	1,460	"	74.5	LF 50% efficiency 89 9% *
Reheating furnace fan	45 KW	1	"	85	58	68.2	2,950	"	87	
Rolling mill cooling water pump	60 HP (45 KW)	1	"	74	56.7	76.6	1,480	"	84.5	
"	"	1	"	74	52 9	71.5	1,480	"	83	
"	"	1	"	86	57 2	66 5	980	"	78	
Rolling mill cutter	15 KW	1	"	37 5	12.9~13 4	35.7	970	"	47	*
Rolling mill conveyer	"	1	"	37 5			1,460	"		Cannot measure
Rolling mill hydraulic pump	22 KW	1	"	44	44	100	1,460	"	89	
Rolling mill for cooling bed	"	1	"	40	40	100	1,450	"	89	
Rolling mill shear	37 KW	1	"	66	25	37.9	970	"	56	LF 25% efficiency 86.3%
Electric arc furnace, air compressor	75 KW	1	"	113	75	66.4	1,455	"	89	
"	"	1	"	113	74	65.5	1,455	"	88	
Oxygen plant compressor	900 KW	1	3,300	183	120	66.7	273	"	98	Synchronous motor
Oxygen plant expansion valve	90 KW	1	"	21.5	15	69.8	700	"	71	The belt was loosed

Possible energy saving by replacing the motors will be a rather insignificant sum of 2,182 kWh, or 3,164 Bt per year. Replacement of motors by purchasing them will require an extremely long depreciation period and does not offer an advantage. Aside from replacing motors, protection relays and contactors should be replaced to conform to the new motors. This should be studied when there are appropriate spare motors that fit the foregoing requirements.

8.8. Lighting

The factory has 382 40-W daylight fluorescent lamps. The following energy saving will be possible per year by replacing them with energy conservation white fluorescent lamps which are also manufactured in Thailand.

$(40 - 35) \times 382 \times 10\ h \times 300\ days \times 10^{-3} = 5{,}730\ kWh/year$

The saving amounts to 8,308 Bt a year.

8.9. Scrap Preheating

Scraps which are the raw material for to electric arc furnaces are charged into the furnaces as the are. By preheating scraps utilizing electric arc furnace exhaust gases, power consumption of 30 to 50 kW per ton of scrap can be saved.

Installation of preheaters should be incorporated in the equipment extention plan which is now being studied. Preheaters require exhaust gas treatment equipment and the present problems such as equipment cost and installation space should be considered.

Blowing fuels into the electric arc furnaces should also be studied.

9. Summary

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

	(equivalent oil) kl/year	%
Hot charging	330.0	13.0
Optimal furnace pressure	30.0	1.2
Ceramic fiber insulation	20.6	0.8
Subtotal	380.6	15.0

	10^3 kWh/year	%
Transformer rearrangement	342.5	0.8
Reduce transformer load losses by improving power factor	108.9	0.2
Change to motors with smaller ratings	2.2	—
Change daylight fluorescent lamps to energy conservation while fluorescent lights	5.7	—
Subtotal	459.3	1.0

Report No. 11: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Sahaviriya Metal Industries Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Sahaviriya Metal Industry Co., Ltd. —

1. Outline of the Factory

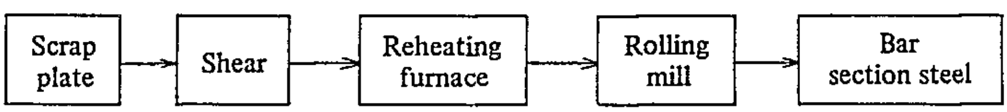
Address	115 Suksawat Rd. Amper Muang, Samutprakarn	
Capital	25 million Bt	
Type of industry	Metal	
Major products	Round bar, Reformed bar, Angle and Channel Section Steel	
Annual product	18,000 t/year	
No. of employees	150	
Annual energy consumption	Electric Power	3,244,000 kWh/year
	Fuel	Heavy oil (A and C) 1,794 kℓ/year
Interviewees	Factory Manager, Mr. Vonlop Boonpipat	
Date of diagnosis	Feb. 3 ~ 4, 1983	
Diagnosers	T. Nakagawa, T. Noda, K. Kurita	

The factory manufactures steel bars and shape steels using 4 lines of rolling mill from steel plates obtained from overhauled ships and thick plates out of specifications. The company is one of the leading reroll companys in Thailand and has other factories in the same industry. The company has 10 reheating furnaces in total, and four of them are installed in this factory.

The factory manager is an electrical engineer and is responsible for all these factories. therefore, he comes to this factory about once a week.

The factory has a production capacity for 35,000 t/year when operating in two shifts. the factory was operating at 50% capacity on one shift when the survey was made.

2. Manufacturing Process

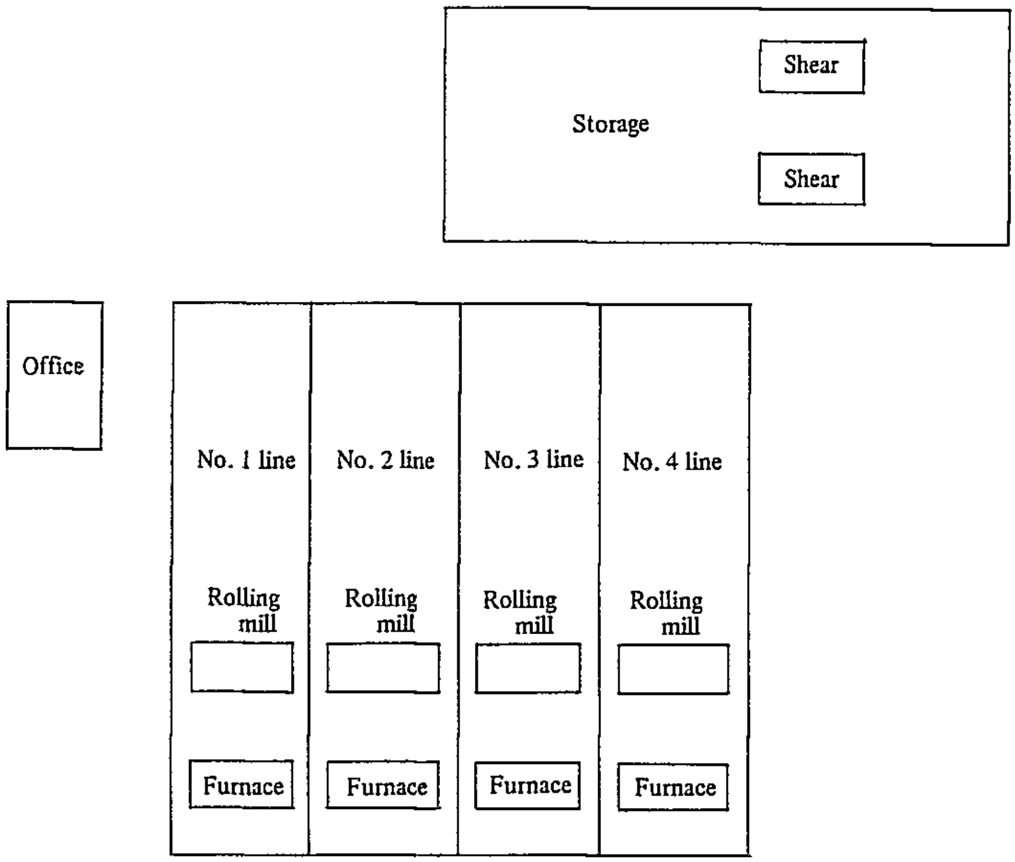


3. Major Equipment

3.1 Major Equipment

Name	No. of units installed	Type, etc.
Shear	8	Belt drive
Reheating furnace	4	8.1mL
Rolling mill	4	Belt drive

3.2 Layout



4. State of Energy Management

4.1 Implementation of Energy Conservation Measures

The factory manager recognizes the necessity of energy conservation. However, the factory does not have targets for energy conservation and has not undertaken concrete energy-conservation measures.

4.2 Grasp of Energy Consumption

The electric power consumed every month is determined from bills of MEA and is recorded accordingly. However, no study is made why consumption changed.

By installing watt-hour meters on each rolling mill and shear, their power consumption can be determined. Energy can be saved by calculating the power consumption rate for each process and product by setting targets based on the data and by improving work methods to achieve the targets. The peak demand can be suppressed by recording the electric power consumed by the entire factory by using MEA's watt-hour meters and by drawing daily load curves.

The factory pays a penalty every month and should have more interest in the power factor by recording readings of MEA's reactive power meter.

The factory had no flowmeters for fuels, and fuel consumption is not obtained. Only the amount of fuel received is grasped.

Such being the case, the energy consumption rates is not calculated, and fuel consumption performance is not examined.

4.3 Energy Conservation Committee and Suggestion System

Although no systematic activities has been undertaken for energy conservation, the factory had use some outside consultants.

Suggestion system or prize-awarding has not been instituted.

4.4 Employee Training, etc.

No employees have been sent to training seminars, etc. for employee education, and the appeal for energy conservation to the employees has not been made.

The factory manager is concerned with power losses caused by heat retention of the reheating furnaces during the night and during idling of mill in due to errors rolling.

5. State of Fuel Consumption

5.1 Fuel Consumption

Fuel consumption reached 1,794 kl/year, burning blended oil of bunker A and C on a 50/50 ratio. As the fuel oil market in Thailand is a seller's one, and there is no assurance that a buyer will always be able to buy the oil of quality he desires. In some instances, 100% bunker C is delivered.

All fuel oil is consumed by reheating furnaces.

5.2 Fuel Consumption Rate

Assuming the current production quantity to be 18,000 t/year, the annual average fuel consumption rate can be calculated as shown in the following. The level is considerably bad.

Average consumption rate = 1,794 x 10^3 l/year/18,000 t/year

= 100 l/t

5.3 Simple Heat Balance of Reheating Furnace

Simple heat balance calculations of rolling steel reheating furnaces are shown in the following. The heat balance was calculated per ton of charged steel at room temperature of 35° C as reference.

5.4 Heat Balance Chart

Input			Output		
Item	10^3 Kcal/t	%	Item	10^3 Kcal/t	%
(1) Heat of fuel combustion	668.2	97.1	(3) Heat of discharging billet	199.8	29.0
(2) Formation of scale	20.0	2.9	(4) Heat of scale	5.3	0.8
			(5) Heat loss in exhaust gas	302.1	43.9
			(6) Heat release from body	45.4	6.6
			(7) Others	135.6	19.7
Total (1) + (2)	688.2	100.0	Total (3)+(4)+(5)+(6)+(7)	688.2	100.0

5.5 Data Given for calculation of the Heat Balance

Weight of Charged Billets

No. of discharging billets (180 billets/h) x average weight of billet (9.3 kg/billet) = 1,674 kg/h.

The number of discharging billets and average billet weight were calculated based on the measured values.

Fuel Oil Consumption

No measurements were available. The fuel oil consumption was estimated based on annual consumption and the operation state as follows.

Average consumption per unit per day

{annual consumption (1,794 x 10^3 l/year)}/(300 days/year x 4 furnace) = 1,495 l/day. furnace

Average consumption per hour during heating:

1,495 l/day. furnace x {1 — Fuel oil consumption rate during heating up and keeping temperature (0.25)} ÷ Rolling time (9 h/day) x specific gravity of fuel (0.91 kg/l) = 113 kg/h

The ratio of fuel oil consumption for heating up furnace temperature and keeping temperature during lunch time was estimated at 25% of the total consumption.

Specific gravity of the blended oil was estimated to be 0.91 kg/l, same as bunker B.

Fuel oil consumption per ton of billets

Fuel oil consumption per hour (113 kg/h)/billet charging amount per hour (1,647 kg/h) = 67.5 kg/t

Heat content of fuel (low level):	9,900 kcal/kg
Theoretical amount of air:	10.4 Nm^3/kg
Theoretical amount of wet exhaust gas:	11.0 Nm^3/kg
Scaling loss of billet:	
The Fe scaling loss per ton of steel was estimated at	15 kg/t (1.5%).
Generating Heat of scale:	1,335 kcal/kg Fe
Heat content of billets	
Heat content at discharging temperature of 1277°C	207.3 kcal/kg
Heat content at charging temperature of 35°C	4.4 kcal/kg
Specific heat of scale:	0.215 kcal/kg°C
Total Fe in scale:	75.5%
Oxygen content in exhaust gas:	8.0%
Temperature of Exhause gas:	810°C
Average specific heat of wet exhaust gas:	0.33 $kcal/Nm^{3}$°C
Surface area of furnace (excluding bottom):	58.8 m^2
Average surface temperature of furnace:	128°C

5.6 Equations for Calculating the Heat Balance

Input

Heat of extracting billet

Fuel oil consumption per ton of billets (67.5 kg/t) x heat content of fuel oil (9,900 kcal/kg) = 668,250 kcal/t

Generating Heat of scale

Fe scaling loss per ton of billets (15 kg/t) x Generating Heat of scale (1,335 kcal/kg Fe) = 20,025 kcal/t

Output

Heat of discharging billet

{1,000 kg/t − Fe scaling loss (15 kg/t)} x {Heat content of billet at extracting temperature (207.3 kcal/kg) − Heat content of billet at reference temperature (4.4 kcal/kg)} = 199,856 kcal/t

Sensible heat of scale

Scaling loss per ton of steel (15 kg/t) x 100/75.5 x specific heat of scale (0.215 kcal/kg° C) x {extracting temperature (1,277° C) − reference temperature (35° C)} = 5,305 kcal/t.

Heat loss in exhaust gas

- Air ratio = 21/{21 − O_2% in exhaust gas (8.0)} ≒ 1.62.
- Actual amount of wet exhaust gas = theoretical amount of wet exhaust gas (11.0) Nm^3/kg) + {air ratio (1.62) − 1} x theoretical amount of air (10.4 Nm^3/kg) = 17.5 Nm^3/kg
- Heat loss in exhaust gas = fuel oil consumption per ton of billet (67.5 kg/t) x amount of wet exhaust gas (17.5 Nm^3/kg) x average specific heat of wet exhaust gas (0.33 kcal/Nm^3° C) x {exhaust gas temperature (810° C) − reference temperature (35° C)} = 302,105 kcal/t

Heat release from furnace (excluding bottom)

[[[{Surface temperature (128° C) + 273° C}/100° C]^4 − [{Reference temperature (35° C) + 273° C}/100° C]^4 x 4.88 x emissivity of furnace surfaces (0.8) + 2.2 x {Surface temperature (128° C) − Open air temperature (35° C)}$^{0.25}$ x {Surface temperature (128° C) − Reference temperature (35° C)}] x Furnace surface area (58.8 m^2) ÷ Weight of steel extracted per hour (1.674 t/h) = 45,435 kcal/t

Note: emissivity of furnace surfaces 0.8

Other heat losses

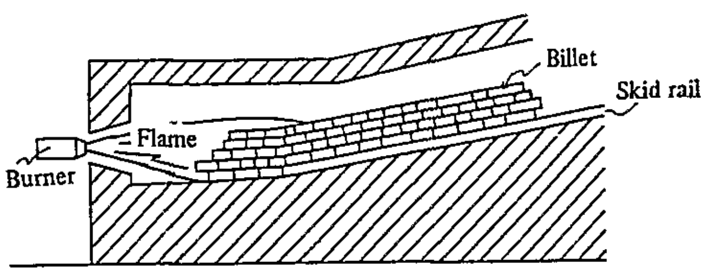
Total heat input (688,275 kcal/t) − Heat output {(199,856 kcal/t) + (5,305 kcal/t) + (302,105 kcal/t) + (45,435 kcal/t)} = 135,574 kcal/t

6. Problems in Heat Control and Potential Solutions

6.1 Heating Method

Because of improper positions and direction of three axial burners mounted on the front wall of the furnace as well as the bad hearth shape and improper extraction opening position, flames come in direct contact with billets heaped in front of the extraction opening causing oil drops to burn on the billets, or flames come in contact with the hearth when billet are less causing oil drops to burn on the hearth.

Such being the case, fuel oil is not properly atomized and burnt, and a considerable amount of black smoke is emitted.



Such a situation seems to originate in the billet charging method, which will be discussed in the next paragraph. More specifically, the lower layers of the billet heap, as they are hard to be heated, has to be heated rapidly just before the extraction in the method of impact heating by flame.

Potential solutions for these problems are shown in the following.

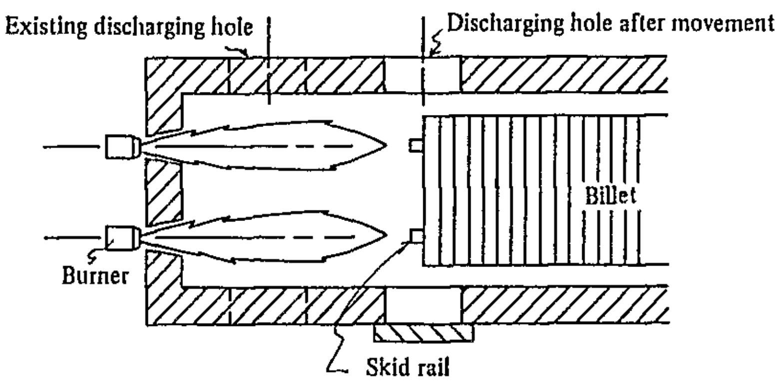
(1) Change in burner height and mounting angle

To reinstall burners after selecting a suitable angle so that burner flames do not impinge billets, ceiling, and side walls.

(2) Change in extraction opening posiiton

A space with a certain distance and volume is needed for fuel oil atomized through a burner to complete perfect combustion. At present, the extraction opening being located too near the burners, a heap of billets is impinged with flames that are in the process of burning.

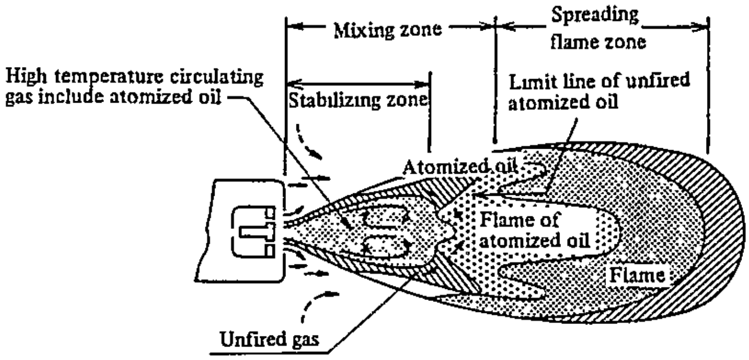
The extraction opening is recommended to be moved about 1 m towards the charging side. When the extraction opening is moved, the effective length of the furnace will shorten. However, this problem can be solved by changing the number of billet layers heaped to 2.



By moving the extraction position, the billet extraction position is placed in the same position as that of the skid end, and billets can be easily extracted by taking out billets using tongs. This offers the advantage of eliminating hard labor under high temperature involved in raking out a heap of billet carried to the skied on the hearth in front of the extraction opening using a bar. The extraction opening should be made as small as possible to reduce the loss of flames emitted. (A manhole for furnace repairs should be provided separately)

(Reference) Structure of Flame

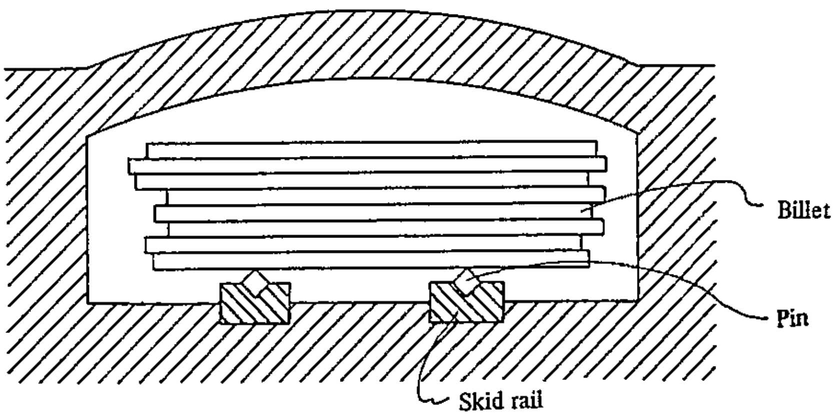
The following figure illustrates the modeled structure of oil flame. The mixing zone in the first half of the flame consists of atomized oil particles that contain fuel oil vapor. In the rear-half diffusion zone a flame gas occupies a considerable portion, but, in the front half of the center core section, a high temperature gas containing oil drops exists.



Therefore, by impinging visible flames on obstacles such as billets and hearth, oil particles turn into groups of large oil drops, being prevented from mixing well with air. Thus, combustion degrades, and this is one large reason why unburnt gases containing soot are generated.

6.2 Charging of Billets

Billets heaped in 6 to 9 layers are charged, and intermittent carrying is conducted with pitches of about 50 cm at extremely long intervals of about 10 minutes. This is degrading heat transfer.



(1) Change in Number of Billet Heap Layers

The number of billet heap layers when charging billets should be reduced to one or two layers.

When billets are heated heaped in 6 to 9 layers, the heat transfer to billets in the furnace are performed mainly by gas radiation from the upside and furnace wall radiation. Heat transfer inside the billet heap will be primarily by thermal conduction, and it is only natural that the temperature of those billets heaped in lower layers would be low compared with that of billets in the upper layers. A soaking period has to be given to eliminate this temperature difference between the top and bottom regions. The time needed to attain a uniform temperature varies in proportion to the square of the thickness (billet thickness x number of billet layers heaped). When the thickness doubles, four times as much time has to be applied for soaking.

Generally, a furnace used to heat steel that has a thickness has both heating and soaking zones. The heating zone heats the top surface temperature of steel to the required temperature, and the soaking zone after the heating zone reduces the temperature difference between the top and bottom surfaces by thermal conduction from the top surface, while maintaing the top surface temperature to the required temperature level.

In this reheating furnace, thin billets are heaped and thermal conduction between billets is small. So it is impossible to soak billets without having a soaking zone, and, it is hoped to heap billets in one or two layers to reduce the temperature difference between billets. By reducing the number of billet layers, the carrying speed inside the furnace have to be faster, and the heating time can be shorter, but billets can be heated to 1200° C in about 30 minutes when the billet thickness is 20 to 30 mm, depending on the furnace temperature profile.

When billets of 1,500L x 50w x 15T (@8.8 kg/pc) are heated in two layers, 4,580 kg/h of the steel will be heated by an effective furnace length of 6.5 m.

$$\frac{6{,}500 \text{ (furnace length)}}{50 \text{ (Billet width)}} \times 2 \text{ (No. of layers)} \times 8.8 \text{ (Weight of one billet)} \times$$

$$\frac{1}{0.5 \text{ (Heating time)}} = 4{,}576 \text{ kg/h}$$

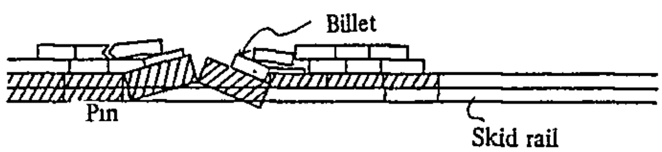
(2) Improved Pusher Operation

In order to reduce the number of billet layers and to discontinue raking out heaped billets, the pusher operation method is inevitably required to be improved. The conventional mode of pusher operation of pushing 50 cm about every 10 minutes should be changed to pushing only several tens of centimeters at intervals of several minutes. Consequently, the pusher mechanism and billet charging method need improvement.

(3) Pin Shape

Because of a large load on the pins loaded with billets sliding on skid rails, there is not piling up of billets caused by defective pin shapes. However, when the number of billet layers is reduced, this may obstruct billet carrying and will become a great hindrance to operations. Therefore, the pin length and diameter needs to be restudied. It is also needed to check the pin shape constantly and to remove pins which are deformed.

State of piling up



6.3 Burner Maintenance

(1) The burners have considerable oil leakage. Maintenance of pipe joints should be performed.

(2) Burner tiles are somewhat damaged. They should be replaced with ones having regular shapes.

6.4 Fuel Oil Temperature

In principle, the factory used blended oil (bunker A50:bunker C50). Depending on the availability of oil from oil suppliers, the factory seems to operate by burning only bunker C.

The fuel oil temperature before the burner was approximately 50° C, which is low even for a blended oil.

When the viscosity of the fuel oil is high, due to low temperature fuel oil cannot be easily atomized in the burner, causing dripping of oil drops on the hearth, long flames, and unburnt gases. Fuel oil heaters should be installed before the burners to heat blended oil and bunker C to 70 and 100° C, respectively.

6.5 Tighter Closing of Furnace Openings

At present, the door on the extraction side is extensively damaged and no charging inlet door and chimney damper are installed. Therefore, the furnace seems to be cooled substantially by open air which flows in from the openings when the furnace is out of operations.

Therefore, the following improvements should be made.

(1) Repair of the door on the extraction side and installation of a charging inlet door and a chimney damper, to make the furnace more airtight.

(2) When the furnace is not in operation during the night, the furnace openings and chimney damper should be completely closed to prevent cooling of the furnace. By doing this, the lowering of the temperature of the billets in the furnace and of the furnace itself can be minimized, thus enabling to shorten the heating time and to save heating fuel oil. Aforementioned improvement would result in fuel saving of about 40%.

Annual saving amount is calculated as follows:

1,794 kl/year x 0.4 = 716.6 kl/year

6.6 Furnace Insulation

As shown in the figure in the following, the surface temperature of the furnace side walls is considerably high.

(charging side)	65°C	121°C	130°C	143°C	170°C	120°C	(extracting side)

Two following methods can be given to insulate the furnace. (1) Insulation of furnace wall outside. (2) Insulation of furnace wall inside.

Outside wall insulation is not desirable for this furnace because of the furnace metals frame. The furnace wall inside insulation using ceramic fibers is recommended. The energy conservation effect by this type of insulation would be considerable. However, the ceramic fibers will be hard to adhere to the inside walls when they are extensively damaged and its life will be affected. Therefore, a careful study is needed when adopting this recommendation.

Results of calculating heat loss from furnace surfaces and the accumulated heat quantity are shown in the following for the present situation and when ceramic fibers 50 mm thick are lined on the inner surfaces of the furnace walls, according to these calculations, the heat loss can be reduced by about 40% by insulating the wall inside.

The heat quantity that can be saved will be as shown in the follwoing.

45,435 Kcal/t x 1.674 t/h x 0.4 = 30,423 Kcal/h

Fuel that can be saved in one year will be as follows.

$$\frac{30{,}423 \text{ Kcal/h} \times 9 \text{ h/day} \times 300 \text{ days/year} \times 4}{9{,}900 \text{ kcal/kg} \times 0.91 \text{ kg/l} \times 1000} = 36.5 \text{ l/year}$$

Further, by reducing the heat accumulated in the furnace, the fuel consumption for heating can be reduced more, and the time needed for heating will also shorten. Investment cost needed to insulate inner surfaces of all 4 furnaces is estimated to be about 75,000 Bt, which will be recovered in a period of six months.

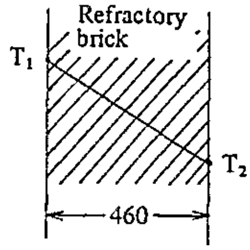
6.7 Installation of Meters

At present, no meters are installed, and operations are conducted intuitionally. Quantitative operations are desired to achieve energy conservation, and at least a fuel oil flowmeter and furnace thermometer should be installed.

6.8 Replacement of Furnace

The existing furnace is not desirable as a heating furnace, and there will be a limit even when the foregoing energy conservation measures are implemented. The fuel consumption rate is below 40 l/t with a energy conservation type heating furnace. A new furnace is highly recommended.

Existing state
(Side wall)

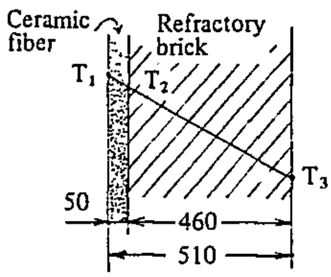


Condition for calculation

1) Emissivity 0.8
2) Atmospheric temp. 35°C
3) At steady condition

T1	1,300°C	1,200°C	1,000°C	800°C	700°C	
Outside surface temp. T2 °C	184	174	153	132	120	
Heat release Kcal/cm²h	2,520	2,271	1,795	1,353	1,148	
Accumlated heat 10^3 Kcal/m²	188.4	174.4	140.3	108.5	95.4	

Installed ceramic fiber
(Side wall)



Condition for calculation

Same as existing state

T1	1,300°C	1,200°C	1,000°C	800°C	700°C	
Boundary surface temp. T2 °C	1,045	918	700	487	396	
Outside surface temp. T3 °C	158	144	118	95	84	
Heat release Kcal/cm²h	1,878	1,600	1,125	734	571	
As compared with existing state %	74	70	63	54	50	Average 62
Accumlated heat 10^3 Kcal/m²	149.3	131.8	97.3	66.1	54.6	
As compared with existing state %	79	76	69	61		

7. State of Electric Power Consumption

Of the four rolling mills, the motor capacities for Nos. 1 and 2 stands were not clear, and there were no nameplates attached on them. According to the factory superintendent, the capacities for the motors for the stands Nos. 1 and 2 were 300kW and 520 HP, respectively.

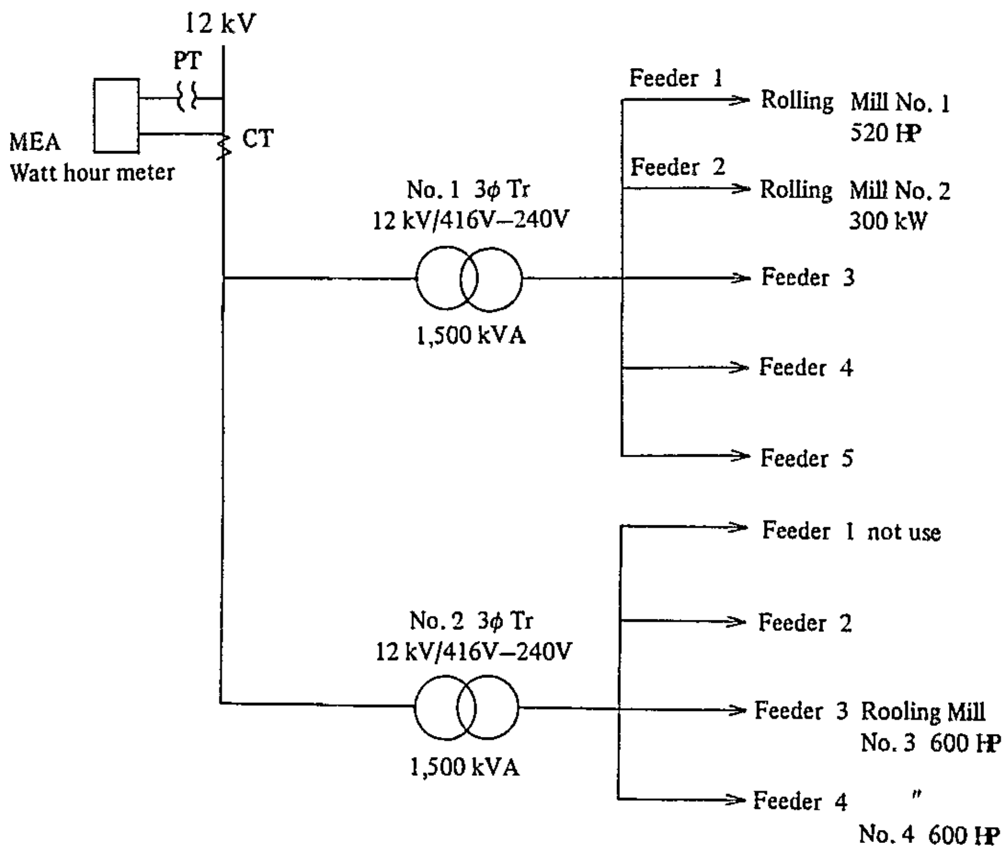
The motor capacities for stands Nos. 3 and 4 were 600 HP. The bulk of the factory's power was consumed by these four rolling mills.

7.1 The principal data relating to power consumption is shown in the following:

- Power Company : MEA
- Peak Demand : 1,400 kW
- Power consumption : 3,244,000 kWh/year 1982
- Load factor : 81.6%
- Penalty : 58,900 Bt/year 1982
- Power factor : 73%.
- Transformers : 1,500 kVA 2 banks
- Power consumption rate : 162.2 kWh/t

7.2 One-Line Diagram

The factory did not have one line diagram. The diagram was made based on an explanation by the factory and on a survey.



8. Problems in Electric Power Control and Potential Solutions

8.1 Repairs and Installation of Meters

The 1,500-kVA transformer has only a voltmeter and an ammeter. However, neither of them showed correct indications.

There was no wattmeter, watt-hour meter, reactive power meter or power factor meter.

To grasp the state of power consumption, it is essential to determine the average power consumption, peak deemand, and power factor.

The average power consumption can be obtained by recording the readings of MEA's watt-hour meter every hour. However, the maximum power and power factor cannot be obtained unless a wattmeter and a power factor meter are installed on the receiving point. In order to tackle the problem of energy conservation, these meter should be installed.

A watt meter should be installed on each of the four rolling mills to check electric power in comparison with production.

8.2 Power Factor

The power factor is low, and the factory is paying penalty every month.

Based on data taken in the first ten months of 1982, the peak demand, reactive power, and power factor are as shown in the following.

In the month in which peak demand showed the highest level:

Peak demand	1,400 kW
Penalty	278 kVar

Reactive power in this instance was:

$$1{,}400 \times 0.63 + 278 = 1{,}160 \text{ kVar}$$

Therefore, the apparent power is

$$\sqrt{1{,}400^2 + 1{,}160^2} = 1{,}818 \text{ kVA}$$

and the power factor is

$$\frac{1{,}400}{1{,}818} = 0.77 \qquad 77\%$$

In the month in which the power factor showed the lowest level:

Peak demand	1,080 kW
Penalty	400 kVar

Reactive power in this instance is:

$$1{,}080 \times 0.63 + 400 = 1{,}080 \text{ kVar}$$

Apparent power is:

$$\sqrt{1{,}080^2 + 1{,}080^2} = 1{,}080 \times \sqrt{2} = 1{,}527 \text{ kVA}$$

Power factor is:

$$\frac{1{,}080}{1{,}080 \times \sqrt{2}} = 0.707 \qquad 70.7\%$$

The foregoing data can be tabulated in a table as shown in the following.

kWh/ month	Peak demand	Penalty	Penalty fee	Reactive power	Apparent power	Power factor
180000	1080 kw	360	5400	1040 kvar	1499	72.0
180000	1080	400	6000	1080	1527	70.7
280000	1280	354	5310	1160	1727	74.1
280000	1280	314	4710	1120	1701	75.2
280000	1400	278	4170	1160	1818	77.0
284000	1280	314	4710	1120	1701	75.2
288000	1240	299	4485	1080	1644	75.4
296000	1240	299	4485	1080	1644	75.4
288000	1080	320	4800	1000	1472	73.4
348000	1120	334	5010	1040	1528	73.3

In the month the highest penalty was paid, the penalty amounted to 6,000 Bt with 400 kVar. Therefore, no penalty would be required when condensers having capacity of 400 kVar is installed. These condensers are to be divided into two groups to be connected to the secondary circuits of the transformers.

To grasp the load state of the Nos. 1 and 2 transformers, their secondary currents were checked by an ammeter on the receiving panel. However, as there was no ammeter to indicate the secondary current for the No. 2 transformer, and as measurements could not be conducted by a clamp-on ammeter because the bus was too thick, the load state was measured by ammeters at the branches. The measured figures are shown in the following.

Volt. and amp. of No. 1 transformer 11°40' Feb. 4

Volt. V	Amp. of R phase	Amp. of S phase	Amp. of T phase	Remarks
390	800 ~ 1200 A	800 ~ 1200 A	850 ~ 1200 A	

Amp. of each branch of No. 1 transformer

Volt. V	Branch 2	Branch 3	Branch 4	Remarks
390	800 ~ 1100 A	800 ~ 1200 A	500 ~ 800 A	Branch 1 is offed

The above-mentioned data shows that an apparent power of 540 to 810 kVA was applied to the No. 1 transformer.

An algebraic sum of currents cannot be obtained for the No. 2 transformer as the phases of the currents flowing to the various branches were not the same.

The current that flowed through the current coil of MEA's watt hour meter on the receiving point was 1.5 A, and the current ratio of CT $\frac{150}{2.5}$ = 60 times. Thus, the apparent power at the receiving point is 1870 kVA

This value is close to the value of the month in which the peak demand was largest.

$Pa = \sqrt{3} \times 12 \times 1.5 \times 60 = 1{,}870$ kVA

Assuming that both Nos. 1 and 2 transformers have the same power factor, the No. 2 transformer has an apparent power of a maximum of 1,060 kVA.

The average value for the power factor at the peak demand in the above-mentioned 10-month data was 0.742.

So the reactive factor in that instance would be:

$\sin \varphi = 0.67$

$\therefore Pa = 1{,}870 \times 0.742 + j1{,}870 \times 0.67 \qquad |Pa| = 1{,}870$

Assuming that the power factors of the loads applied to the Nos. 1 and 2 transformers were the same as mentioned before:

$\dot{P}a_1 = 810 \times 0.742 + j810 \times 0.67 = 601 + j543 \qquad |\dot{P}a_1| = 810$

$\dot{P}a_2 = 1{,}060 \times 0.742 + j1{,}060 \times 0.67 = 787 + j710 \qquad |\dot{P}a_2| = 1{,}060$

Connecting 200-kVar condensers to the secondary sides of these two transformers, the apparent powers for them will be as follows:

$P\acute{a}_1 = 601 + j343 \qquad |Pa_1| = 692$ kVA

$P\acute{a}_2 = 787 + j510 \qquad |Pa_2| = 938$ kVA

Assuming the copper loss of the 1500-kVA transformer under full load to be 15 kW, the amount of power saving obtained by installing condensers will be:

$$15 \times \{(\frac{810}{1{,}500})^2 - (\frac{692}{1{,}500})^2 + (\frac{1{,}060}{1{,}500})^2 - (\frac{938}{1{,}500})^2\} \times 2{,}840 \text{ h} = 7{,}975 \text{ kWh/year}$$

11,564 Bt/year

58,890 Bt/year of penalties can also be saved, or a savings of 70,454 Bt/year in total. A 200-kVar condenser including a switch seems to be purchased and installed for 70,000 Bt. The cost for two will be 140,000 Bt. which can be depreciated in two years.

8.3 Transformer

By concentrating lighting load and other motive power load for living in the factory into one transformer, another transformer can be released on the 65 holidays every year resulting in the following savings.

Putting the iron loss of the 1,500-kVA transformer at 5 kW:

$5 \times 24 \times 65 = 7{,}800$ kWh/year 11,310 Bt/year

The buses on the primary and secondary sides of the transformer are exposed, posing the danger of short circuit when something drops on them. A roof should be provided on them. (The flanks are protected by wire netting).

8.4 Lighting

(1) Due to the lack of utilizaiton of daylight, twelve 400-W mercury lamps are used over the rolling mills, etc. (5 lamps on the No. 2 rolling mill and cooling bed, 7 lamps on the Nos. 3 and 4 rolling mills). By replacing part of the roof with plastic sheet and by extinguishing these lamps, the annual power savings will be:

$400 \text{ W} \times 12 \times 10^{-3} \times 2{,}840 \text{ h} = 13{,}632 \text{ kWh/year}$

19,766 Bt/year

(2) There are twenty-six 40-W daylight fluorescent lamps in the factory and 25 of them in the offices and other places. By changing these lamps to energy conservation type white fluorescent lamps, an power savings of 5 W will be possible per lamp.

$5 \times 51 \times 2{,}840 \text{ h} \times 10^{-3} = 724 \text{ kWh/year}$

1,050 Bt/year

The total cost savings related to lighting will be:

20,816 Bt/year

8.5 Billet Charging into Rolling Mills

Billets are carried by a roller conveyor. The conveyor is discontinued at the mill inlet, and a worker lifts a billet and charges it into the mill. By remodelling it into a system as described in the following, greater safety and higher labor efficiency can be obtained.

(1) Extending the roller conveyor to the mill charging inlet and setting guides on both the right and left sides. By doing this, a worker does not have to lift the billets.

(2) The roller conveyor in this factory are connected with a motor by a belt. By remodeling it into a chain conveyor using sprockets and a chain, motive power can be transmitted without causing slipping.

8.6 Loose Shear Belt

A loose belt on a shear and a ripped belt on a combustion air fan are found. For belt life and safety, all equipment should have proper belts.

9. Summary

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

	kl/year	%
Reduced amount of heat release	36.5	2.0
Improved method of billet heating	717.6	40.0
Subtotal	754.1	42.0

	10^3 kWh/year	%
Improved power factor by installing condenser	8.0	0.25
Releasing one transformer on holidays	7.8	0.24
Less lights used during the day	13.6	0.42
Replacement of lamps	0.7	0.02
Subtotal	30.1	0.93

Report No. 12: Metal

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

— Union Metal Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Union Metal Co., Ltd. —

1. Outline of the Factory

Address	79 Poochaosamingprai Rd. Bangyaprak Phrapradaeng, Samutprakarn	
Capital	100 million Bt	
Type of industry	Metal	
Major products	Round steel bar, Aluminum building material, Brass sheet	
Annual product	Round steel bar 7,538 t/year Aluminum building material 1,746 t/year Brass sheet 118 t/year	
No. of employees	Worker 450, Staff 48	
Annual energy consumption	Electric Power	9,300,000 kWh/year
	Fuel	Fuel Oil 1,600 kℓ/year LPG 130 t/year
Interviewees	Plant Manager Mr. Mana Traiphong Asst. Plant Manager Mr. Henry K. Cheng	
Date of diagnosis Diagnosers	Feb. 7 ~ 8, 1983 T. Nakagawa, T. Noda, K. Kurita	

This company is a joint venture between Thailand and Hong Kong. Engineers from Hong Kong are always on duty at the company.

Three types of products are manufactured.

(1) Semiprocessed plate is purchased and rerolled to manufacture steel bars.

(2) Aluminum base metal is extruded to manufacture construction materials such as sash.

(3) Brass scrap is melted, then cast and cold rolled to manufacture brass sheeting.

This company entered into technical license agreements with Hong Kong Chiap Hua Manufacturing Co., Ltd. for the manufacture of steel bars and brass and with Comalco of Australia for aluminum products.

Aluminum billets are imported from Australia and New Zealand.

The production capacity of the steel bar is 18,000 t/year, but its operation last year was about 42%.

The factory is currently operated eight hours per day with one shift.

The factory for aluminum construction materials operated last year at about 62% of its 2,400 t/year production capacity.

Operations are basically on a one-shift basis but there is considerable overtime. Twenty-five percent of the annual operation is performed in two shifts.

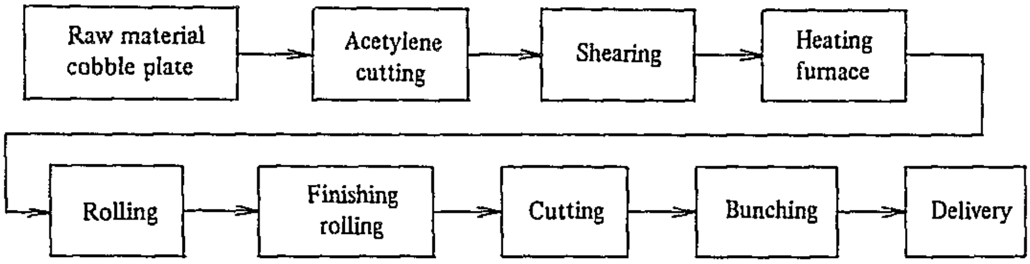
The production capacity of the brass sheet is 300 t/year but it operated last year at about 39%.

Since the market for brass sheets is very small, production is performed on an order basis.

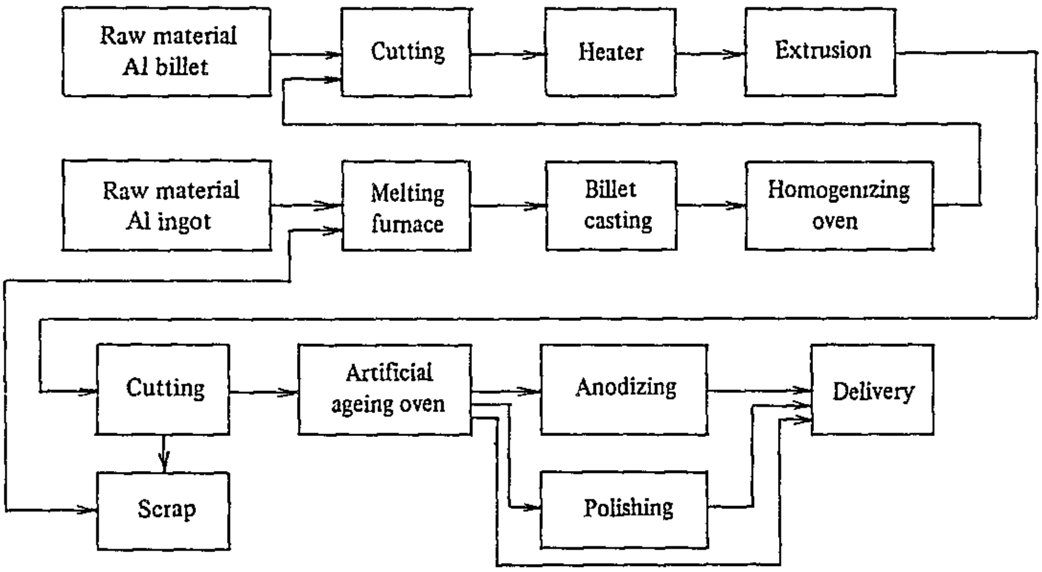
Production of aluminum construction materials is ranked third in the industry but the amount of production of steel bars is smaller in the industry.

2. Manufacturing Process

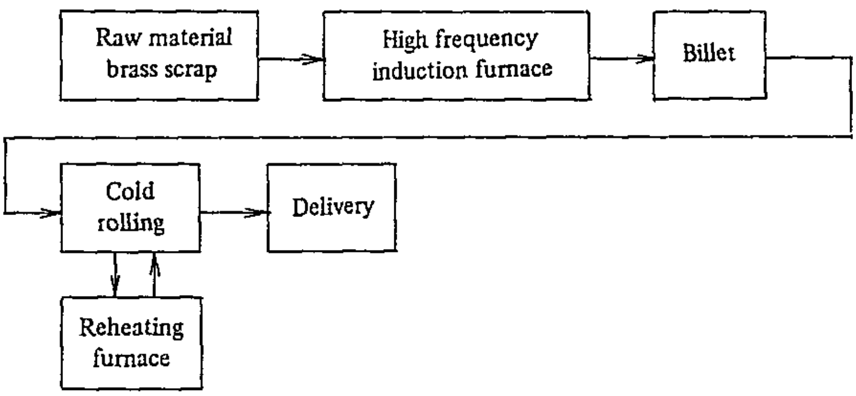
Steel Rolling Process



Aluminium Extrusion Process



Brass Sheet Rolling Process



3. Major Equipment

3.1 Major Equipment

Steel bar factory

Name	No. of units installed	Type, etc.
Reheating furnace	1 set	30 t/shift
Reheating furnace	2 sets	20 t/shift
Rolling mill	3 sets	
Shearing machine	10 sets	100 HP 1 set 60 HP 2 sets 30 HP 4 sets 25 HP 3 sets

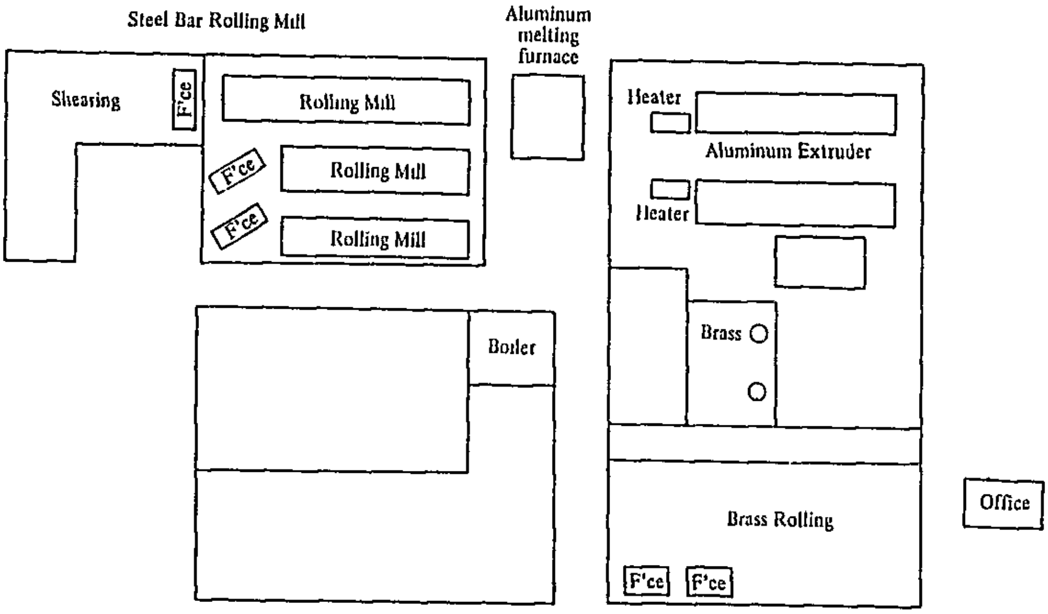
Aluminum factory

Melter	1 set	
Induction heater	1 set	Induction heater (800 kg/h)
Reheating furnace	1 set	LPG (800 kg/h)
Extruder	2 sets	
Anodizing plant	1 set	
Boiler	2 sets	
Ageing oven	1 set	
Homogenizing furnace	1 set	Car type

Brass sheet factory

Name	No. of units installed	Type, etc.
Oven	1 set	
Induction furnace	2 sets	Capacity 0.5 t 180 kW
Rolling mill	1 set	

3.2 Layout



4. State of Energy Management

4.1. Investment for Energy Conservation

Target of energy conservation as the company is not concretely set.

Investment fund of which can be recovered within three years is considered but investment of large amount per one case is deemed to be difficult and a policy such as a plan with small amount of investment will be executed one by one.

4.2. Grasp of Energy Consumption

The consumption of electric energy is measured once a week, but fuel consumption is not measured, and only the received amount is known.

The energy consumption rate has been grasped for the steel bar, but those of the aluminum extrusion and brass are not analyzed.

To control the amount of energy consumption, it is necessary to install a flowmeter for fuel and an watt-hour meter for electric power in each facility to measure the energy used and record them. By calculating and controlling the energy consumption rate bases on these measurements, the optimum fuel consumption can be assessed when production fluctuates.

An important point to consider is that in this factory, a service tank is installed on a frame and a burner is fed by natural flow. Since the flow of fuel may be interrupted by the installation of a flow meter, attention should be paid to the selection of the meter and method of installation.

4.3. Energy Conservation Committee and Suggestion System

Although there is no organization for energy conservation, a meeting of section chiefs and their superiors is held to deal with problems when necessary.

There are no contracts with consultants. There is no suggestion system for improvements and no award system.

4.4. Employee Training

Selected employees participate in seminars for training three or four times every year. These seminars cover all aspects related to human relations, management, safety and the handling of LPG, etc.

Employees are not encouraged to conserve energy directly by the general manager of the factory, but through the section chiefs.

4.5. Other

Misrolled materials and scraps are left in disorder in the steel bar factory. This poses a problem from standpoints of efficiency and safety.

It is recommended that the factory take proper measures to arrange and maintain these work areas.

Although the factory for aluminum construction materials is judged to be more aware of proper arrangement than the steel bar factory, more attention is required on safety, as there are many pieces of equipment in a smaller space.

5. State of Heat Energy Consumption

5.1. The state of consumption and details on usage of fuel are as follows:

C Fuel oil : 1,600 kl/year

Details on usage	Round steel Bar	56%	(reheating furnace)	(896 kl)
	Aluminum	20%	(boiler for anodizing)	(320 kl)
		11%	(melting furnace)	(170 kl)
	Brass	13%	(including aluminum, homogenizing furnace)	(208 kl)

L.P.G. 130 t/year

All for aluminum

Heating of aluminum	:	90%	(117 t)
Ageing furnace	:	10%	(13 t)

5.2. Fuel Energy Consumption Rate

Round bar: $(1{,}600 \times 10^3) \times 0.56/7.538\ t = 118.9\ l/t$

Heating of aluminum: $(117 \times 10^3)/(1{,}476 \times 0.5) = 158.5\ kg/t$

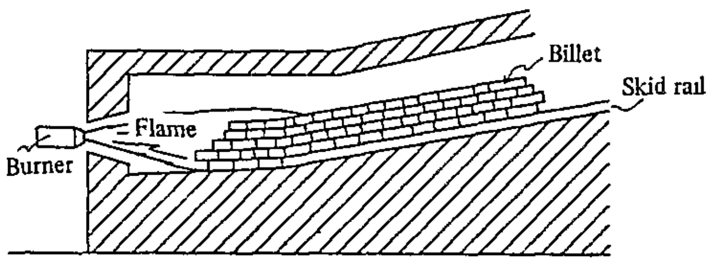
It was assumed that the same amount of metal was heated in the LPG heating furnace and induction heating furnace.

Although there may be a problem in the accuracy of values used and set values in the assuemd conditions, the fuel energy consumption rate is very poor for both round steel bars and aluminum. It is considered that there is enough room for energy conservation.

6. Problems in Heat Control and Potential Solutions

6.1. Heating Method of Billet Reheating Furnace

Because of improper positions and direction of three axial burners mounted on the front wall of the furnace as well as the bad hearth shape and improper extraction opening position, flames come in direct contact with billets heaped in front of the extraction opening causing oil drops to burn on the billets, or flames come in contact with the hearth when billets are less causing oil drops to burn on the billets or on the hearth to burn. Such being the case fuel oil is not properly atomized and burn, and a considerable amount of black smoke is emitted.



Such a situation seems to originate in the billet charging method, which will be discussed in the next paragraph. More specifically the lower layers of the billet heap, as they are hard to heated, has to be heated rapidly just before the extraction in the method of impact heating by flames.

Potential solutions for these problems are shown in the following.

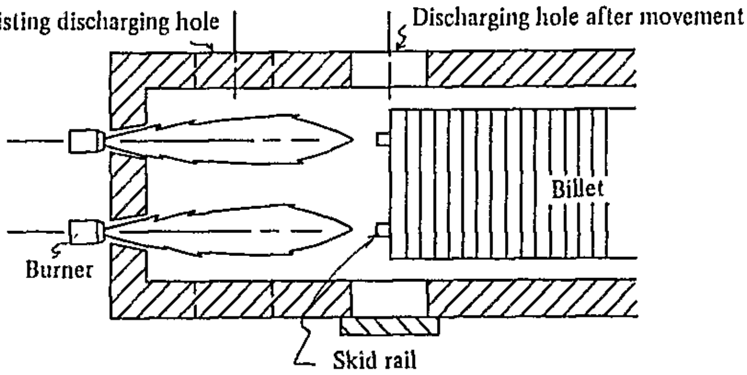
(1) Change in burner height and mounting angle

To reinstall burners after selecting a suitable angle so that burner flames do not impinge billets, ceiling, and side walls.

(2) Change in extraction opening position

A space with a certain distance and volume is needed for fuel oil atomized through a burner to complete perfect combustion. At present, the extraction opening being located too near the burner, a heap of billets are impinged with flames that are in the process of burning.

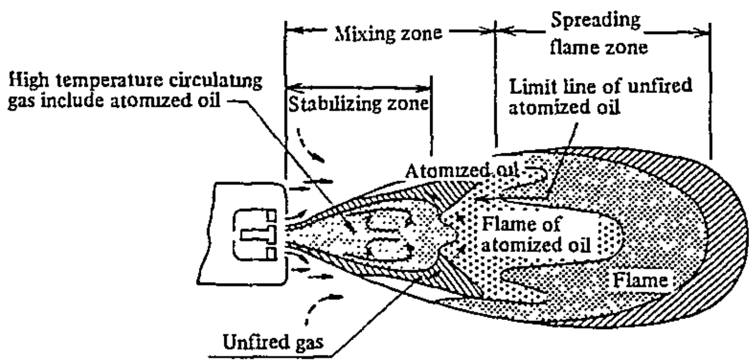
The extraction opening is recommended to be moved about 1 m towards the charging side. When the extraction opening is moved, the effective length of the furnace will shorten. However, this problem can be solved by changing the number of billet layers heaped to 2.



By moving the extraction position, the billet extraction position is placed in the same position as that of the skid end, and billets can be easily extracted by taking out billets using tongs. This offers the advantage of eliminating hard labor under high temperature involved in raking out a heap of billets carried to the skid end onto the hearth in front of the extraction opening using a bar. The extraction opening should be made as small as possible to reduce the loss of flames emitted. (A manhole for furnace repairs should be provided separately.)

(Reference) Structure of Flame

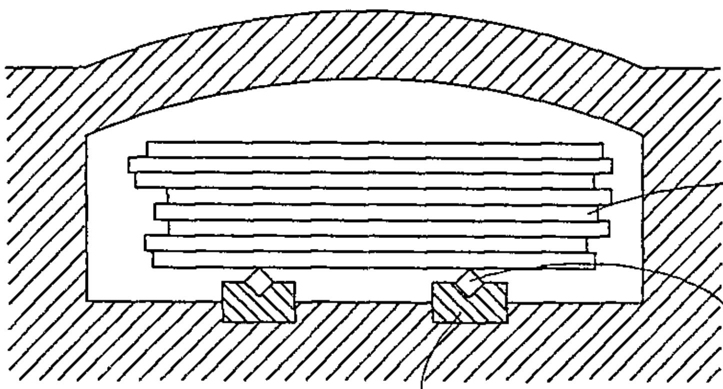
The following figure illustrates the modeled structure of oil flame. The mixing zone in the first half of the flame consists of atomized oil particles that contain fuel oil vapor and generated from oil drops. In the rear-half diffusion zone, a flame gas occupies a considerable portion. But in the front half of the center core section, a high temperature gas containing oil drops exists.



Therefore, by impinging visible flames on obstacles such as billets and hearth, oil particles turn into groups of large oil drops, being prevented from mixing well with air. Thus, combustion degrades, and this is one large reason why unburnt gases containing soot are generated.

6.2. Charging of Billets

Billets heaped 5 to 7 layers are charged, and intermittent carrying is conducted at extremely long intervals. This is degrading heat transfer.



(1) Change in Number of Billet Heap Layers

The number of billet heap layers when charging billets should be reduced to one or two layers.

When billets are heated heaped in 5 to 7 layers, the heat transfer to billets in the furnace are performed mainly by gas radiation from the upside and furnace wall radiation. Heat transfer inside the billet heap will be primarily by thermal conduction, and it is only natural that the temperature of those billets heaped in low layers would be low compared with that of billets in the upper layers. A soaking period has to be given to eliminate this temperature difference between the top and bottom regions. The time needed to attain a uniform temperature varies in proportion to the square of the thickness (billet thickness x number of billet layers heaped). When the thickness doubles four times as much time has to be applied for soaking.

Generally, a furnace used to heat steel that has a thickness has both heating and soaking zone. The heating zone heats the top surface of steel to the required temperature, and the soaking zone after the heating zone reduces the temperature difference between the top and bottom surfaces by thermal conduction from the top surface, while maintaining the top surface temperature to the required temperature level.

In this rerolling furnace, thin billets are heaped and thermal conduction between billets is small. So it is impossible to soak billets without having a soaking zone, and it is hoped to heap billets in one or two layers to reduce the temperature difference betwee billets. By reducing the number of billet layers, the carrying speed inside the furnace have to be faster, and the heating time can be shorter. But billets can be heated to 1,200° C in about 30 minutes when the billet plate thickness is 20 to 30 mm, depending on the furnace temperature profile.

When billets 1,500 L x 50 W x 15 T (@8.8 kg/pc) are heated in two layers, 9,150 kg/h of the steel will be heated by an effective furnace length of 13 m.

$$\frac{13{,}000\ (\text{Furnace length})}{50\ (\text{Billet width})} \times 2\ (\text{No. of layers}) \times 8.8\ (\text{Weight of one billet})$$

$$\times \frac{1}{0.5\ (\text{Heating time})} = 9{,}150\ \text{kg/h}$$

(2) Improved Pusher Operation

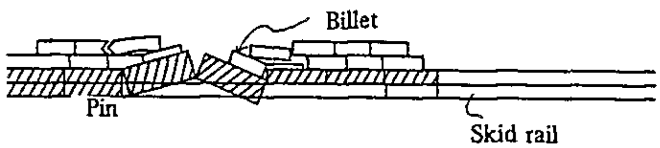
In order to reduce the number of billets layers and to discontinue raking out heaped billets, the pusher operating method is inevitably required to be improved. The conventional mode of pusher operation of pushing should be changed to pushing only several centimeters at interval of several minutes.

Consequently, the pusher mechanism and billet charging method need improvement.

(3) Pin Shape

Because of a large load on the pins loaded with billets sliding on skid rails, there is not piling up of billets caused by defective pin shapes. However, when the number of billet layers is reduced, this may obstruct billet carrying and will become a great hindrance to operations. Therefore, the pin length and diameter needs to be restudied. It is also needed to check the pin shape constantly and to remove pins which are deformed.

State of piling up



6.3. Burner Maintenance of Billet Reheating Furnace

(1) The burners have considerable oil leakage. Maintenance of pipe joints should be performed.

(2) Burner tiles are somewhat damaged. They should be replaced with ones having regular shapes.

6.4. Fuel Oil Temperature of Billet Reheating Furnace

Although an oil tank with a small capacity is installed near the wall of each furnace and oil in the tank is heated by heat transferred from furnace wall, the temperature of the fuel oil is raised to only about 45° C, as the heating surface is small.

When the viscosity of the fuel oil is high due to low temperature, fuel oil cannot be easily atomized in the burner, causing dripping of oil drops on the hearth, long flames, and unburnt gases. Fuel oil heater should be installed before the burner to heat the fuel oil to 100°C respectively.

6.5. Tighter Closing of Furnace Openings of Billet Reheating Furnace

At present, the door on the extraction side is extensively damaged and no charging inlet door and chimney damper are installed. Therefore, the furnace seems to be cooled substantially by open air which flows in from the openings when the furnace is out of operations.

Therefore, the following improvement should be made.

(1) Repair of the door on the extraction side and installation of a charging inlet door and a chimney damper, to make the furnace more airtight.

(2) When the furnace is not in operation during the night, the furnace openings and chimney damper should be completely closed to prevent cooling of the furnace. By doing this, the lowering of the temperature of the billets in the furnace and of the furnace itself can be minimized, thus enabling shorten the heating time and to save heating fuel oil.

We conclude that introducing the above-mentioned measures will result in energy conservation of approximately 40%, which will translate to the annual conservation shown in the following.

896 kl/year x 0.4 = 358 kl/year

6.6. Insulation of Billet Reheating Furnace

Two methods can be used to insulate the furnace. (1) Insulation of furnace wall outside. (2) Insulation of furnace wall inside. Outside wall insulation is not desirable for this furnace because of the furnace structural metals frame. The furnace wall inside insulation using ceramic fibers is recommended. The energy-conservation effect with this type of insulation would be considerable. However, the ceramic fiber will be hard to adhere to the inside walls when they are extensively damaged and its life will be affected. Therefore, a careful study is needed when adopting this recommendation.

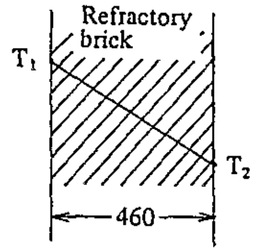
Results of calculating heat loss from furnace surfaces and the accumulated heat quantity are shown in the following for the present situation and when ceramic fibers 50 mm thick are stuck on the inner surfaces of the furnace walls.

Assuming that the surface area of the furnace is 60 m^2 and the average internal temperature is 1,000°C. When insulated with ceramic fiber, the following savings can be obtained:

$$\frac{(1.795 - 1.125)\ \text{kcal/m}^2\text{h} \times 60\ \text{m}^2 \times 8\ \text{h} \times 300\ \text{day}}{9{,}900 \times 0.86 \times 1{,}000} \times 3\ \text{unit} = 34.0\ \text{kl/year}$$

The cost for lining the three furnaces will be approximately 112,000 Bt, which can be depreciated in approximately nine months.

Existing state
(Side wall)

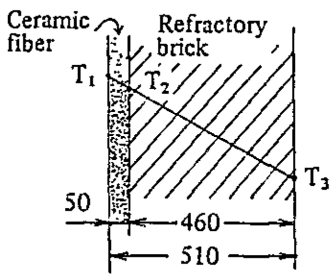


Condition for calculation

1) Emissivity 0.8
2) Atmospheric temp. 35°C
3) At steady condition

T_1	1,300°C	1,200°C	1,000°C	800°C	700°C	
Outside surface temp. T_2 °C	184	174	153	132	120	
Heat release Kcal/m²h	2,520	2,271	1,795	1,353	1,148	
Accumulated heat 10^3 Kcal/m²	188.4	174.4	140.3	108.5	95.4	

Installed ceramic fiber
(Side wall)



Condition for calculation

Same as existing state

T_1	1,300°C	1,200°C	1,000°C	800°C	700°C	
Boundary surface temp. T_2 °C	1,045	918	700	487	396	
Outside surface temp. T_3 °C	158	144	118	95	84	
Heat release Kcal/m²h	1,878	1,600	1,125	734	571	
As compared with existing state %	74	70	63	54	50	Average 62
Accumulated heat 10^3 Kcal/m²	149.3	131.8	97.3	66.1	54.6	
As compared with existing state %	79	76	69	61		

6.7. Installation of Meters

At present, no meters are installed, and operations are conducted by intuitionally. Quantitative operations are desired to achieve energy conservation, and at least a fuel oil flowmeter and furnace thermometer should be installed.

6.8. Replacement of Furnace

The existing furnace is not desirable as a heating furnace, and there will be a limit even when the foregoing energy-conservation measures are implemented. The fuel consumption rate is below 40 l/t with a energy-conservation type heating furnace. A new furnace is highly recommended.

6.9. Aluminum Melting Furnace

(1) The burner tiles have considerable damage and because the burner is located in a high position, its maintenance is not easy. Therefore, a platform must be provided under the burner to maintain it properly.

Burner tiles must be replaced with those of the regular configuration.

(2) The flame is blown off and atomization is poor. The temperature of fuel oil must be kept at 100° C. Since exhaust gas burns at an exhaust hole in the furnace during melting and considerable amount of black smoke is discharged from the stack, an adjustment to increase the air ratio is required.

(3) An attempt must be made to charge quickly and shorten the melting time to save energy.

6.10. Aluminum Billet Heating Furnace

Combustion in the inlet zone is frequently repeating on-off and the time when the flame is out. Exhaust gas is discharged from several ducts provided over each zone.

It is recommended that two exhaust ducts at inlet zone be left as is and other exhaust ducts be closed. Also, by stopping a burner at the inlet zone and introducing combustion gas generated at an extraction zone into inlet zone, combustion gas can be utilized for heating the billets, thereby conserving fuel.

6.11. Aluminum Homogenizing Furnace

(1) Control of Combustion

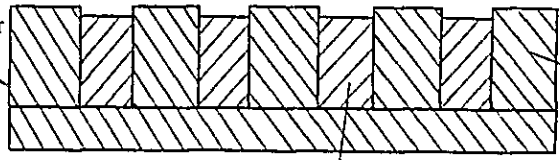
The portion of flame not ignited is long and chars the buffle plate. Serious damage of the burner tiles is observed.

The fuel oil temperature was 42° C. To improve combustion, a fuel oil heater must be provided to raise the fuel temperature at the burner over 100° C and to improve atomization. Burner tiles should be replaced and the flame shortened by adjusting the air ratio.

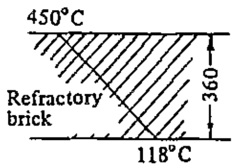
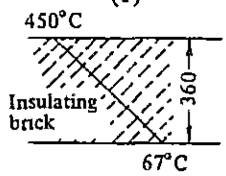
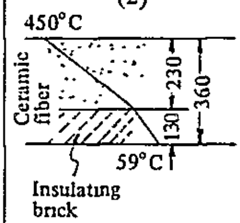
(2) Insulation of Carriage

Improved insulation on carriage in an attempt to reduce the heat loss and regenerative heat of the carriage must be made by adding as much insulation brick and material as possible.

Since the loaded weight is two tons and the processing temperature is low, the carriage can be operated with only insulating bricks.



The effect of adding insulation material is considerable as shown in the following calculation example.

	Existing state	Improvement plan	
		(1)	(2)
Insulating composition of car			
Heat release	793 $Kcal/m^2h$	147 $Kcal/m^2h$	75 $Kcal/m^2h$
Compared with existing state	100	18	9
Accumulated heat	$40.1 \times 10^3 Kcal/m^2$	$12.6 \times 10^3 Kcal/m^2$	$3.6 \times 10^3 Kcal/m^2$
Compared with existing state	100	31	9

Data for calculation: Temperature of under car 50°C
Emissivity of under car 0.8

By using the above-mentioned calculation results based on the following assumptions, a fuel oil savings of about 12 kl can be expected annually.

Dimension of carriage:

Length 7 m x width 1.5 m x thickness 0.36 m (estimated)

Operating time:

8 h/day x 250 day/year

State of carriage insulation:

By combining proposals for improvements (1) and (2) in the above table, the area ratio (1) versus (2) is 2:1.

6.12. Boiler

(1) Improvement of Air Ratio

Air ratio is 1.67 with an 8.4% oxygen content in the exhaust gas.

Fuel can be conserved by operating a boiler with air ratio of 1.3 (Oxygen content = 4.85%) by adjusting the damper of a blower.

Temperature of exhaust gas	:	380° C
Loss of exhaust gas with 8.4% oxygen	:	20.9%
Loss of exhaust gas with 4.85% oxygen	:	16.5%

Therefore, the annual fuel conservation becomes as follows:

$$(1 - \frac{1 - 0.209}{1 - 0.165}) \times 320 \text{ kl/year} = 16.9 \text{ kl/year}$$

(2) Temperature of Exhaust Gas

Temperature of exhaust gas is a remarkably high 380° C. The amount of exhaust gas should be reduced by improving the air ratio and also external and internal surfaces of the heat transfer tube should be cleaned.

When the temperature of the exhaust gas is lowered to 230° C, the following effect can be expected together with an improvement of the air ratio.

Current loss of exhaust gas	:	20.9%
Loss of exhaust gas when air ratio is 1.3 and temperature of exhaust gas is 230° C	:	9.4%
Amount of fuel conservation	:	

$$(1 - \frac{1 - 0.209}{1 - 0.094}) \times 320 \text{ kl/year} = 40.6 \text{ kl/year}$$

(3) Quality of Feedwater and Blow Water

The quality of feedwater and blow water was as follows:

	PH	Conductivity $\mu s/cm$
Feed water	6.27	340
Softened water	8.75	25
Blow water	9.72	14,000

Since the P_H of the blow water is low, it must be adjusted as follows by using boiler compound:

Feedwater	:	pH 7 to 9
Blow water	:	pH 11.0 to 11.8

Since the electrical conductivity is a high 14,000 μS/cm, blowing must be frequently carried out to reduce it to less than 4,500 μS/cm and prevent scale from sticking to the heat transfer surface.

(4) Other

Parts inside the boiler room must be set aside and well arranged.

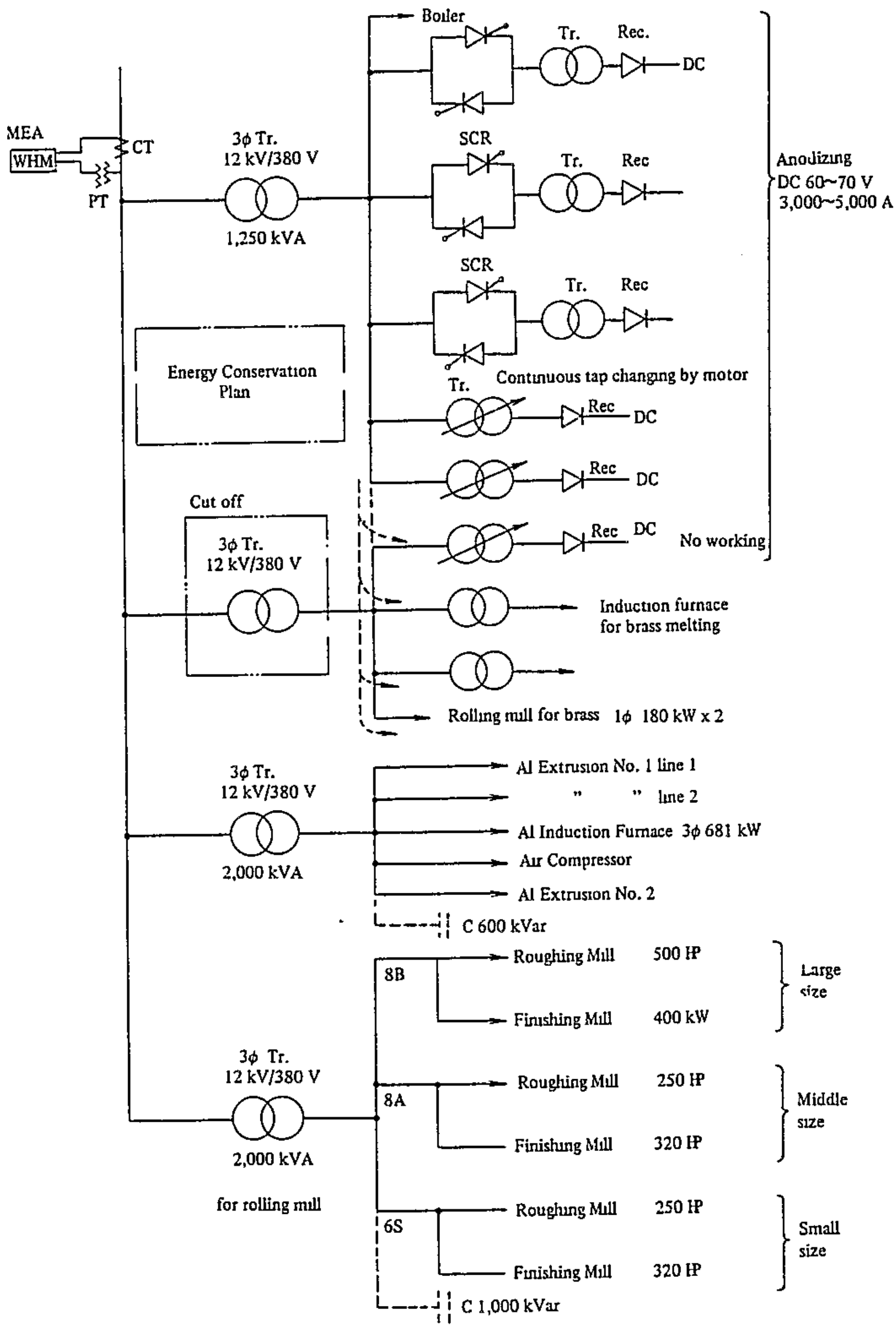
7. State of Electric Power Consumption

There are three main departments of round steel bars, aluminum construction material and brass. Electric power is consumed in the following proportions: iron, 25%; aluminum, 60%, and brass, 15%.

7.1. The Principal Data Relating to Power Consumption

• Electric Company	:	MEA	
• Peak Demand	:	3,180 kW on average	
• Annual Power consumption	:	9,300,000 kWh	
	:	Detail: Iron	2,325,000 kWh
	:	Aluminum	5,580,000 kWh
	:	Brass	1,395,000 kWh
• Load factor	:	84.8% for average value of peak demand	
	:	Annual operating time	3,450 hours
	:	Average electric power	2,696 kW
• Penalty	:	1,000 kVar/month on average	
• Power factor	:	69.2% Power factor is improved only for induction heating furnace.	
• Transformer	:	3 ϕ 1,250 kVA x 2 3 ϕ 2,000 kVA x 2	
• Electricity power consumption rate:			
	:	Steel round bar	308.4 kWh/t
	:	Aluminum	3,780.5 kWh/t
	:	Brass	11,822 kWh/t

7.2. One-Line Diagram



8. Problems in Electric Power Control and Potential Solutions

8.1. Maintenance of Measuring Equipment

There are no measuring instruments for incoming side such as a voltmeter, ammeter, wattmeter, power-factor meter and frequency meter at receiving panel.

For this reason, it is difficult to grasp the total load conditions of the entire factory.

For instance, although the terminal voltage of the rolling mill motor is low, it cannot be determined whether it is caused by a low primary voltage or an improper tap.

In addition, some of the ammeter indications at the secondary side of the transformer were inaccurate.

These instruments must be installed and calibrated for accurate reading to maintain optimum electric power control.

Since an watt-hour meter and reactive power meter from MEA are installed in conspicuous places it is hoped that readings will be recorded every hour to control peak demand and improve the power factor.

8.2. Power Factor

The power factor is low and a penalty is paid every month.

(1) The current power factor is estimated using two methods.

When peak demand is 3,180 kW and the penalty is 15,000 Bt/month, the following results can be obtained from the relationship shown below:

(Amount of reactive power/month − Peak demand x 0.63) x 15 = Penalty, Bt/month

Amount of reactive power = 3,003 kVar

Apparent power = $\sqrt{3,180^2 + 3,003^2}$ = 4,337 kVA

$\therefore$ Power factor $= \dfrac{3,180}{4,337} = 73.3\%$

Alternatively, an hourly reading of the MEA meters was taken and the following table was obtained by the same calculation.

Time	Power kwh/h	Reactive power kVar h/h	Apparent power kVA	Power factor %
2.7 3.30 PM ~ 4.30 PM	1,800	1,800	2,545	70.7
2.8 10.06' AM ~ 11.06' AM	2,640	2,400	3,568	74.0
11.06' AM ~ 12.06' AM	2,580	2,400	3,524	73.2
12.06' AM ~ 1.06' PM	2,640	2,400	3,568	74.0
1.06' PM ~ 2.06' PM	2,520	2,340	3,439	73.3

That is, the current power factor is found to be about 70 ~ 75%.

(2) The load of each transformer was measured to determine the capacity of the condenser which will be inserted into each transformer to improve the power factor.

Since the current capacity of the main bus of each transformer was too large to be measured by the available clip-on wattmeter, it was measured for each branch. The results of the measurement are as shown in the following table:

Rating and Use for Tr.	Branch Name	kW	V	AR	AS	AT	Cos. φ
Tr. for Al Anodizing 1,250 kVA 12 kV/ 400 V 60 1 A/1,801 A % Z = 6.0 tap 12.6 kV, 12.3 kV, 12 kV, 11.7 kV, 11.4 kV	Anodizing						
	DC 3,000 A	174	384	345	383	388	0.683
	DC 5,000 A	233	379	660	719	660	0.533
	Boiler	34	379	94.5	65.2	62.3	0.8
Tr. for Al Anodizing 1,250 kVA 12 kV/ 400 V 60.1 A/1,801 A % Z = 6 0 tap 12 6 kV, 12.3 kV, 12 kV, 11.7 kV, 11.4 kV	Anodizing						
	DC 3,000 A	132	388	245	217	215	0 905
	DC 5,000 A	114.2	387	225	223	184	0.764
	Boiler	43	387	86.2	72.9	81.1	0.8
Tr. for Al Extrusion 1,000 kVA 12 kV/ 400 V 98.7 A/2,887 A % Z = 6.1% tap 5 step 12.6 kV, 12.3 kV, 12 kV, 11.7 kV, 11 4 kV	Extrusion No. 1 line 1	78	381	196	196	194	0.603
	" " line 2	86.2	381	250	253	258	0.516
	Induction Heater	348	380	540	594	405	0.89
	Air Compressor	120	382	231	280	276	0.657
	Extrusion No. 2	215	378	481	416	405	0.789
Tr. for Rolling Mill (Fe) 2,000 kVA same as for Al Extrusion	Roll No. 8B	407~ 819	373	482~ 712	375~ 659	348~ 1,043	0.885
	No. 8A	341~ 528	379	286~ 520	299~ 986	593~ 1,431	0.876~ 0 815
	" No. 6S	488~ 840	378	778~ 1,235	429~ 1,540	418~ 1,164	0.821
Tr. for Brass 1,250 kVA same as upper	Office Building	102	398	138.3	216	116	0 685
	Brass Casting Shop	10	398	21.4	26	18	0 678
	Rolling Mill	28.1	398	169	173	170	0.239
Tr. for Brass 1,250 kVA	Office Building	42.7	393	123.2	148.4	166.3	0.427
	Brass Casting Shop	12.7	391	45	29.3	47.7	0.417
	Rolling Mill	25.8	393	186.6	167 8	164.5	0.225
Tr. for Al Extrusion 2,000 kVA	Extrusion No. 1 line 1	67.5	384	192	192.5	190	0 528
	" " line 2	122	384	269	277	270	0.679
	AJAX Induction Heater	352	383	558	615	400	0.863
	Air Compressor	147	384	262	192	180	0 844
	Extrusion No. 2	145	387	386	292	319	0.678
Tr for Rolling Mill (Fe) 2,000 kVA	Rolling Mill 8B	288~ 782	384	421~ 938	440~ 901	418~ 1,003	0.858
	" 8A	360~ 1,179	399	460~ 1,069	355~ 784	284~ 790	0.659
	" 6S	139~ 1,016	378	395~ 581	408~ 1,060	399~ 834	0 532
Tr. for Al Anodizing 1,250 kVA	DC 3,000 A	134.3	372	249	244	259	0.837
	DC 5,000 A	72.9	372	140.5	138.2	135.4	0.819
	Boiler	44	372	74.2	68.4	66.5	0.8
Tr. for Brass 1,250 kVA	Office Building	161	384	353	398	335	0 686
	Brass Casting Shop	20.9	384	35	23.8	30	0.897
	Rolling Mill	19.3	382	56.1	46.2	48.1	0.606
	Extrusion No. 1 line 1	72	375	205~ 219	180	169	0.616
Tr. for Al Extrusion 2,000 kVA	" " line 2	113	371	249	259	251	0.701
	AJAX Induction Heater	316	372	518	608	395	0.946
	Air Compressor	142	372	300	326	316	0.697
	Extrusion No. 2	235	372	477	438	305	0.833
Tr. for Rolling Mill (Fe) 2,000 kVA	Roll No. 8B	94.2~ 1,999	370	370~ 654	620~ 1,400	536~ 1,054	0.778
	Roll No. 8A	270~ 549	352	550~ 1,140	714~ 1,036	619~ 1,180	0.79
	Roll No 6S	133~ 164	357	684~ 1,095	410~ 1,296	680~ 1,324	0.647

When the load of each transformer at each measurement is calculated, it becomes as follows:

10 AM, Feb. 8 First Measurement

- Load of 1,250 kVA transformer for Al anodizing

Anodizing DC 3,000A $132 + j132\frac{\sqrt{1-0.905^2}}{0,905} = 132 + j62$

Anodizing DC 5,000A $114 + j114\frac{\sqrt{1-0.764^2}}{0.764} = 114 + j96$

Boiler $43 + j43\frac{\sqrt{1-0.8^2}}{0.8} = 43 + j32$

Results of the load calculations and other information for each transformer of 1250 kVA for brass, 2000 kVA for Al extrusion and 2000 kVA for the rolling mill are shown in the following table.

No. 1 measuring Feb. 8 10 AM

Tr. Rating and Use for	Branch Name	kw	Cos. φ	Apparent Power kVA
For Al Anodizing 1,250 kVA 12 kV/400 V 60.1 A/1,801 A % Z = 6.0 tap 12.6, 12.3, 11.7, 11.4 kV	Anodizing DC 3,000 A Anodizing DC 5,000 A Boiler Total for Al Anodizing 1,250 kVA Tr	132 114 43 289	0.905 0.764 0.8 0.835	132 + j 62 114 + j 96 43 + j 32 289 + j 190 = 346
For Brass 1,250 kVA 12 kV/400 V 60.1 A/1,801 A % Z = 6.0 tap 12.6, 12.3 12, 11.7, 11.4 kV	Office Building Brass Cashing Shop Rolling Mill Total for Brass 1,250 kVA Tr.	43 13 26 82	0.427 0.417 0.225 0.335	43 + j 91 13 + j 28 26 + j 112 82 + j 231 = 245
For Al Extrusion 2,000 kVA 12 kV/400 V 98.7 A/2,887 A % Z = 6.1% tap 12.6, 12.3, 12, 11.7, 11.4 kV	Al Extrusion No 1 line 1 Al Extrusion No 1 line 2 Induction Heater Air Compressor Al Extrusion No 2 Total for Al Extrusion 2,000 kVA Tr.	78 86 348 120 215 847	0.603 0.516 0.89 0.657 0.789 0.758	78 + j 103 86 + j 143 348 + j 178 120 + j 138 215 + j 167 847 + j 729 = 1,118
For Rolling Mill (Fe) 2,000 kVA 12 kV/400 V 98.7 A/2,887 A % Z = 6.1% tap 12.6, 12.3, 12, 11.7, 11.4 kV	Rolling Mill No. 8B Rolling Mill No 8A Rolling Mill No 6S Total for Rolling Mill 2,000 kVA Tr.	596 528 664 1,788	0.885 0.815 0.821 0.841	596 + j 314 528 + j 375 664 + j 462 1,788 + j 1,151 = 2,126
	Receiving Apparent Power	3,006	0.794	3,006 + j 2,301 = 3,786

No. 2 measuring Feb. 8 11 AM

Tr. Rating and Use for	Branch Name	kw	Cos. φ	Apparent Power kVA
For Al Anodizing 1,250 kVA	Al Anodizing DC 3,000 A	174	0.683	174 + j 186
	Al Anodizing DC 5,000 A	233	0.533	233 + j 370
	Boiler	34	0.8	34 + j 26
	Total for Al Anodizing 1,250 kVA Tr	441	0.604	441 + j 582 = 730
For Brass 1,250 kVA	Office Building	102	0.685	102 + j 108
	Brass Cashing Shop	10	0.678	10 + j 11
	Rolling Mill	28	0.239	28 + j 114
	Total for Brass 1,250 kVA Tr.	140	0.515	140 + j 233 = 272
For Al Extrusion 2,000 kVA	Al Extrusion No 1 line 1	68	0.528	68 + j 109
	Al Extrusion No 1 line 2	122	0.679	122 + j 132
	Induction Heater	352	0.863	352 + j 206
	Air Compressor	147	0.844	147 + j 93
	Al Extrusion No 2	145	0.678	145 + j 157
	Total for Al Extrusion 2,000 kVA Tr	834	0.767	834 + j 697 = 1,087
For Rolling Mill 2,000 kVA	Rolling Mill 8B	535	0.858	535 + j 320
	Rolling Mill 8A	487	0.659	487 + j 556
	Rolling Mill 6S	369	0.532	369 + j 587
	Total for Rolling Mill 2,000 kVA Tr.	1,391	0.689	1,391 + j 1,463 = 2,019
	Receiving Apparent Power	2,806	0.686	2,806 + j 2,975 = 4,090

No. 3 measuring Feb. 8 1:10 PM

Tr. Rating and Use for	Branch Name	kw	Cos. φ	Apparent Power kVA
For Al Anodizing	Al Anodizing DC 3,000 A	134	0.837	134 + j 88
	Al Anodizing DC 5,000 A	73	0.819	73 + j 51
	Boiler	44	0.8	44 + j 33
	Total for Al Anodizing 1,250 kVA Tr	251	0.826	251 + j 172 = 304
For Brass 1,250 kVA	Office Building	161	0.686	161 + j 171
	Brass Cashing Shop	21	0.897	21 + j 10
	Rolling Mill	19	0.606	19 + j 25
	Total for Brass 1,250 kVA Tr.	201	0.698	201 + j 206 = 288
For Al Extrusion 2,000 kVA	Al Extrusion No 1 line 1	72	0.616	72 + j 92
	Al Extrusion No 1 line 2	113	0.701	113 + j 115
	Induction Heater	316	0.946	316 + j 108
	Air Compressor	142	0.697	142 + j 146
	Al Extrusion No 2	235	0.833	235 + j 156
	Total for Al Extrusion 2,000 kVA Tr.	878	0.818	878 + j 617 = 1,073
For Rolling Mill 2,000 kVA	Rolling Mill 8B	698	0.778	698 + j 564
	Rolling Mill 8A	549	0.79	549 + j 426
	Rolling Mill 6S	164	0.647	164 + j 387
	Total for Rolling Mill 2,000 kVA Tr	1,411	0.716	1,411 + j 1,377 = 1,972
	Receiving Apparent Power	2,741	0.756	2,741 + j 2,372 = 3,625

The load of each transformer is summarized in the following table.

Trans.	No. 1 measuring		No. 2 measuring		No. 3 measuring		Average	
	Apparent Power kVA	Power Factor %	Apparent Power kVA	Power Factor %	Apparent Power kVA	Power Factor %	Apparent Power kVA	Power Factor %
1,250 kVA for Al Anodizing	289+j 190 = 346	83.5	441+j 582 = 730	60.4	251+j 172= 304	82.6	327+j 315= 454	72
1,250 kVA for Brass	82+j 231= 245	33.5	140+j 233= 272	51.5	201+j 206= 288	69.8	141+j 223= 264	53.4
2,000 kVA for Al Extrusion	847+j 729= 1,118	75.8	834+j 697= 1,087	76.7	878+j 617= 1,073	81.8	853+j 681= 1,091	78.2
2,000 kVA for Rolling Mill	1,788+j 1,151= 2,126	84.1	1,391+j 1,463= 2,019	68.9	1,411+j 1,377= 1,972	71.6	1,530+j 1330= 2,027	75.5
Receiving Apparent Power (Total)	3,006+j 2,301= 3,786	79.4	2,806+j 2,975= 4,090	68.6	2,741+j 2,372= 3,625	75.6	2,851+j 2,549= 3,824	74.6

From these results, the power factor, though a one-hour value, is found to be in the range of 68 ~ 80%.

When a 1,000 kVar condenser is inserted into the 2000 kVA transformer for rolling mill and a 600 kVar condenser is inserted into the 2000 kVA transformer for Al extrusion to improve the power factor, the following results:

	Condenser	Apparent power after condenser insertion	Power factor
2,000 kVA for Al extrusion	600 kVar	$853 + j(681 - 600) = 857$	99.5%
2,000 kVA for rolling mill	1,000 kVar	$1{,}530 + j(1{,}330 - 1{,}000) = 1{,}565$	97.8%
Power received		$2{,}851 + j(2{,}549 - 1{,}600) = 3{,}005$	94.9%

In addition, the transformer overload for rolling mill is resolved.

The reduction of copper loss of the transformer due to a reduction of apparent power becomes as follows:

$$18\ \text{kW} \times \{(\frac{1{,}091}{2{,}000})^2 - (\frac{857}{2{,}000})^2\} \times 3{,}450^h + 18\{(\frac{2{,}027}{2{,}000})^2 - (\frac{1{,}565}{2{,}000})^2\} \times 2{,}400\text{h}$$

$= 24{,}996$ kWh/year.

This reduction of loss and release from payment of the 180,000 Bt/year penalty results in a savings of 216,000 Bt/year.

While the installation of condensers necessitates an expenditure of 400,000 Bt, this expense can be recovered within two years.

8.3. Integration of Transformer

As shown in the data in the preceding paragraph, since 1250 kVA transformers have an extremely small load, they can be integrated to allow the load for brass to be supplied from the transformer for Al anodizing. (600 VCV 1C/325 mm^2 x 3 aerial rack or messenger sling installation)

The value of the second measurement corresponding to the largest load also has potential capacity as follows:

$581 + j815 = 1{,}000$ kVA

When transformers are integrated, the average value of three measurements becomes as follows:

$468 + j538 = 713$ kVA

Assuming that the copper loss of the 1250 kVA transformer is 16 kW and the no-load loss is 5 kW, a reduction of the no-load loss by separating one unit becomes as follows:

$5 \times 24 \times 365 = 43{,}800$ kWh/year

Assuming that the operating time for brass is 1,200 hours/year, a reduction of the copper load loss becomes as follows:

$$16 \times \{(\frac{264}{1{,}250})^2 + (\frac{454}{1{,}250})^2 - (\frac{713}{1{,}250})^2\} \times 1{,}200 = -2{,}858 \text{ kWh/year}$$

Finally, the merit of transformer integration becomes as follows:

$43{,}800 - 2{,}858 = 40{,}942$ kWh/year, 59,366 Bt/year

8.4. Voltage Drop of Rolling Mill Motor

It is estimated that apparent power applied to a transformer exceeds the capacity of the transformer due to an abrupt increase in load when the rolling mill contacts the material.

The vectorial sum of apparent power of each branch indicates the value described before but a somewhat larger value will be tentatively indicated.

When a full capacity load to transformer is applied, voltage drops by 6.1% because percentage impedance is 6.1%.

When a secondary rated voltage of 400V is applied, voltage drops by 24.4V.

This voltage drop is approximately proportional to $\sqrt{1 - \cos^2\alpha} = \sin\alpha$, if the power factor is assumed to be $\cos\alpha$, $\sin\alpha$ indicates a large value when the power factor is small, such time as rush current flow and voltage applied to the motor further decreases.

When voltage drops, electric current of motor increases excessively and may cause overheating.

When the primary voltage is 11.5 kV and tap is fired at 12 kV, and 400 V so the secondary voltage is

$$11{,}500 \text{ V} \times \frac{400}{12{,}000} = 383 \text{ V}$$

When considering voltage drop, the primary side tap is preferable set at 11.4 kV. If then the following calculation is made:

$$11{,}500 \text{ V} \times \frac{400}{11{,}400} = 404 \text{ V}$$

This may be adequate for the voltage drop.

Because the primary voltage or service voltage from MEA may become lower than than 11 kV, the tap of the 1,250 kVA transformer for the rolling mill may be set at 11.4 kV. A voltage check is recommended.

8.5. Lighting

Daylight fluorescent lamps were used in the canteen and in other areas of the factory and offices.

By replacing them with energy-conservation white fluorescent lamps, energy conservation of 5 W per lamp can be achieved.

As there are about sixty lamps, energy saving becomes as follows:

$5 \times 60 \times 10 \times 300 \times 10^{-3} = 900$ kWh/year

8.6. Other

(1) The primary and secondary buses of the four transformers are uncovered and present a danger to workers. A shielding plate must be provided.

(2) Cover of Brass Melting Furnace

A cover is not provided on the brass melting induction furnace. The heat loss from melted metal at 1,200°C reaches 88,000 kcal/m^2h or 100 kW/m^2.

Electric power can be saved by providing a cover lined with insulation material.

9. Summary

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

	kl/year	%
Improvement of billet heating process	358.4	22.4
Improvement of insulation of steel billet reheating furnace	34.0	2.1
Insulation of carriage of aluminum homogenizing furnace	12.0	0.8
Improvement of air ratio of boiler and reduction of exhaust gas temperature	40.6	2.5
subtotal	445.0	27.8

	10^2kWh/year	%
Improvement of power factor by means of condenser	25.0	0.3
Integration of transformer	40.9	0.4
Change of daylight flourescent lamps to white flourescent lamps	0.9	0.1
Subtotal	66.8	0.8