

Text No.27

ECCJ FACTORY

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INTRODUCTION

1. Objective of ECCJ Factory Case Study

The energy conservation program at the ECCJ Factory and related policy recommendations are examined as a case study.

Item	Training	ECCJ Factory	Measurement training	Boiler training
Assessment of present situation		o	o	o
Identification of problems		o	o	o
Formulation of improvement program		o		o
Implementation of improvement measures				o

These provide basic data for the formulation of energy conservation policy in the industry.

2. How to Use the Textbook

- 1) The textbook is prepared by analyzing energy data in factory , and compiling the data on a facility-by-facility basis. The data are necessary to assess the present state of energy consumption and formulate improvement programs.
- 2) Techniques necessary to conduct data analysis are described in textbooks for individual facilities. (See textbook numbers* shown in item 4 on the next page.)
- 3) Topics are chosen aiming at enabling trainees to develop the ability to formulate improvement measures that include not only an energy conservation plan for each facility but a coordinated operation plan for different facilities.
- 4) As well as energy consumption reductions due to the implementation of improvement measures, attention is also focused on its productivity improvement effect.
- 5) A list of equipment necessary to implement improvement measures is attached to facilitate the investment assessment for each measure and priority analysis for energy conservation measures at a factory.
- 6) Data measurement techniques will be learned through hands-on practice using measuring instruments.
- 7) With energy prices as basic variables of this case study, two scenarios (high energy price scenario and low energy price scenario) are set to analyze the effects of energy price changes on the scope of technology introduction options available at the factory and nature of policy assistance required.

3. Output of Case Study

- (1) Improvement program of energy consumption at ECCJ Factory

The formulation of an improvement program involves the following six issues:

- 1) Problems with operation plan and energy consumption for each facility
 - 2) Improvement measures and their effects (energy, CO₂, etc.)
 - 3) Investment in improvement measures and payback period
 - 4) Priority of improvement measures
 - 5) Energy conservation implementation structure and organization in factories
 - 6) Implementation incentives
- (2) Policy recommendations for ECCJ Factory
- Through an analysis of the basic data and planning of energy conservation program at the ECCJ Factory as basic data, recommendations are made on policy formulation for factory energy conservation.

4. Lecturers and Lecture Schedule for Case Study

Data	AM/PM	Facility	Text No.	Lecturer
May 14	PM	Outline		Mr. Tanabe, ECCJ Mr. N. Fukushima, ECCJ
June 3	AM	Transformer, Lighting	16	Mr. Kanao, Mitsubishi Electric Corporation
June 4	AM	Blower, Pump, Compressor	16	Mr. Kazama, Sumikin Management Co., Ltd.
June 9	AM/PM	Boiler	26	Mr. Ishibashi, Tokyo Gas
June 10	AM	Air conditioner	18	Mr. Yamaguchi, Obayashi Corporation
June 16	AM	Energy management	(at factory)	Mr. Kawaguchi, Fukuyama Works, Mitsubishi Electric Corporation
June 18	PM	Heat recovery of condensate	(at factory)	Mr. Haya fune, TLV Corp.
June 23	AM	Dyeing machine, Drying machine	22	Mr. Inaba, Gunze Development Co., Ltd.
June 23	AM	Heat insulation	23	Mr. Hoshi, Shinagawa Furnace
June 24	PM	Heat furnace	24	Mr. Ikeda, Chugai-ro Co., Ltd.
June 24	PM	Group work		Mr. N. Fukushima, ECCJ
June 26	AM/PM	Group work		Mr. N. Fukushima, ECCJ Mr. Kazama, Sumikin Management Co., Ltd.
June 27	AM/PM	Group work		Mr. N. Fukushima, ECCJ Mr. Kanao, Mitsubishi Electric Corporation
June 30	AM	Group work		Mr. N. Fukushima, ECCJ
June 30	PM	Presentation		Mr. Kazama, Sumikin Management Co., Ltd. Mr. Kanao, Mitsubishi Electric Corporation Mr. Inaba, Gunze Development Co., Ltd. Mr. Hoshi, Shinagawa Furnace Mr. Ikeda, Chugai-ro Co., Ltd. Mr. Yamaguchi, Obayashi Corporation Mr. Ishibashi, Tokyo Gas Mr. N. Fukushima, ECCJ Mr. Tanabe, ECCJ

1. Factory Name

ECCJ Factory

2. Factory Location

Somewhere in Wonderland

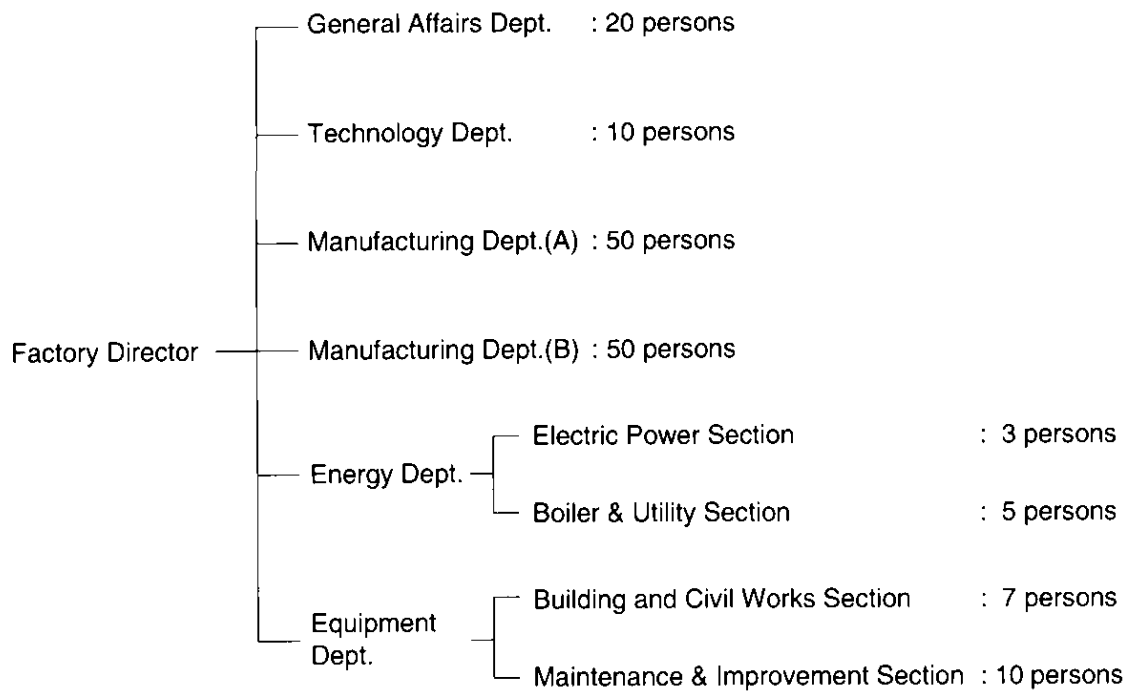
3. Energy Conservation Policy

Energy conservation policy is not established in wonderland.

- 1) No regulation
- 2) No economic incentive for energy conservation investment
- 3) No information

4. Factory Organization

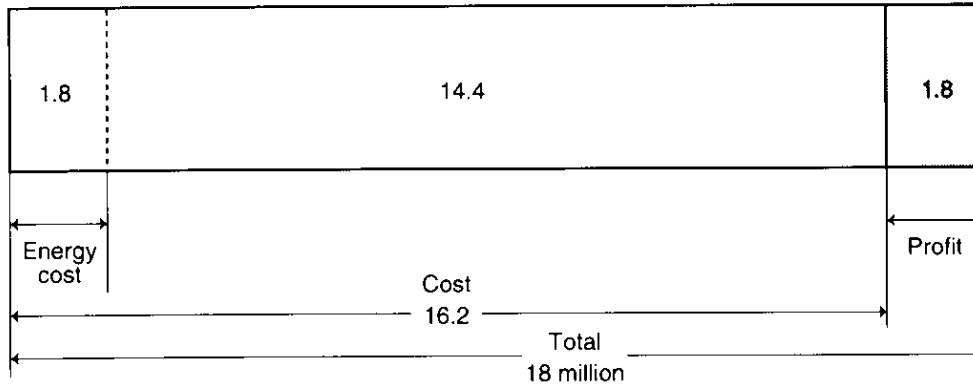
- 1) Employees : 155 (persons)
- 2) Organization chart



3) Factory scale (Fuji)

Turnover : US\$18

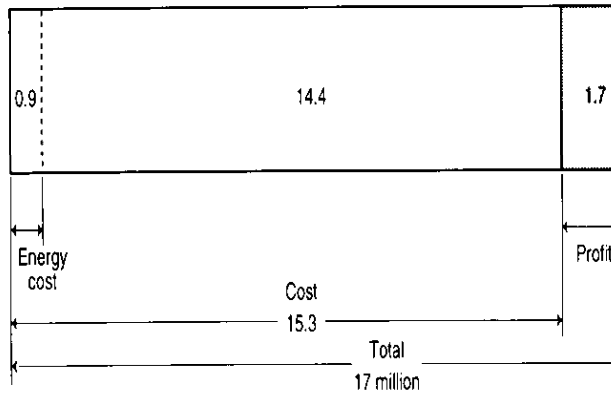
Unit : US\$million



4) Factory scale (Sakura)

Turnover : US\$11 million

Unit : US\$million



- 5) Facility operation hour : 8:00 – 22:00
 - Boiler 10 t/h 14 h/day
 - Boiler 5 t/h 24 h/day
 - Heating furnace 24 h/day (7,200 h/year)
 - Production machine A, B 24 h/day
- 6) Working day : 25 day/month
- 7) Interest rate : 10%/year

5. Basic Data

(1) Fuel

- 1) Components : C = 86%, H = 13%, O = 0.7%, N = 0.2%, S = 0.1%
- 2) Calorific value : 42,119 kJ/kg
- 3) A0 : 11.09 Nm³/kg
- 4) G0 : 11.82 Nm³/kg
- 5) Specific heat : Air : 1.30 kJ/Nm³°K
: Exhaust gas : 1.38 kJ/Nm³°K
- 6) Specific weight : 0.83

(2) Energy consumption breakdown by equipment

Equipment	Energy consumption	Cost (dollars)		Energy cost share
		Fuji	Sakura	
Boiler 10 t/h	3,152,100 kg/y	630,420	315,225	35%
Boiler 5 t/h	2,841,840 kg/y	568,367	284,184	31%
Furnace	441,471 kg/y	88,294	44,147	5%
Dyeing machine	(541900) kg/y	(11,098)	(5,549)	Included in boiler
Dryer	(568,160) kg/y	(2,382)	(1,191)	Included in boiler
Blower	255,660 kWh/y	51,344	24,394	3%
Pump	105,264 kWh/y	21,140	10,044	2%
Compressor	375,000 kWh/y	75,311	35,780	4%
Lighting system	288,000 kWh/y	57,839	27,479	3%
Manufacturing system	unknown	292,880	146,440	17%
Total		1,785,649	878,693	100%

(3) Basis of CO₂ emission calculation

- 1) Fuel : 0.86 kg(c)/kg fuel
- 2) Electricity : 0.12 kg(c)/kWh

(4) Energy prices (Fuji)

1) Electric charge

Electric charge per month (\$) = Demand charge + Energy charge

Demand charge per month = Peak demand (kW) × Unit price (\$/kW) × (1.85 – p.f.)

p.f. = power factor

Lead p.f. is treated as p.f. = 1.0

Unit price = 14 \$/kW

Energy charge (\$ per month) = Power consumption per month (kWh) × Unit price (\$/kWh)

Unit price = 0.17 \$/kWh

Present situation in ECCJ Factory

Demand power = 1,500 kW

p.f. = 87%

Power consumption / day = 22,252.67 kWh

Integrate unit price = 0.201 \$/kWh

2) Fuel charge

0.2 \$/kg

(5) Energy prices (Sakura)

1) Electric charge

Electric charge per month (\$) = Demand charge + Energy charge

Demand charge per month = Peak demand (kW) × Unit price (\$/kW) × (1.85 – p.f.)

p.f. = power factor

Lead p.f. is treated as p.f. = 1.0

Unit price = 7 \$/kW

Energy charge (\$ per month) = Power consumption per month (kWh) × Unit price (\$/kWh)

Unit price = 0.08 \$/kWh

Present situation in ECCJ Factory

Demand power = 1,500 kW

p.f. = 87%

Power consumption / day = 22,252.67 kWh

Integrate unit price = 0.095 \$/kWh

2) Fuel charge

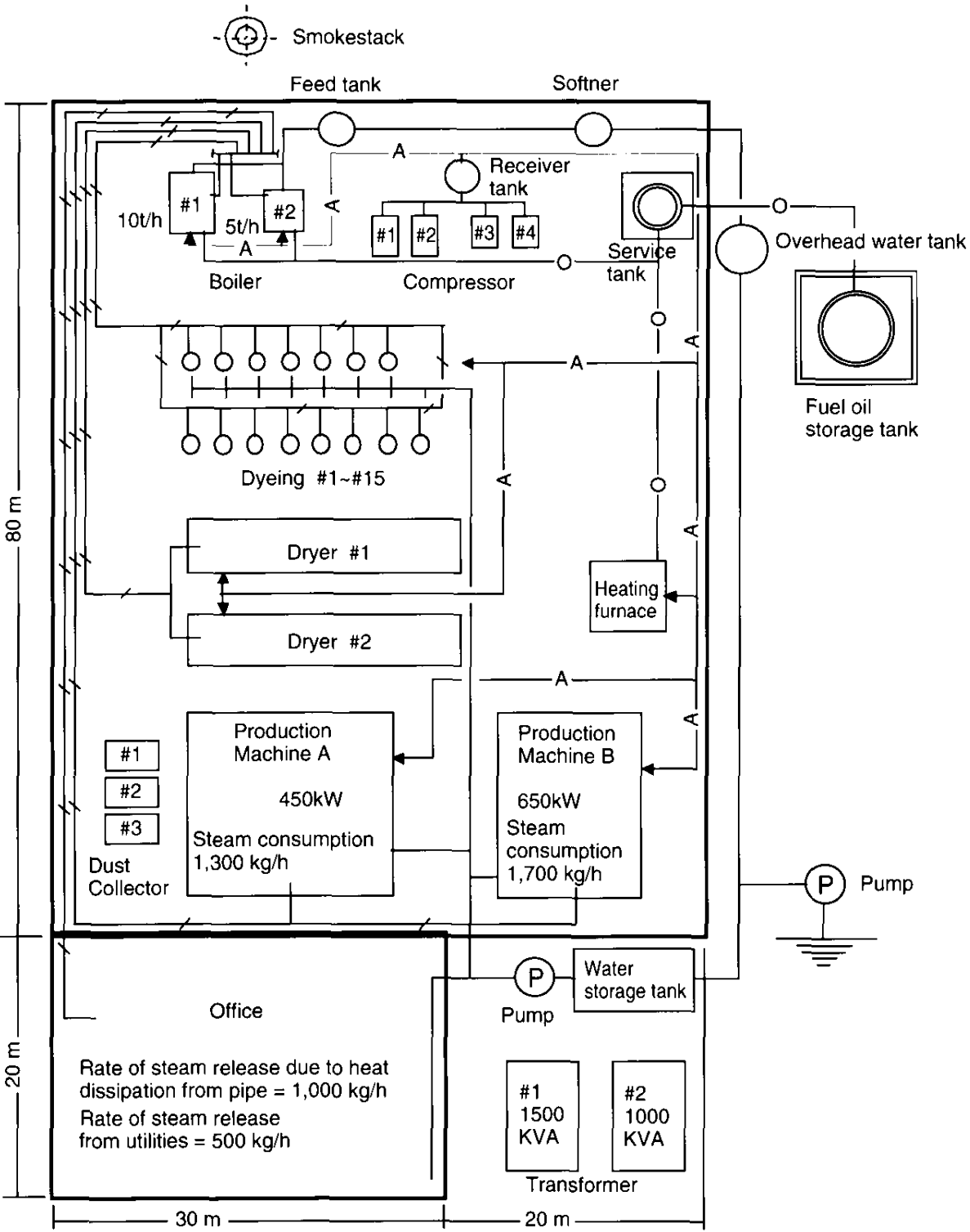
0.1 \$/kg

(6) Others

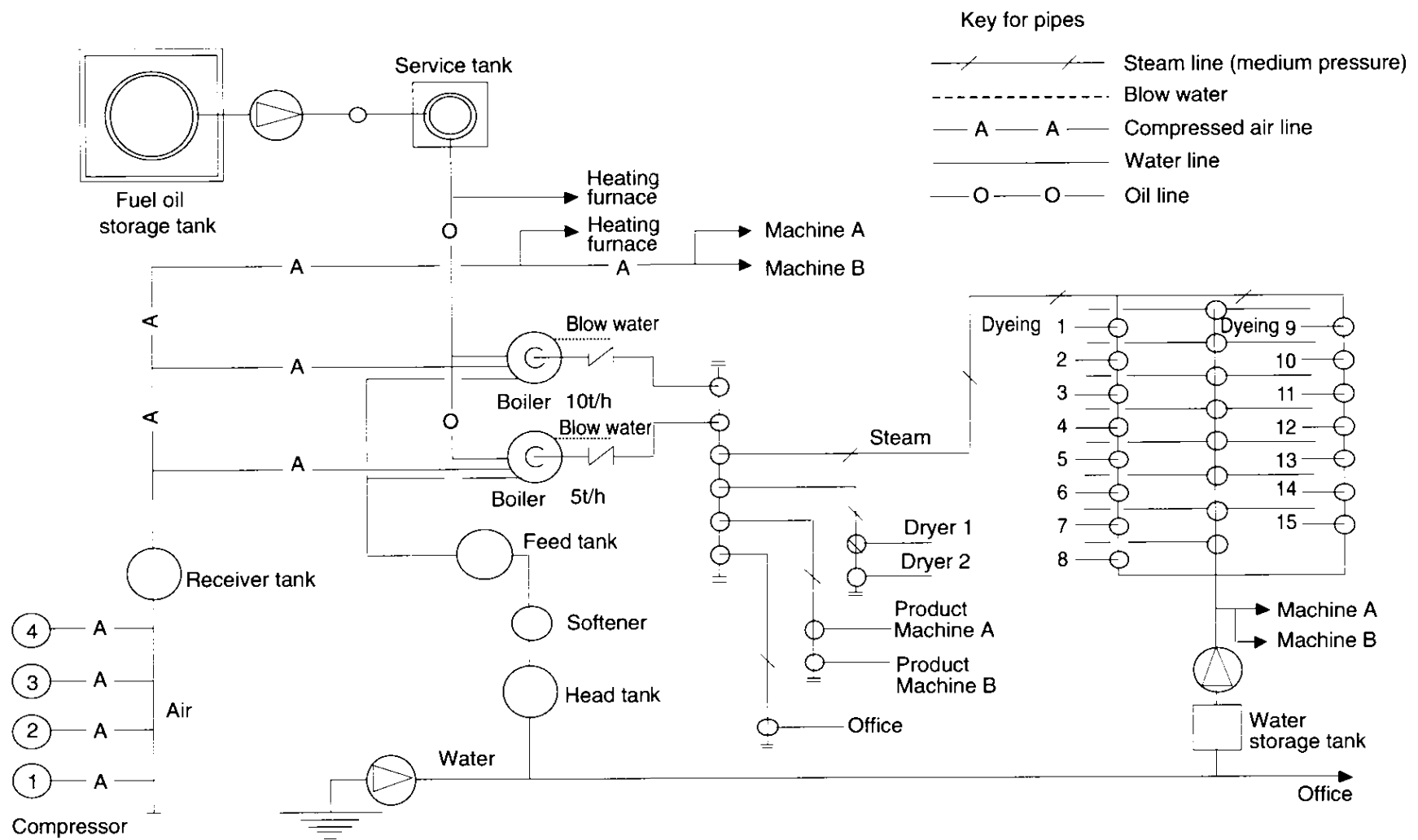
1) Ambient temperature : 33°C

2) Water temperature : 20°C

6. Factory Layout



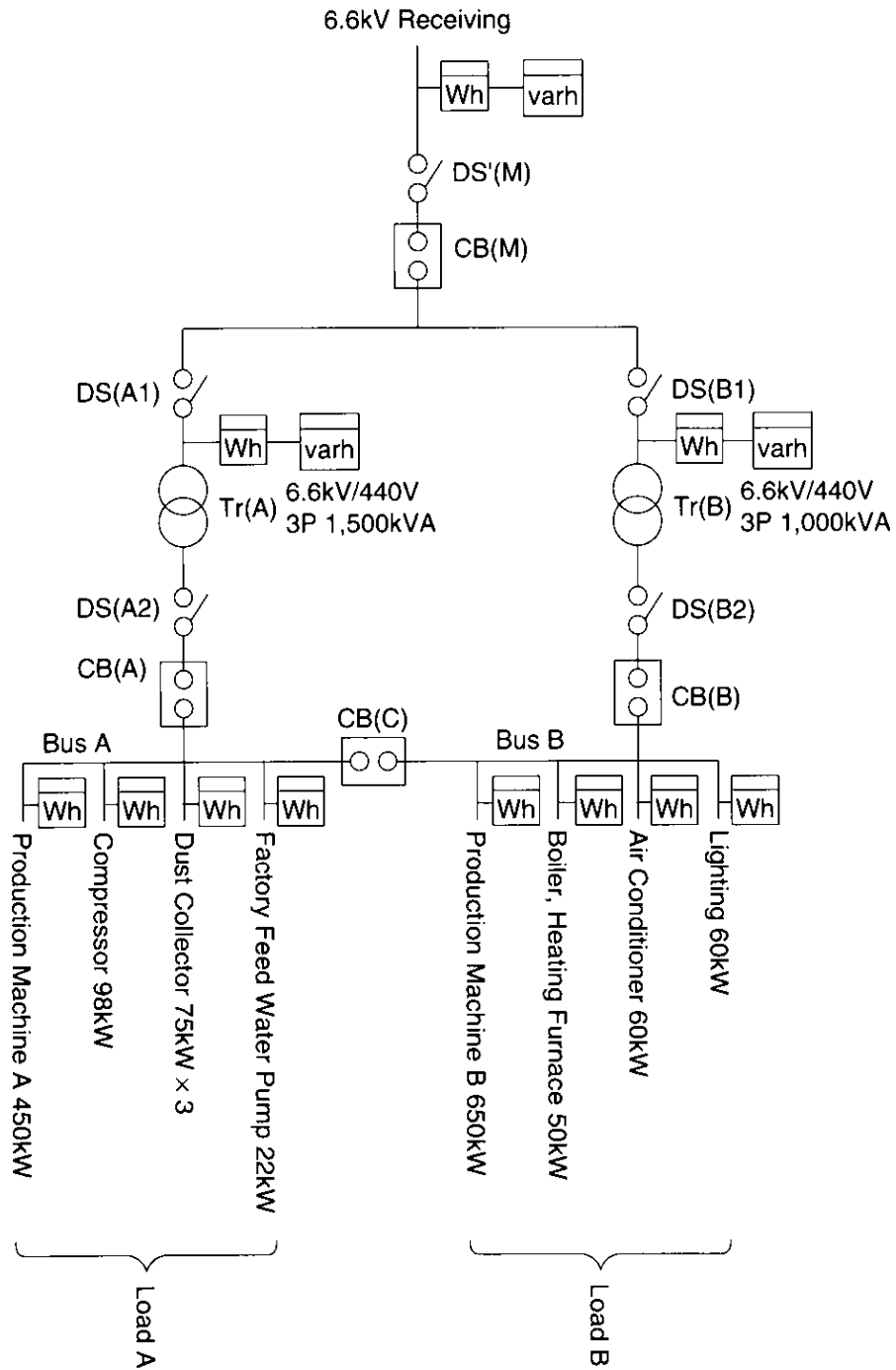
7. Utility Flow Sheet



8. Installation of Measuring Instruments

Item	Name of apparatus	Quantity	Utilities					No. of meters	
			Electricity	Fuel	Water	Steam	Compressed air	Watt-meter	Ammeter
Supply equipment	Supply meter	1						2	
	Transformer	2						4	
	Storage pump	1	●					1	1
	Feed water pump	1	○						
	Boiler	2	○	●	●		○		4
	Compressor	4	●					1	1
Production equipment	Heating furnace	1	○	●	●		○	1	2
	Dyeing machine	5	○		●	●			2
	Drying machine	2	○			●			1
	Making machine	2	●		○	○	○	2	
Environmental equipment	Dust collector	3	●					1	
Auxiliary equipment	Illumination	1	●					1	
	Air conditioning	1	●			●		1	1
Number of meters installed			● With meter		○ Without meter			14	12

9. Single Line Diagram



Operating condition

① Tr(A) and Tr(B) are possible to make parallel operation.

② Their primary and secondary connections are same and their phase rotations are same.

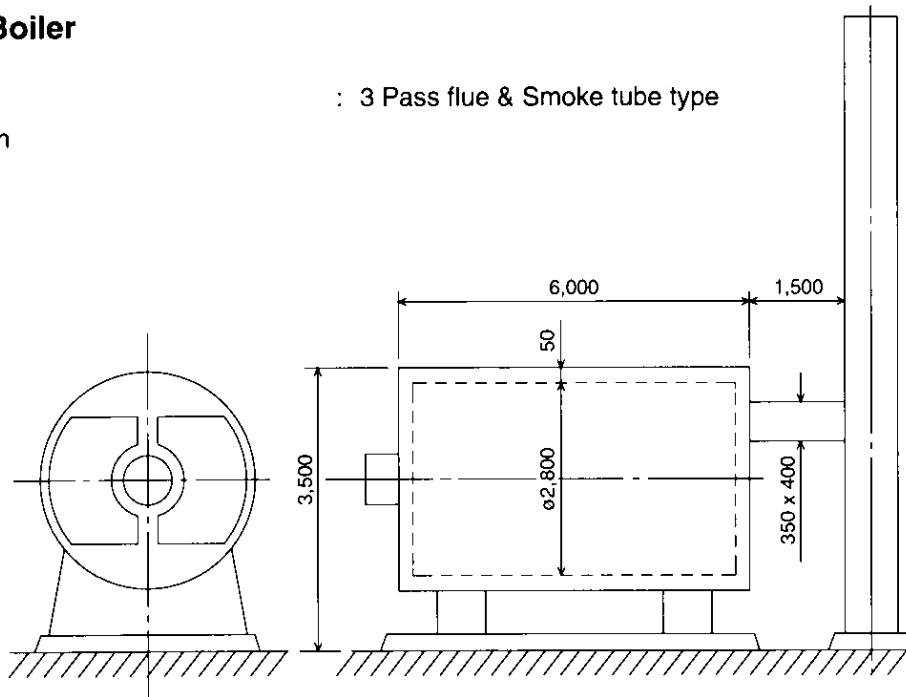
③ Their % impedance are inverse proportional to their capacities.

④ CB(M), CB(A) and CB(B) are close and CB(C) is open.

⑤ DS'(A1) and DS(B1) can cut exciting current of transformer.

10. No. 1 Boiler

- (1) Type : 3 Pass flue & Smoke tube type
 (2) Dimension



- (3) Capacity : 10t/h Gauge 0.8 MPa (Working)
 Gauge 1.0 MPa (Design)

(4) Analysis Data

- 1) Exhaust gas Temp. : 270°C
 2) O₂% in exhaust gas : 8%
 3) NO_x% in exhaust gas : 250 ppm
 4) Surface temp. of body : 150°C
 5) Water quality

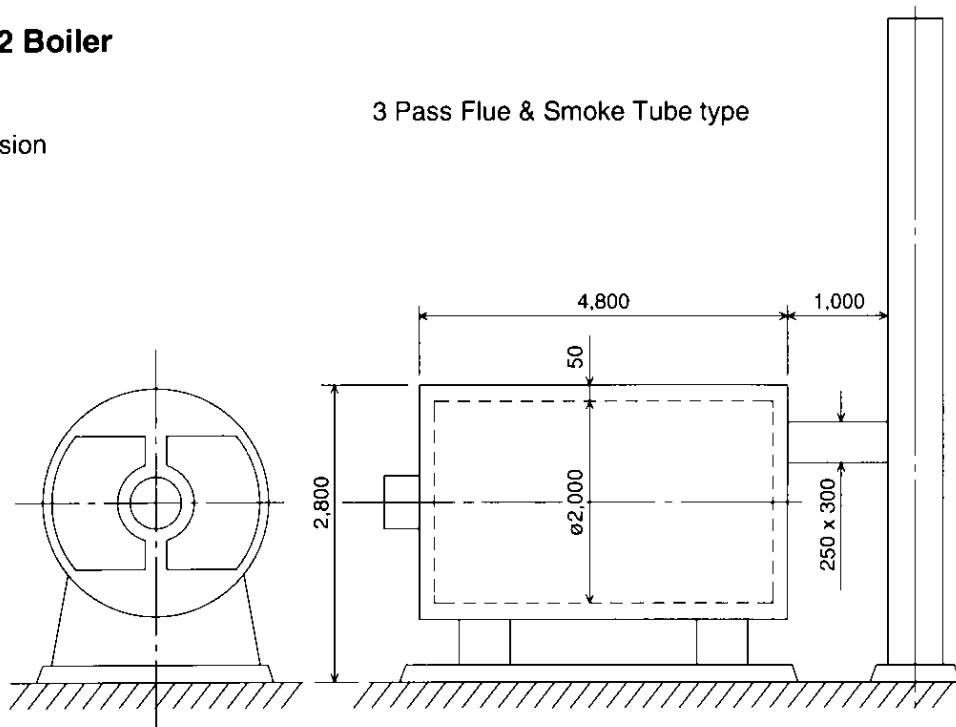
	Feed water	Boiler water
pH	7	9
Conductivity	200 μS/cm	2,000 μS/cm
Hardness	200 mgCaCO ₃ //	

- 6) Air preheater : Nothing
 7) Economizer : Nothing
 8) Condensate recovery : Nothing
 9) Fuel consumption : 750.5 kg/h
 10) Water consumption : 10.6 × 10³kg/h
 11) Ambient temp. : 33°C
 12) Fuel temp. : 33°C
 13) Feed water temp. : 20°C
 14) Combustion air temp. : 33°C
 15) Burner type : Compressed air atomizing burner
 16) Blow rate : 6%
 17) Operation hour : 14 h/day × 25 day/m × 12 = 4,200 h/y
 18) Scale thickness on boiler tube : 1 mm
 19) Dryness of Steam : 98%

11. No. 2 Boiler

- (1) Type:
(2) Dimension

3 Pass Flue & Smoke Tube type



- (3) Capacity : 5t/h Gauge 0.8 MPa (Working)
Gauge 1.0 MPa (Design)

(4) Analysis Data

- 1) Exhaust gas Temp. : 350°C
 2) O₂% in exhaust gas : 8%
 3) NO_x% in exhaust gas : 250 ppm
 4) Surface temp. of body : 150°C
 5) Water quality :

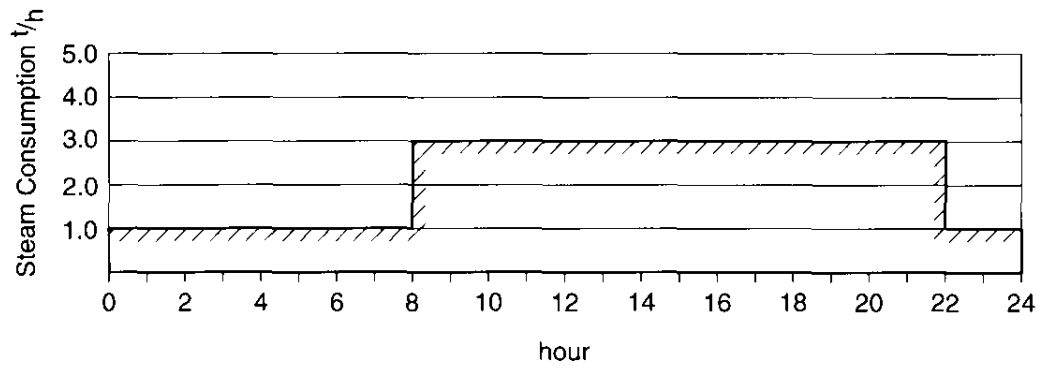
	Feed water	Boiler water
pH	7	9
Conductivity	200 μS/cm	2,000 μS/cm
Hardness	200 mgCaCO ₃ /l	

- 6) Air Preheater : Nothing
 7) Economizer : Nothing
 8) Condensate Recovery : Nothing
 9) Fuel consumption : 394.7 kg/h
 10) Water consumption : 5.2 × 10³kg/h
 11) Ambient temp. : 33°C
 12) Fuel temp. : 33°C
 13) Feed water temp. : 20°C
 14) Combustion air temp. : 33°C
 15) Burner type : Compressed air atomizing burner
 16) Blow rate : 6%
 17) Operation hour : 24h/day × 25day/m × 12 = 7,200 h/y
 18) Scale thickness on boiler tube : 1 mm
 19) Dryness of steam : 98%

12. Base Load of Steam

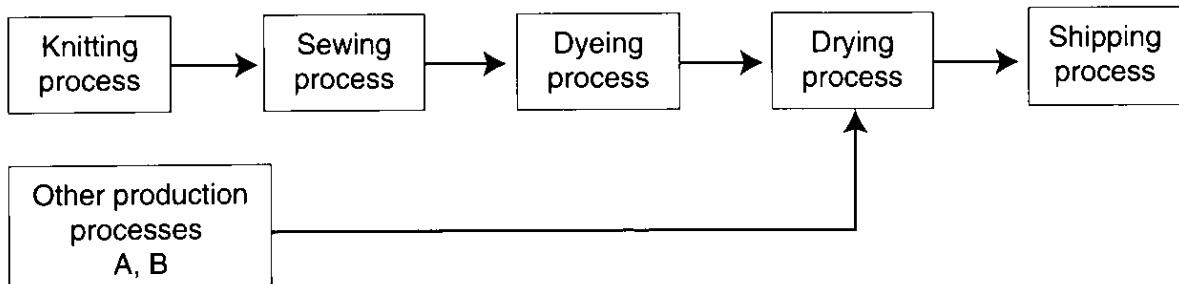
0:00–8:00 : 1t/h
22:00–24:00 : 1t/h
8:00–22:00 : 3t/h

Load curve



13. Steam-Consuming Equipment

(1) Production processes



(2) Equipment

unit: kg/hour

	Steam consumption	Details
Production process A	1,300	Assumed to be fixed
Production process B	1,700	Assumed to be fixed
Dyeing equipment	3,615 · 117	2 hours/cycle, 15 machines
Drying equipment	2,052	2 driers
Utilities	500	Fixed through the year
Piping loss	1,000	Radiation loss, trap release, etc.
		Pressure in pipe: 0.7 Mpa, 160°C

(3) Piping conditions

In the piping facilities, 60% of the pipe is not properly heat-insulated. The effect of insulation is assumed to be zero for that section of the pipe

a. Present condition of steam pipe

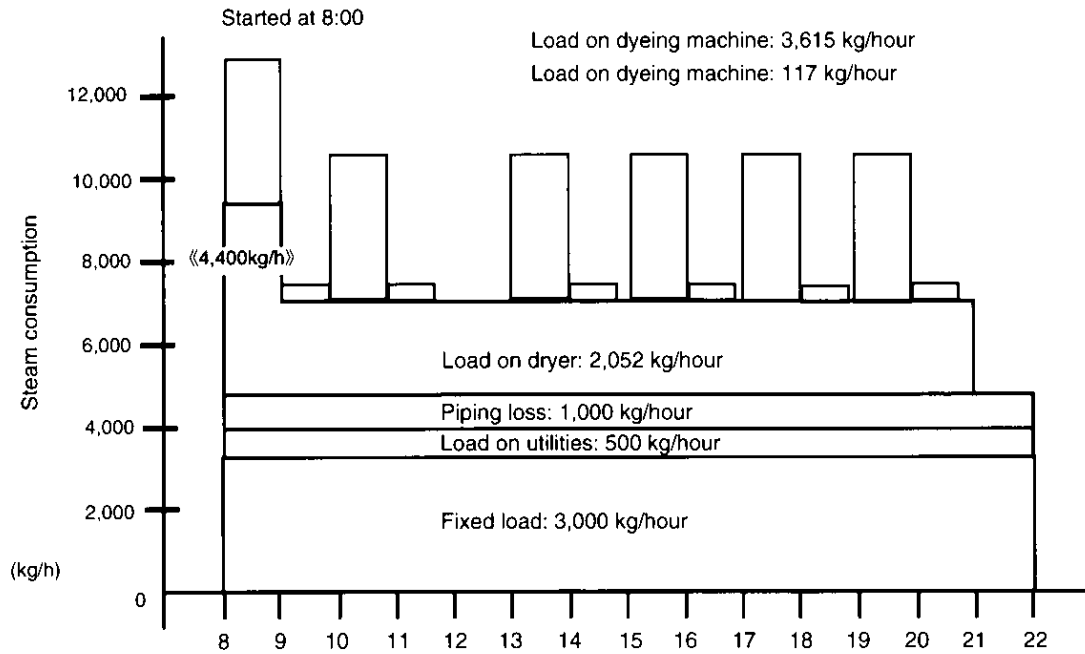
	Size (converted)	Pipe length (converted)	Heat insulation
Pipe conditions	80 A	500 m	60% non-insulated

b. Heat insulation conditions

	Not insulated	Insulated	Effect of insulation
Heat dissipation (kj/mh)	2,721	293	2,428

(4) Load curve of steam consumption in ECCJ plant

Load curve of steam consumption in production plant

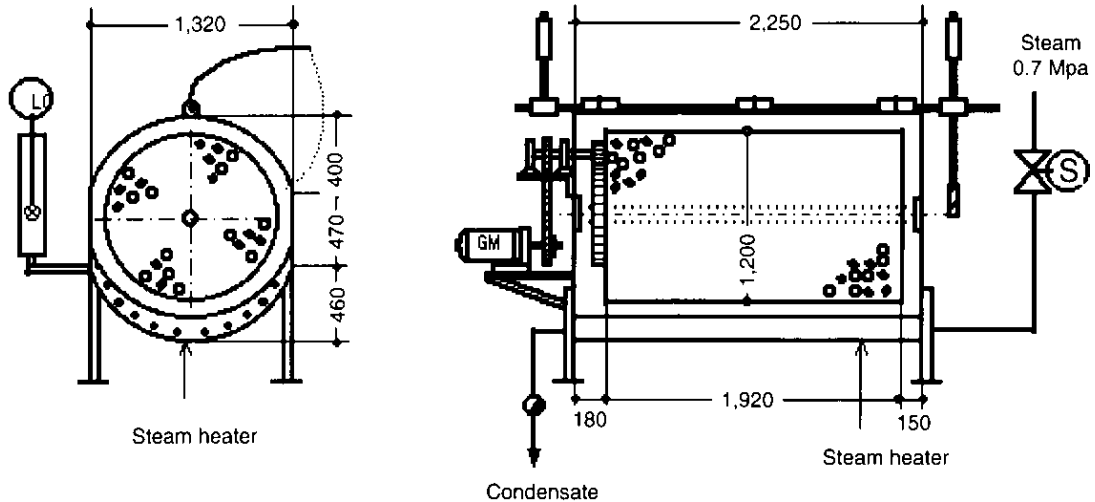


*** Equipment to be improved**

- 1) Dyeing machine
- 2) Drier
- 3) Steam pipe
- 4) Number of operating boilers decreased from two to one

14. Dyeing Machine

- (1) Type: Drum type dyeing machine
- (2) Dimensions

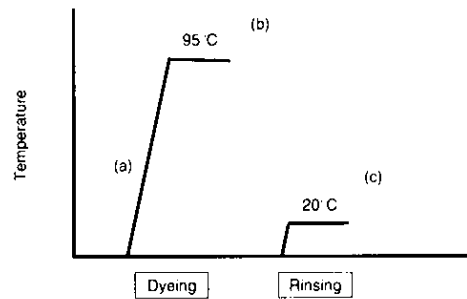


- (3) Operation of the equipment
 - Number of units installed : 15 units
 - Operation cycle : 6 cycles/day, 120 minutes/cycle
- (4) Motor : 1.5 kW/unit
- (5) Dyeing tank surface area : 12.1 m² (cylindrical part: 9.3 m², vertical part: 2.8 m²)
- (6) Heat insulation conditions : Not insulated
- (7) Dyeing machine material : SUS 304 (Emissivity $\epsilon = 0.35$)
 - Heated weight = 1,560 kg (specific heat $C = 0.46$ kJ/kg · K)
- (8) Dyeing product : Nylon 100%, 85 kg/cycle, specific heat $C = 1.80$ kJ/kg · K
- (9) Heating steam : Pressure $P = 0.7$ MPa
 - Enthalpy of dry saturated steam $h'' = 2,762.1$ kJ/kg
 - Enthalpy of saturated water $h' = 716.0$ kJ/kg
 - Dryness fraction $X = 0.98$
 - Enthalpy of wet saturated steam $h = h' + X(h'' - h')$
 $= 2,721.1$ kJ/kg
 - Latent heat $\gamma = 2,005.1$ kJ/kg
- (10) Raw water temperature : 20°C
- (11) Room temperature : 33°C
- (12) Steam consumption : 248.8 kg/cycle · unit
- (13) Dyeing tank surface temperature :

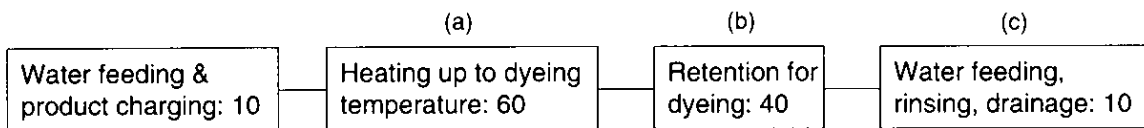
Solution temperature	95°C assumed
Solution contact surface	90
Atmosphere contact surface	90

- (14) Water feeding volume : 1,300L/ cycle
 - Dyeing solution volume per cycle = 1,300L for dyeing + 1,300L for rinsing = 2600L/cycle
 - $2,300L \times 6$ cycles/day $\times 15$ units = 207 m³/day
- (15) Heating method for dyeing solution: Indirect heating by steam heater
 Condensate is discharged into the air.
- (16) Weight and temperature of discharged product: nylon = 85 kg

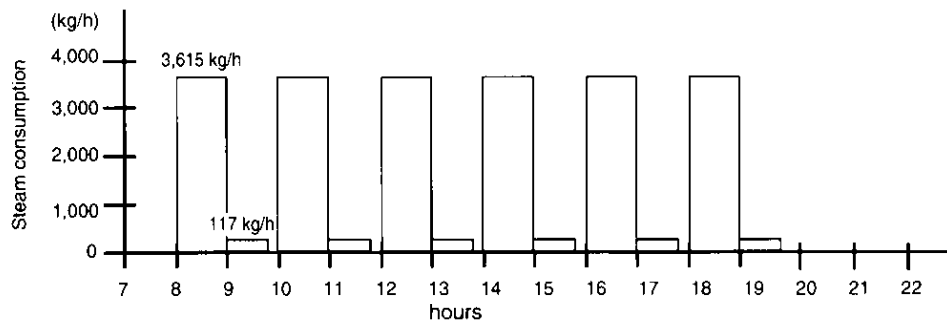
(17) Dyeing heat pattern (Only dyeing is performed in the dyeing process.)



(18) Dyeing process (the numbers indicate time in minutes)



(19) Load curve (15 units)



(20) Assumed conditions

a. Current heat balance

- Heat input: heat for heating tanks, heat for heating products, heat for heating liquid, heat radiation, heat of condensate

Total heat input = 656,185 kJ/cycle, 2 hours/cycle

Steam consumption = [heating up to dyeing temp. (60min)]

+ [retention for dyeing (40min)] = 248.8 kg/2h

- Heat output: heat of effluent, heat brought out by fabric, heat dissipation, heat of condensate, other heat

(Heat output)	(kJ/cycle)
1. heat of effluent	408,135
2. heat brought out by products	3,060
3. heat dissipation	25,505
4. heat of condensate	157,316
5. other heat	62,168

b. Use of recovered heat

- Heat recovered from effluent is used to heat the dyeing process water. Heat recovery from effluent serves to heat the dyeing process water up to 53°C.
- Heat of condensate is used to heat the boiler water.

* **Improvement measures for energy conservation**

- 1) Heat recovery from effluent
- 2) Heat recovery from condensate
- 3) Heat insulation
- 4) Lower liquid ratio

Data for heat insulation (dyeing machine)

(1) Heat dissipation from non-insulated equipment (existing)

Calculations are made based on the surface temperature of the tank, which is known, at the processing temperature of the process. The thermal emissivity (ϵ) of the tank, which is made of stainless steel, is assumed to be 0.35.

The tank is nearly cylindrical. As in the case of a boiler, calculations should be made separately for the cylindrical part and the vertical wall part. Each process has a heating period. The heat loss during such a period is calculated assuming that the tank surface temperature is equal to the average between the process temperature and room temperature.

Calculations of heat loss per cycle are shown below.

Process	Part	Surface temp. (°C)	Surface area (m ²)	Heat release (kj/m ² h)	Hours/cycle (h)	Dissipation (kj/m ² h)
Heating	Cylindrical part	61.5	9.33	808	60/60	7,539
	Vertical part	61.5	2.74	875	60/60	2,398
	Total	—	—	—	—	9,937
Dyeing	Cylindrical part	90	9.33	1,900	40/60	11,816
	Vertical part	90	2.74	2,055	40/60	3,753
	Total	—	—	—	—	15,569
Total/unit		—	—	—	—	25,506

The dyeing machine is operated six cycles per day and 300 days per year. The heat loss per unit is calculated as follows:

$$25,506 \text{ kj/m}^2\text{h} \times 6 \text{ cycles/day} \times 300 \text{ days} = 45.9108 \times 10^6 \text{ kj}$$

(2) Heat dissipation after improvement (insulation thickness: 15 mm polyester foam)

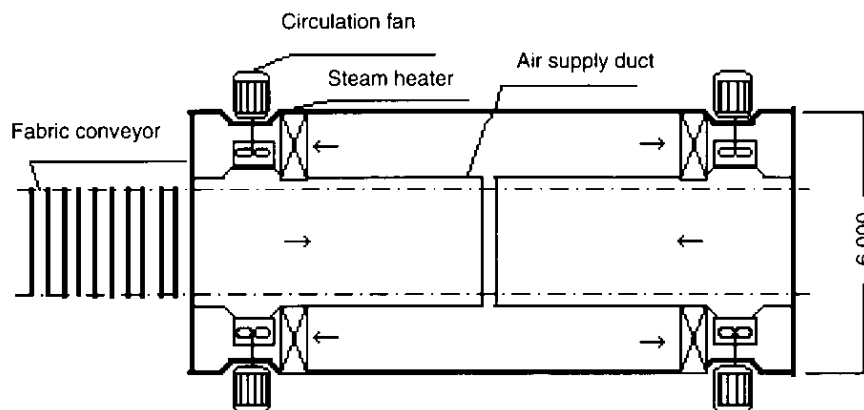
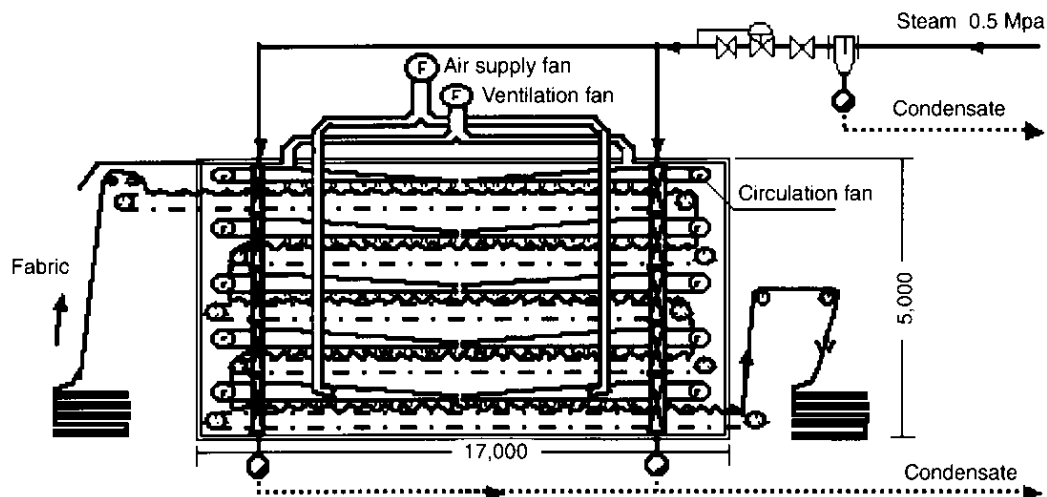
Process	Part	Surface temp. (°C)	Surface area (m ²)	Heat release (kj/m ² h)	Hours/cycle (h)	Dissipation (kj/m ² h)
Heating	Cylindrical part	42	9.33	188	60/60	1,757
	Vertical part	42	2.74	192	60/60	527
	Total	—	—	—	—	2,284
Dyeing	Cylindrical part	51	9.33	410	40/60	2,553
	Vertical part	50	2.74	430	40/60	787
	Total	—	—	—	—	3,340
Total/unit		—	—	—	—	5,624

The dyeing machine is operated six cycles per day and 300 days per year. The heat loss per unit is calculated as follows:

$$5,624 \text{ kj/m}^2\text{h} \times 6 \text{ cycles/day} \times 300 \text{ days} = 10.1232 \times 10^6 \text{ kj}$$

15. Drying Machine (short loop heater)

- (1) Type: Box type continuous drying machine
- (2) Dimensions



- (3) Operation of the equipment

Number of units installed	: 2 units
Operation mode	: Continuous 9:00–21:00, 12 hours/day, 300 days/year
Warm-up	: 8:00–9:00
- (4) Motor

Hot air circulation fan	: 7.5 kW × 20 units
Air supply fan	: 3.75 kW
Exhaust fan	: 3.75 kW
- (5) Drying machine surface area : 434 m² (roof = 105 m², vertical wall = 230 m², bottom = 102 m²)
- (6) Heat insulation conditions : Glass wool 20 mm layer $\lambda = 0.052 \text{ W/m}^2\text{k}$
 $\epsilon = 0.23$
- (7) Dry product : Cotton 100% Specific heat $C = 1.30 \text{ kJ/kg}\cdot\text{K}$
- (8) Heating steam : Pressure $p = 0.5 \text{ MPa}$

(9) Properties of steam for heating : $p = 0.5 \text{ Mpa}$

Enthalpy of dry saturated steam $h'' = 2,570 \text{ kJ/kg}$
 Enthalpy of saturated water $h' = 666.8 \text{ kJ/kg}$
 Dryness fraction $X = 0.89$
 Enthalpy of wet saturated steam $h = h' + X(h'' - h') = 2,360.5 \text{ kJ/kg}$
 Latent heat $g = 488.6 \text{ kJ/kg}$
 Room temperature 33°C

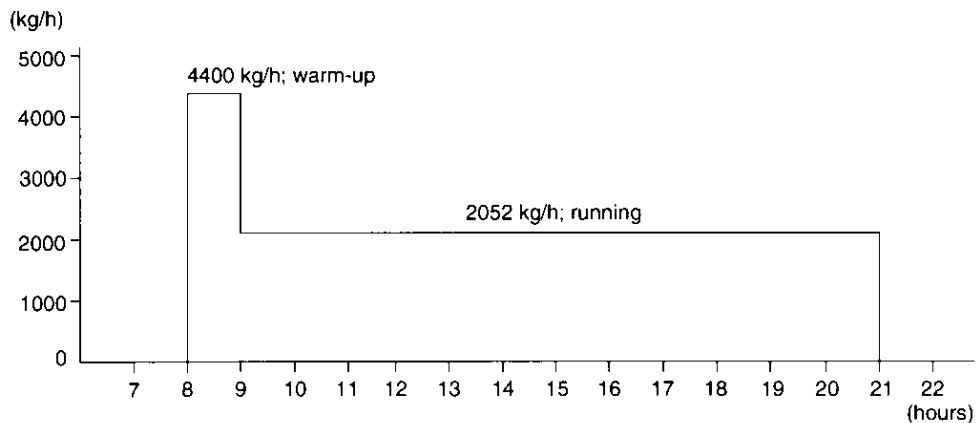
(10) Production rate : Cotton fabric 570 kg/h
 $570 \text{ kg/h} \times 13 \text{ h/d} = 6,840 \text{ kg/d-unit}$
 $6840 \times 2 \text{ units/day} = 13,680 \text{ kg/day}$

(11) Conditions of the drying machine
 Steam consumption per product (kg) : $1.80 \text{ kg/kg-fabric}$
 Power consumption per product (kg) : $0.23 \text{ kwh/kg-fabric}$
 Fabric drying rate : 570 kg/h
 Moisture content : Inlet 101.9% , Outlet 4.5%
 Feeding air : DB 33°C WB 23°C Enthalpy $h = 68.2 \text{ kJ/kg}$
 Exhaust air : DB 70°C WB 42°C Enthalpy $h = 184 \text{ kJ/kg}$
 Exhaust air volume : $238 \text{ Nm}^3/\text{min-unit}$

(12) Drying machine
 Chamber temperature:
 Upper part : 98°C
 Middle part : 90°C
 Lower part : 60°C } Average temperature 85°C
 Body surface temperature : 82°C
 Heat-insulated surface temperature : 43°C

(13) Steam consumption : $1,026 \text{ kg/h} \times 2 \text{ units} = 2,052 \text{ kg/h}$
 $(2,052 \times 12 \text{ h}) + 4,400 \text{ kg/h} = 29,024 \text{ kg/day}$
 $(4,400 \text{ kg/h: Temporary consumption during warming-up})$

(14) Load curve



(15) Assumed conditions

a. Exhaust conditions: Heat exchanger is installed for waste heat recovery, and VVVF control is introduced.

	P _{present}	Heat exchanger	Heat exchanger + VVVF control
Exhaust air DB $^\circ\text{C}$	70	50	50
Exhaust air WB $^\circ\text{C}$	42	40	44
Exhaust air enthalpy ($h = \text{kJ/kg}$)	184.1	161.1	200.9
Steam consumption per unit production (kg/kg-fabric)	1.80	1.43	1.33
Exhaust air volume (Nm^3/min)	238	238	157

b. The warm-up period is excluded in the loss calculations.

c. Current heat balance (reference: 0°C, 1 hour)

(Heat input)

Item	Calculation	kJ/hour	%
Heat of steam	$1.8 \text{ kg/kg} \times 570 \text{ kg/h} \times 2,712.2 \text{ kJ/kg}$	2,782,717	60.2
Heat of electricity	$0.23 \text{ kWh} \times 570 \text{ kg/h} \times 3,600 \text{ kJ/kWh}$	471,960	10.2
Heat of supplied air	$238 \text{ Nm}^3/\text{min} \times 1.3 \text{ kg/Nm}^3 \times 60 \text{ min} \times 68.2 \text{ kJ/kg}$	1,266,065	27.4
Heat of fabric	$570 \text{ kg/h} \times 1.30 \text{ kJ/kg} \cdot \text{K} \times 33^\circ\text{C}$	24,453	0.5
Heat of fabric moisture	$570 \text{ kg/h} \times 1.019 \times 4.186 \text{ kJ/kg} \cdot \text{K} \times 33^\circ\text{C}$	80,235	1.7
Total		4,625,430	100.0

(Heat output)

Item	Calculation	kJ/hour	%
Heat of waste gas	$238 \text{ Nm}^3/\text{min} \times 1.3 \text{ kg/Nm}^3 \times 60 \text{ min} \times 184.1 \text{ kJ/kg}$	3,417,632	73.9
Heat of fabric	$570 \text{ kg/h} \times 1.30 \text{ kJ/kg} \cdot \text{K} \times 70^\circ\text{C}$	51,870	1.1
Heat of fabric moisture	$570 \text{ kg/h} \times 0.045 \times 4.186 \text{ kJ/kg} \cdot \text{K} \times 70^\circ\text{C}$	7,516	0.2
Heat of condensate	$1.8 \text{ kg/kg} \times 570 \text{ kg/h} \times 666.8 \text{ kJ/kg}$	684,137	14.8
Heat dissipation	$510 \text{ m}^2 \times [\text{convective dissipation (kJ/m}^2) + \text{radiant dissipation (kJ/m}^2)]$	141,996	3.1
Other heat	input – output	322,279	6.9
Total		4,625,430	100.0

*** Improvement measures for energy conservation**

1) Recovery of heat from waste gas

Heat input	Reduction in heat of steam for drying (1.80 to 1.43 kg)
Heat output	Reduction in heat of waste gas (184.1 to 161.1 kg)
	Reduction in heat of condensate (1.08 to 1.43 kg)

2) Control of temperature of waste gas (VAVF control)

3) Recovery of condensate

4) Heat insulation

Data for heat insulation (dryer)

(1) Heat dissipation from uninsulated dryer (existing: glass wool 20 mm)

The existing dryer has been provided with glass wool of a 20 mm thickness.

The dryer is a rectangular parallelepiped, and heat dissipation should be calculated separately for the top, side and bottom. Calculations are made on the assumption that heat storage in the shell and the insulator is ignorable and that the internal temperature, heat conductivity (λ) of glass wool and thermal emissivity (ϵ) are 82°C, 0.052 W/m²K, and 0.23, respectively.

Heat loss calculations for one dryer unit are shown below.

Part	Surface temp. (°C)	Surface area (m ²)	Heat release (kj/m ² h)	Dissipation (kj/m ² h)
Top	45	102	343	34,986
Side	47	230	330	75,900
Bottom	50	102	305	31,110
Total/unit		—		141,996

The dryer is operated for 13 hours per day and 300 days per year. The heat loss per unit is calculated as follows:

$$141,996 \text{ kj/m}^2\text{h} \times 13 \text{ hours} \times 300 \text{ days} = 5.538 \times 10^6 \text{ kj}$$

(2) Heat dissipation after improvement (glass wool 50 mm)

The insulation thickness is increased to improve the insulating performance of the dryer.

As in the existing dryer, glass wool is used as insulation material, and the insulation thickness is increased up to 50 mm which is the economically optimum insulation thickness for the inside temperature of 100°C.

Calculations are made on the assumption that heat conductivity (λ) of glass wool and the thermal emissivity (ϵ) are 0.188 kj/mh · K and 0.23, respectively.

Heat loss calculations for one cycle after insulation improvement are shown below.

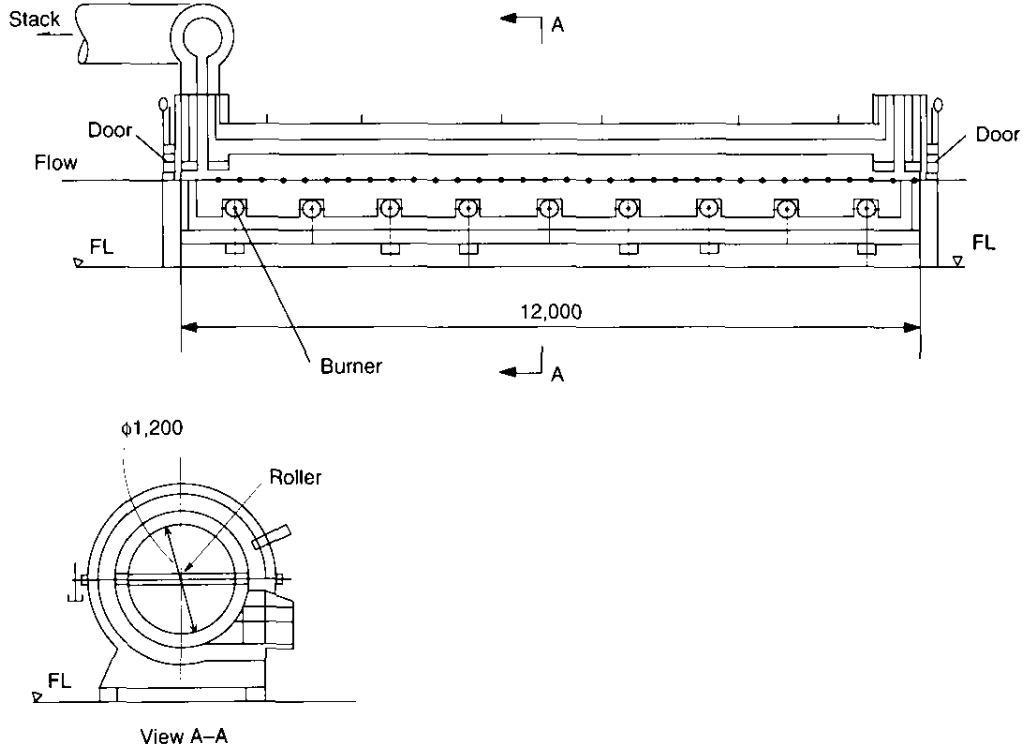
Part	Surface temp. (°C)	Surface area (m ²)	Heat release (kj/m ² h)	Dissipation (kj/m ² h)
Top	40	102	159	16,218
Side	41	230	155	36,650
Bottom	42	102	150	15,300
Total/unit		—		37,168

The heat loss per unit is calculated as follows:

$$67,168 \text{ kj/m}^2\text{h} \times 13 \text{ hours} \times 300 \text{ days} = 2.6195 \times 10^6 \text{ kj}$$

16. Heating Furnace

- 1) Type : Roller hearth type, Bar heating furnace for quenching
 2) Dimension :



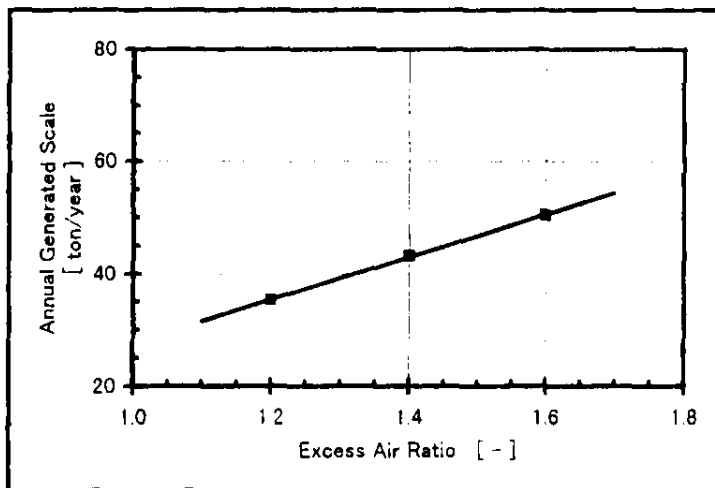
- 3) Capacity : 1000 kg/hr
 4) Fuel : Fuel A oil $H_L = 42,119$ kJ/kg
 Theoretical air quantity 11.09 Nm³/kg
 Quantity of the waste gas (air ratio = 1) 11.82 Nm³/kg
 5) Fuel consumption : 61.315 kg/h
 6) Combustion air temp. : 33°C
 7) Fuel temp. : 33°C
 8) Air ratio : 1.6
 9) NOx% in exhaust gas : 250 ppm
 10) Waste gas temp. : 1000°C
 11) Furnace wall temp. : 1000°C
 12) Material temp. : 33°C → 950°C
 13) Surface temp. of body : Cylindrical wall 134°C, Vertical wall 135°C
 14) Furnace wall structure
 fire brick : SK 33 115 mm
 insulating brick : B6 115 mm
 15) Other heat loss
 cooling water : 2 m³/h 30°C → 40°C
 furnace pressure : 49 Pa

- 16) Generated scale : 7 kg/ton of raw material
- 17) Average specific heat at constant pressure
 air : 1.298 kJ/m³ NK
 waste gas : 1.381 kJ/m³ NK
 specific heat of iron : 0.699 kJ/kgK
 scale : 0.900 kJ/kg K
- 18) Heat of oxydizing reaction (Fe)
 : 5,588 kJ/kg
- 19) Total Fe in scale : 0.755
 • Air ratio could be reduced to 1.2.
 • Scale loss at air ratio 1.2 would be 70% of that at air ratio 1.6.
- 20) Burner type : Compressed air atomizing burner

Scale loss improvement

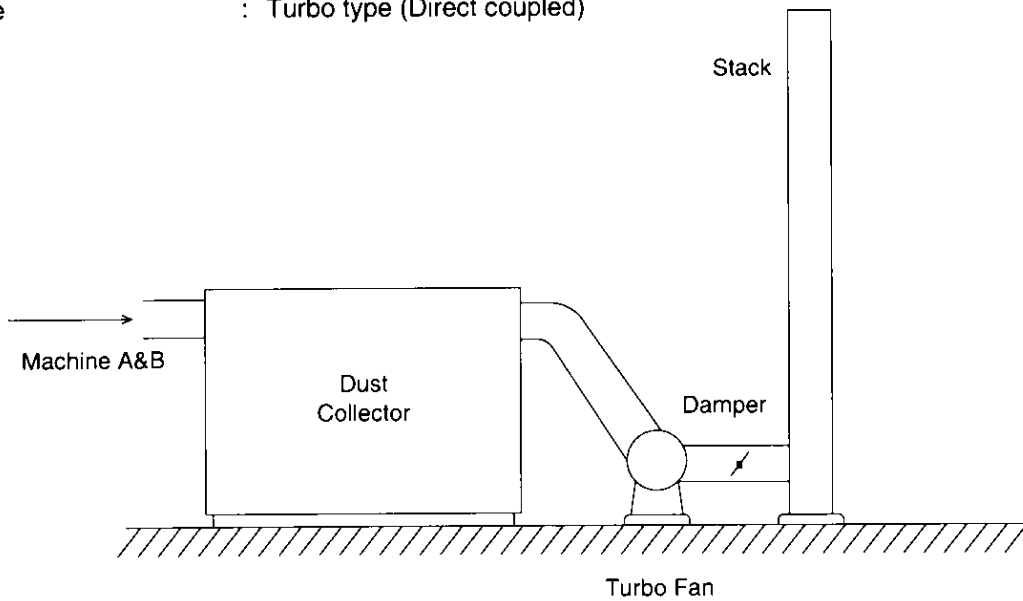
Excess Air Ratio	Generated Scale	Annual Generated Scale
-	kg/ton	ton/year
1.6	7.0	50.4
1.4	6.0	43.2
1.2	4.9	35.3

Heating Furnace Operation Hour : 7200 h/year



17. Blower for Dust Collector

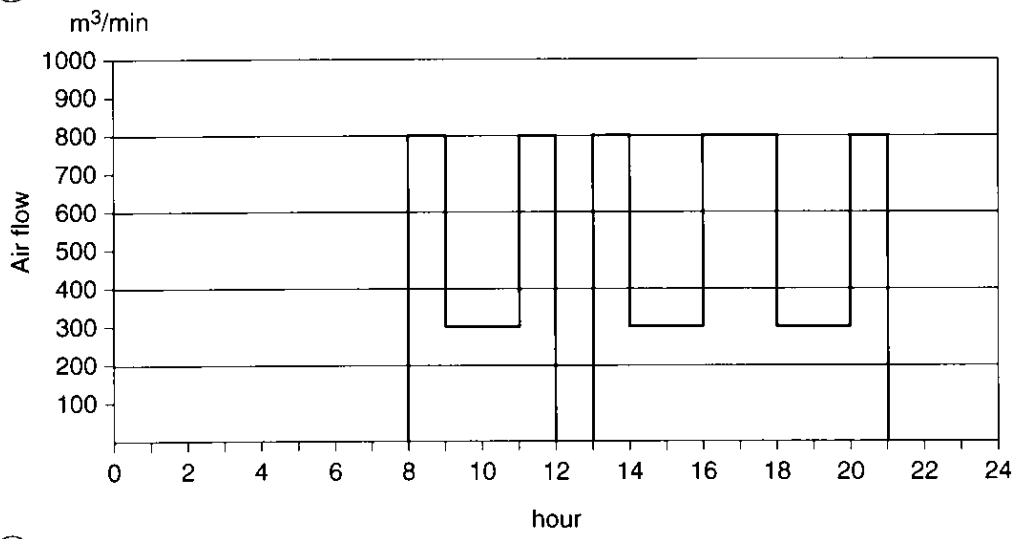
(1) Type : Turbo type (Direct coupled)



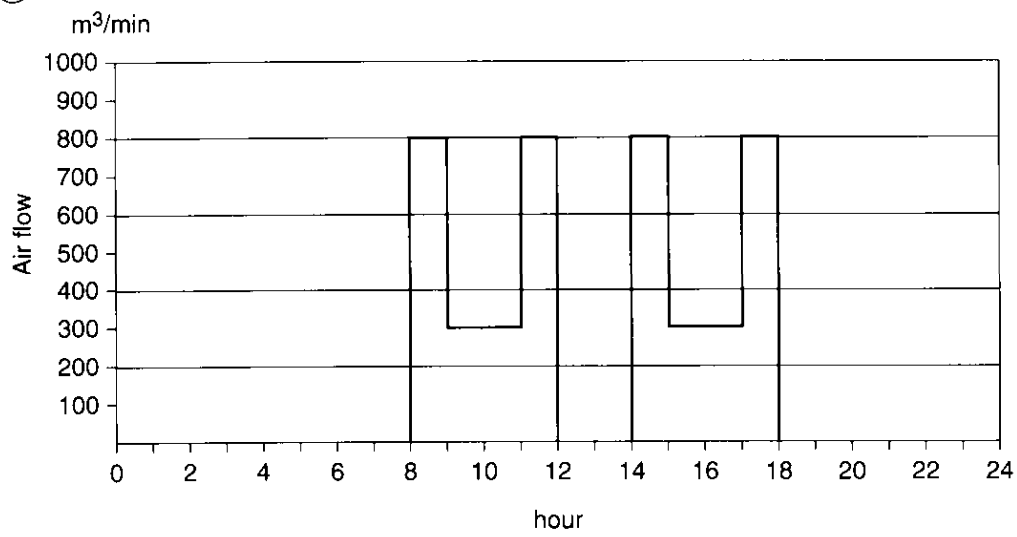
- (2) Static pressure : 1.5 kPa
- (3) Air flow per unit : 800 m³/min – 300 m³/min
Controlled by discharge damper (damper opening 100% at 800 m³/min)
- (4) Blower efficiency : 0.7
- (5) Motor type : Induction motor
- (6) Motor capacity : 75 kW × 3 unit

(7) Load curve

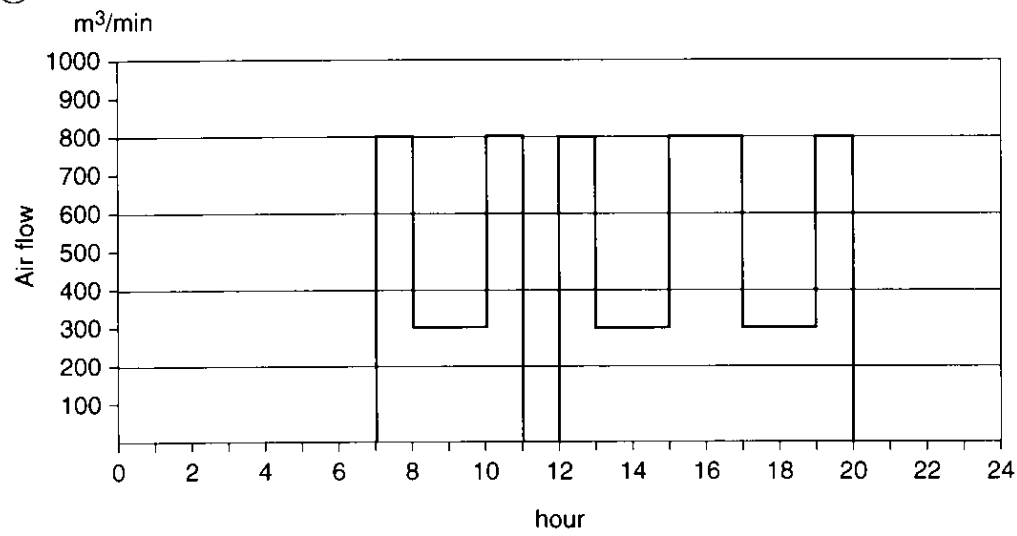
① Unit No. 1



② Unit No. 2

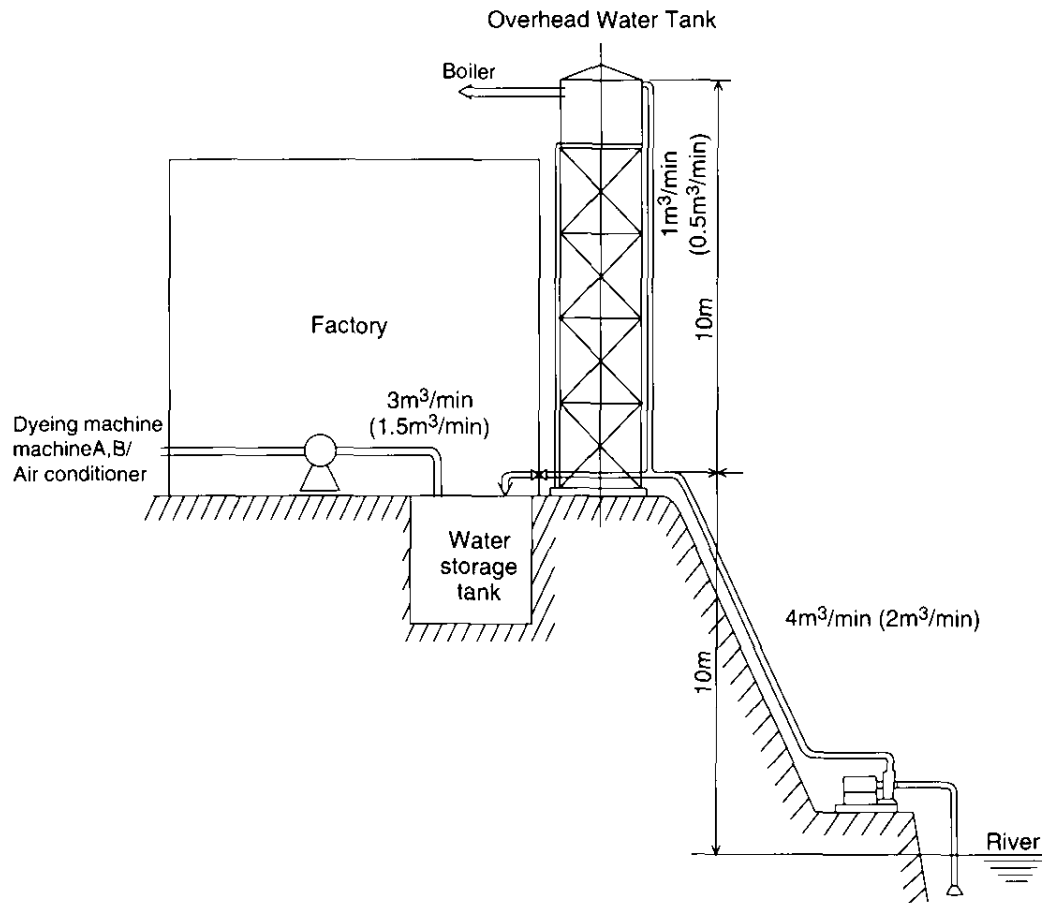


③ Unit No. 3



18. Pump

(1) Type : Single suction volute pump (General purpose type)

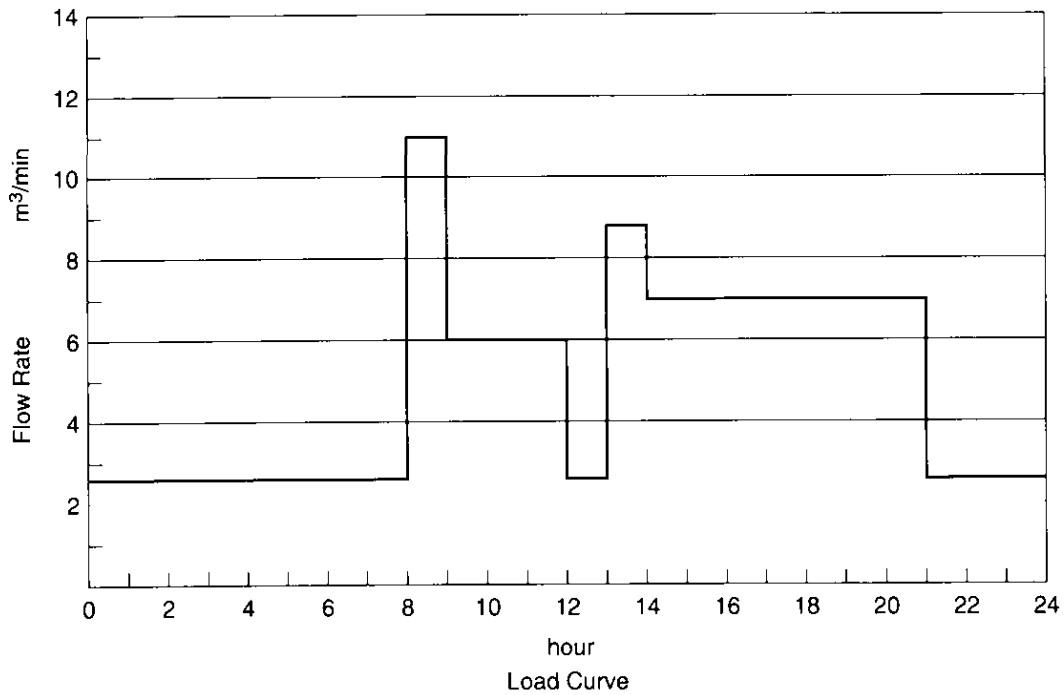


- | | |
|--------------------|---|
| (2) Motor capacity | : 22 kW |
| (3) Flow rate | : $4\text{ m}^3/\text{min} \times 20\text{ mH}_2\text{O}$ |
| (4) Water temp. | : 20°C |
| (5) Working hour | : 8:00–20:00 $4\text{ m}^3/\text{min}$ |
| | : 20:00–8:00 $2\text{ m}^3/\text{min}$ |

19. Compressor

No. of equipment		1	2	3	4
Type		screw	screw	reciprocating	reciprocating
Temp. of intake air [°C]		50	50	50	50
Discharge pressure [Gauge MPa]		0.7	0.7	0.7	0.7
Flow rate [m ³ /min]		4.0	3.2	3.0	1.8
Power [kW]	load	30	25	25	18
	unload	18	13	5	3.6

Maximum pressure of user side Gauge 0.5 MPa
 Air pressure drop factor $\Delta p = 0.05 \sim 0.1$ MPa



Compressor Operation Pattern

h	0-8	8-9	9-12	12-13	13-14	14-21	21-24
Load (m ³ /min)	2.5	11	6	2.5	9	7	2.5
No							
1 (4.0m ³ /min)		←	→		←	→	
2 (3.2m ³ /min)	OFF	←	→	OFF	←	→	OFF
3 (3.0m ³ /min)	←						→
4 (1.8m ³ /min)	OFF	←				→	OFF
Total	3	12	12	4.8	12	12	3

As long as it is switched on, each compressor automatically alternates between loaded and unloaded states. As the pressure settings for switching from load operation to no load operation and vice versa have not been adjusted, each compressor jumps from one mode to the other at random depending on changes in the overall air demand.

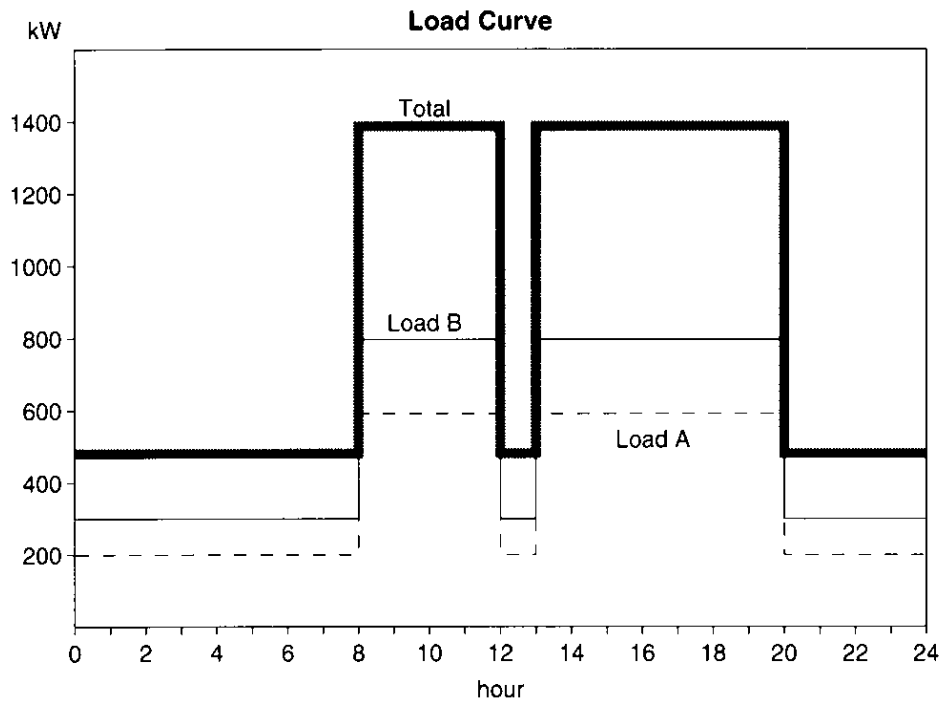
The combined daily electric energy consumption of the compressors was measured to be 1,250 kWh.

Compressor Operation Schedule

Case 0

time	0 ~ 8	8 ~ 9	9 ~ 12	12 ~ 13	13 ~ 14	14 ~ 21	21 ~ 24	
required flow rate	2.5 m ³ /min	11.0 m ³ /min	6.0 m ³ /min	2.5 m ³ /min	9.0 m ³ /min	7.0 m ³ /min	2.5 m ³ /min	
SCREW TYPE No.13		intermittent	Unload		intermittent	Unload		
Flow rate 4.0 m ³ /min		3.0 m ³ /min	0 m ³ /min		1.0 m ³ /min	0 m ³ /min		
Load 30 kW								
Unload 18 kW		<u>27 kW</u>	<u>18 kW</u>		<u>21 kW</u>	<u>18 kW</u>		
SCREW TYPE No.14		continuous	intermittent		continuous	intermittent		
Flow rate 3.2 m ³ /min		3.2 m ³ /min	1.2 m ³ /min		3.2 m ³ /min	2.2 m ³ /min		
Load 25 kW								
Unload 13 kW		<u>25 kW</u>	<u>17.5 kW</u>		<u>25 kW</u>	<u>21.3 kW</u>		
RECIPRO TYPE No.15	intermittent	continuous	continuous	intermittent	continuous	continuous	intermittent	
Flow rate 3.0 m ³ /min	2.5 m ³ /min	3.0 m ³ /min	3.0 m ³ /min	0.7 m ³ /min	3.0 m ³ /min	3.0 m ³ /min	2.5 m ³ /min	
Load 25 kW								
Unload 5.0 kW	<u>21.7 kW</u>	<u>25 kW</u>	<u>25 kW</u>	<u>9.7 kW</u>	<u>25 kW</u>	<u>25 kW</u>	<u>21.7 kW</u>	
RECIPRO TYPE No.16		continuous	continuous	continuous	continuous	continuous		
Flow rate 1.8 m ³ /min		1.8 m ³ /min	1.8 m ³ /min	1.8 m ³ /min	1.8 m ³ /min	1.8 m ³ /min		
Load 18 kW								
Unload 3.6 kW		<u>18 kW</u>	<u>18 kW</u>	<u>18 kW</u>	<u>18 kW</u>	<u>18 kW</u>		
Average Power	<u>21.7 kW</u>	<u>95.0 kW</u>	<u>78.5 kW</u>	<u>27.7 kW</u>	<u>89.0 kW</u>	<u>82.3 kW</u>	<u>21.7 kW</u>	Total
Power Consumption	173.6 kWh	95.0 kWh	235.5 kWh	27.7 kWh	89.0 kWh	576.1 kWh	65.1 kWh	1262.0 kWh

20. Transformer



(1) Load of Transformer A

Hour	0–8	8–12	12–13	13–20	20–24
kW	200	600	200	600	200
p.f.%	90	85	90	85	90

(2) Load of Transformer B

Hour	0–8	8–12	12–13	13–20	20–24
kW	300	800	300	800	300
p.f.%	90	85	90	85	90

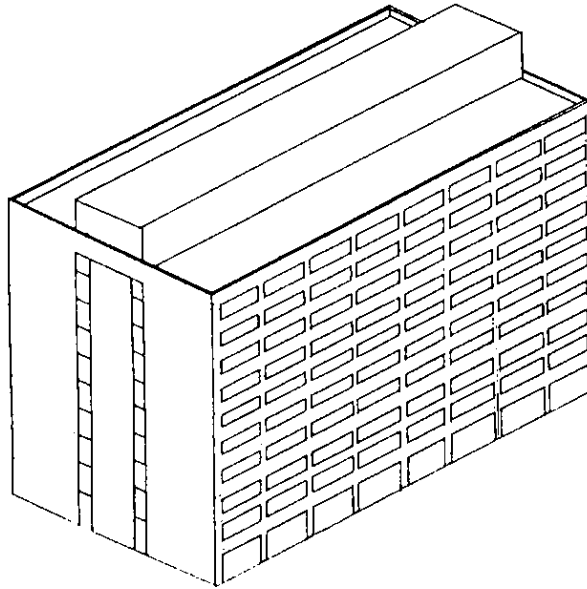
(3) Transformer Loss

Transformer	No load loss	Copper-Loss (at full load)
1,500 kVA	4.5 kW	16.5 kW
1,000 kVA	2.5 kW	12.5 kW

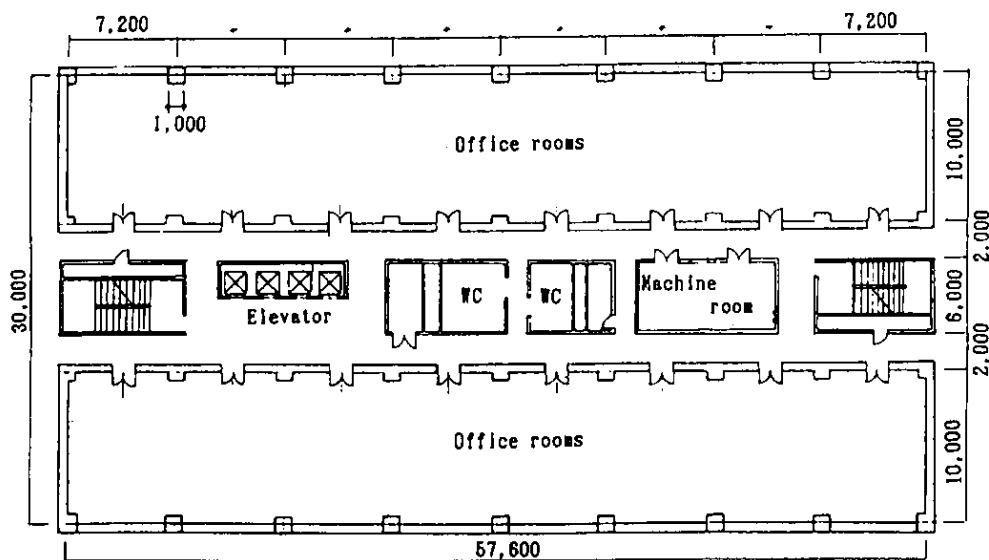
Air-conditioning

1. Outline of building

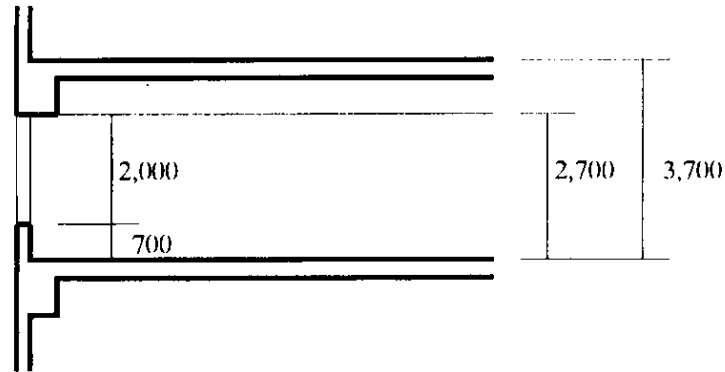
Name	: ECCJ Office building
Location	: Areas where only cooling is required throughout the year
Total number of stories	: 10 above ground (No underground floors)
Structure	: Steel structure
External appearance	: As shown below
Working hours	: 8:00-18:00



Typical plan : As shown below (Assumed to be common for all 10 stories)



Window cross section : As shown below



2. Thermal characteristic of the building

Wall	:	Heat transmission coefficient	$K = 1.17 \text{ [W/m}^2\text{K]}$
Roof	:	Heat transmission coefficient	$K = 0.83 \text{ W/m}^2\text{K]}$
Window glass	:	Heat transmission coefficient	$K = 6.29 \text{ [W/m}^2\text{K]}$ (with the blind open) $K = 4.95 \text{ [W/m}^2\text{K]}$ (with the blind closed)
	:	Shading coefficient	$SC = 0.96 \text{ [ND]}$ (with the blind open) $SC = 0.53 \text{ [ND]}$ (with the blind closed)

3. Air-conditioning load calculation conditions

Room temperature & humidity	:	$24^\circ\text{C (DB) 50% (RH)}$
Air-conditioning hours	:	8:00–18:00
Lighting hours	:	8:00–18:00
Room occupants	:	0.1 [person/m ²] (per air-conditioned area)
Lighting	:	20 [W/m ²] (per air-conditioned area) • 40 W × 3 flourescent lamps/unit • 127.5 W/unit (energy consumption) • 1,800 units/building
Heat generation from office equipments	:	10 [W/m ²] (per air-conditioned area) (sensible heat only)
Fresh air intake code)	:	30 [m ³ /h/person] (minimum 20 [m ³ /h/person] by building code)
Air infiltration	:	0.2 [times/h]

4. Assumption for annual cooling load calculation

$$\text{Annual cooling load [kWh/Y]} = \text{Peak cooling load [kWh/h]} \times 1000 \text{ [h/Y]}$$

Temperature difference between inside and outside : $\Delta\theta_o$ [deg C] (for window)

Equivalent temperature difference : $\Delta\theta_e$ [deg C] (for wall and roof)

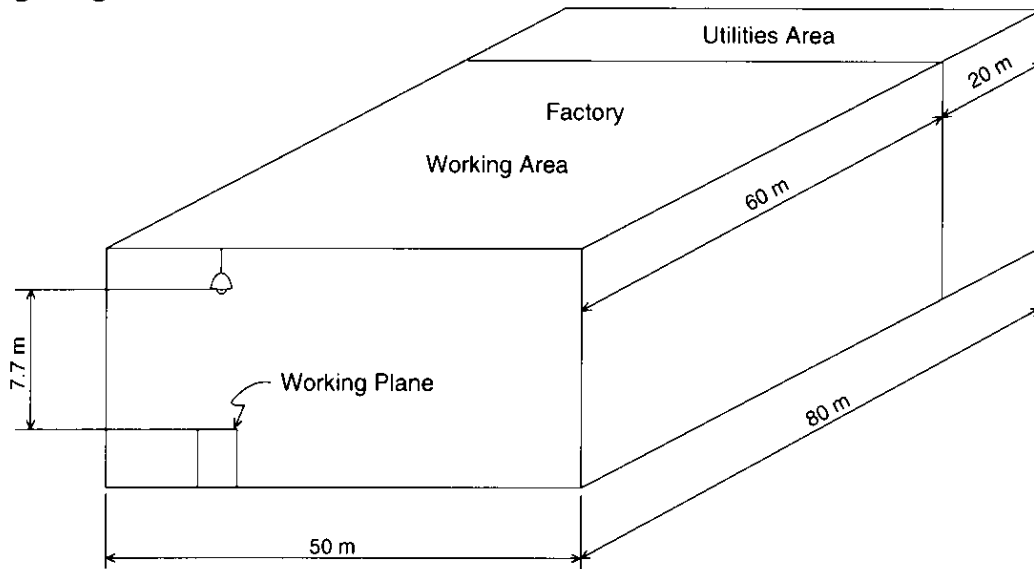
Time (O'clock)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
θ_o		2	1	1	1	1	1	2	3	5	6	7	7	7	7	7	6	6	5	4	3	3	2	2	2
θ_e	Roof	3	2	2	2	1	2	4	9	14	19	25	29	32	33	32	30	26	21	16	11	8	6	4	3
	N	3	2	2	2	1	2	3	4	5	5	6	7	8	8	8	9	9	9	9	7	6	4	4	3
	E	2	2	2	2	1	3	9	14	18	19	19	16	14	12	11	10	9	8	7	6	5	4	3	3
	S	2	2	2	2	1	1	2	2	4	6	9	11	13	14	14	12	11	9	7	6	5	4	3	3
	W	3	2	2	2	1	1	2	2	3	5	6	7	9	12	16	20	23	23	20	14	10	7	5	4

[NOTE] If the room set temperature θ_r is not equal to 26°C, add (26- θ_r) to each value in the Table.

Solar heat gain with standard glass : S_n [W/m²]

Time (O'clock)		5	6	7	8	9	10	11	12	13	14	15	16	17	18
S_n	N	20	100	55	38	42	43	43	43	43	43	40	38	76	99
	S	8	24	33	40	77	131	171	180	157	108	56	36	30	20

21. Lighting



- (1) Lighting area : $80\text{ m} \times 50\text{ m} = 4,000\text{ m}^2$
- (2) Height of light source from working plane : 7.7 m
- (3) Lamp : Fluorescent mercury lamp 400 W (60 lm/W) \times 150
- (4) Illumination standard : 500 lx (at Working area) 300 lx (at Utilities area)
- (5) Reflectivity : Floor 10%
Ceiling 30%
Wall 20%
- (6) Utilization factor

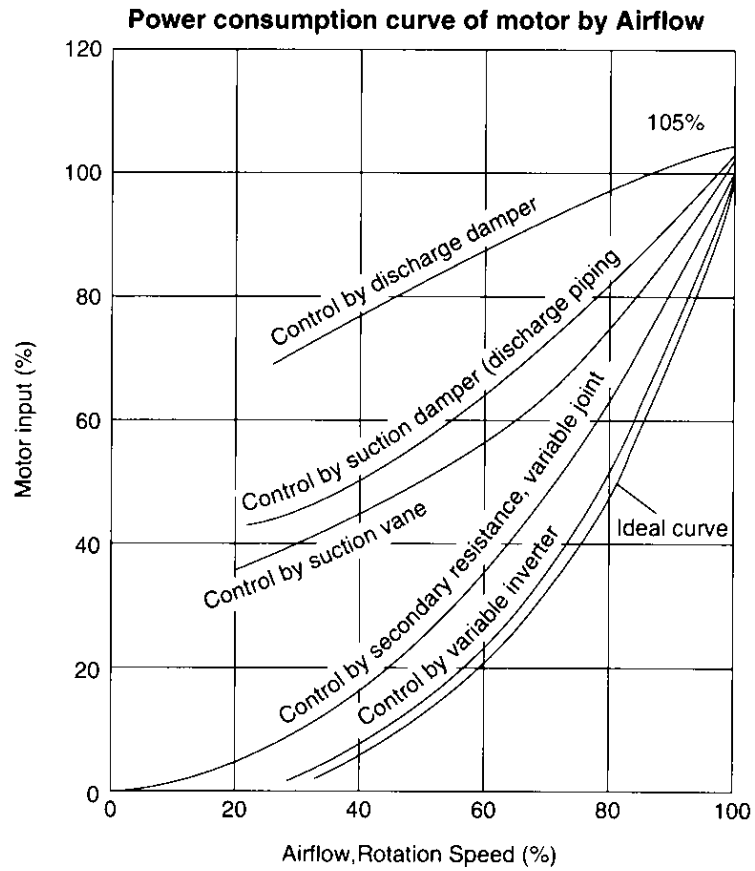
Reflectivity from floor %		10							
		70		50			30		
Reflectivity from ceiling %		40	20	60	40	20	60	40	20
		Reflectivity from wall %		40	20	60	40	20	60
Room Index	RI=0.60	0.36	0.32	0.41	0.35	0.31	0.40	0.35	0.31
	RI=0.80	0.45	0.41	0.50	0.44	0.40	0.48	0.43	0.40
	RI=1.00	0.52	0.48	0.56	0.51	0.48	0.54	0.50	0.47
	RI=1.25	0.57	0.53	0.60	0.56	0.52	0.58	0.54	0.51
	RI=1.50	0.62	0.58	0.64	0.60	0.57	0.62	0.59	0.56
	RI=2.00	0.67	0.64	0.68	0.65	0.62	0.66	0.63	0.61
	RI=2.50	0.70	0.67	0.71	0.68	0.66	0.68	0.66	0.64
	RI=3.00	0.72	0.70	0.72	0.70	0.68	0.70	0.68	0.67
	RI=4.00	0.75	0.73	0.75	0.73	0.71	0.72	0.71	0.69
	RI=5.00	0.77	0.75	0.76	0.74	0.73	0.73	0.72	0.71
RI=7.00	0.79	0.77	0.77	0.76	0.75	0.75	0.74	0.73	
RI=10.00	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.75	

- (7) Maintenance factor : 0.8

22. Steam Piping

- (1) Pipe diameter : Main pipe 12 inches, Branch pipe 6 inches
- (2) Pipe length : Main pipe 100 m, Branch pipe 100 m
- (3) Insulation : 20 mm glasswool
- (4) Steam pressure : Gauge 0.8 MPa working pressure
- (5) Number of valve : Main pipe 3
Branch pipe 10
- (6) Number of flange : Main pipe 10
Branch pipe 20
- (7) Steam leakage :
Steam leakage from 10 flanges and screw joints on the pipe lines.
It is almost equivalent to the leakage from 10 holes with 1.5 mm in diameter.
- (8) Peeling of insulation :
There are some broken insulation parts on pipe lines.
Total length of broken insulation parts on pipe lines is about 10 m length.

23. Reference



Efficiency of motor (%) (Standard type)

Motor rating kW	Load factor			
	25%	50%	75%	100%
3.7	71	84	84	86
11	80	88	89	89
22	81	89	91	91
37	83	90	91	91
55	85	91	92	92
75	87	92	93	93

Efficiency of motor (%) (High efficiency motor)

Motor rating kW	Load factor			
	25%	50%	75%	100%
3.7	76	86	86	88
11	84	91	92	92
22	85	92	93	93
37	87	93	94	94
55	88	93	94	94
75	89	94	95	95

**24. Price List of Improved Equipment and Other Related Items
(for trainee reference)**

No	Equipment name	Improved equipment name	Specifications	Price US\$ (including laborage)
1	Boiler	1. Economizer	For 5 t/h Boiler For 10t/h Boiler	60,000 70,000
		2. Air heater	For 5 t/h Boiler For 10t/h Boiler	30,000 40,000
		3. Portable oxygen analyzer	Measuring range: O ₂ : 0–25%	4,000
2	Dyeing machine	1. Condensate recovery system (1) Recovery piping work	40 mm × 90 m @ 80 pipes/90 m	7,200
		(2) Storage tank unit (3) Water pump unit (VVVF control)	20 m ³ tank Pump with VVVF	5,000 7,000
		2. Drainage waste-heat recovery system (1) Heat exchanger	Plate-type heat exchanger	40,000
		(2) Piping including installation	Piping complete with circulating pump	10,000
		(3) Water tank including installation	60 m ³ , double-chamber type	24,000
		3. Heat insulation work Polyethylene heat insulator	Thickness: 15 mm $\lambda=0.041$ W/mk $\epsilon=0.23$ @\$60/m ²	726 units × 15 units = 10,890
		4. Liquor ratio reduction measure (1) Liquor circulation system (2) Drum interior modification	2.2 kW pump Installation of SUS vane	2,000 1,500
3	Drier	1. Waste heat recovery system (1) Rotary-type heat exchanger	Disk-type sensible heat exchanger	40,000
		2. Exhaust air humidity control system (1) VVVF controller (2) Sensor	2.2 kW Humidity 40 → 44°C	2,000 500
		3. Condensate recovery system (1) Recovery pump unit (2) Modification of boiler feedwater supply system (3) Piping work	5.5 kW Water level control measure 32 A/60 m @\$75/m	20,000 5,000 4,500
4	Heating furnace	1. Automatic combustion equipment (Including damper control)	Temperature control equipment Flow rate control equipment Automatic valve	32,000
		2. Thermal insulation material	Ceramic fiber 25 mm plywood ring 50 mm 75 mm 100 mm	16,600 23,800 33,300 40,400

No	Equipment name	Improved equipment name	Specifications	Price US\$ (including laborage)	
4	Heating furnace	3. Waste heat recovery collecting system 1	Recuperator Maximum exhaust gas volume 1,100 m ³ N/h Maximum air volume 1,000 m ³ N/h Exhaust gas intake temperature 800°C Air outlet temperature 650°C Burner (for hot air) Air duct therman insulation	120,000	
		4. Waste heat recovery system 2	Maximum exhaust gas volume 500 m ³ N/h Maximum air volume 450 m ³ N/h Exhaust gas intake temperature 800°C Air outlet temperature 650°C Burner (for hot air) Air duct therman insulation	50,000	
5	Piping work		1 1/2'~2'	800 \$/m	
			2 1/2'~3'	1,400 \$/m	
			4'~5'	2,300 \$/m	
			6'~8'	4,600 \$/m	
			10'~12'	8,000 \$/m	
6	Thermal insulation	Heat insulation	Appendix 1		
		Ceramic fiber	Appendix 2		
7	Blower	1. Motor	Standard	200 V or 400 V	100 \$/kW
			High efficiency	200 V or 400 V	130 \$/kW
		2. Inverter controller		500 \$/kW	
8	Pump	Pump	Head = 10 m	1,700 \$/kW	
			Head = 20 m	1,200 \$/kW	
9	Lithing factory	1. Sodium lamp with stabilizer	150 W	400 \$/unit	
		2. Sodium lamp with stabilizer	250 W	450 \$/unit	
10	Lighting office	High efficiency fluorescent lamp	45 W × 2	280 \$/unit	
11	Condenser		6.6 kV	25 \$/kVA	
12	Air compressor	Operation controller for unit numbers	Controller for 4 units	15,000	

Heat insulation (glasswool rockwool and calcium silicate) installation cost for various pipe diameter per unit volume (m³) in US\$

Insulation thickness(mm)	Diameter of pipe				
	1/2-3/4"	1-2"	2-6"	8-12"	14"-flat face
15	10,904	9,939	9,073	8,295	7,122
20	8,373	7,597	6,908	6,298	5,390
25	6,889	6,238	5,666	5,162	4,424
30	5,918	5,356	4,865	4,437	3,815
35	5,235	4,739	4,310	3,938	3,400
40	4,729	4,286	3,904	3,574	3,102
45	4,340	3,939	3,594	3,298	2,878
50	4,032	3,665	3,351	3,083	2,704
55	3,782	3,444	3,156	2,911	2,566
60	3,575	3,262	2,996	2,770	2,453
65	3,402	3,109	2,862	2,653	2,360
70	3,254	2,980	2,749	2,554	2,283
75	3,127	2,869	2,652	2,469	2,216
80	3,017	2,773	2,568	2,396	2,160
85	2,920	2,689	2,495	2,333	2,110
90	2,834	2,614	2,431	2,277	2,067
95	2,758	2,548	2,374	2,228	2,029
100	2,689	2,489	2,323	2,184	1,996
150	2,264	2,126	2,012	1,919	1,795

Note: In case of heat insulation of pipe, installation cost per unit volume is depending on the insulation and pipe diameter.

The cost for insulation is derived from following formula.

$$\text{Insulation cost} = 1.2 * (12000 * X^{-K} + 100) * 10\$/\text{m}^3$$

where X = thickness of insulator

K = constant and selected from following

Diameter of pipe	K factor
1/2 to 3/4	1.09
1 to 2"	1.13
2-6"	1.17
8 to 12"	1.21
14" to flat face	1.28

Heat insulation installation cost for veneering ceramic fiber per unit area (m²) in US\$

Veneering thickness (mm)	Installation cost	(US\$/m ²)
25	350	
50	500	
75	700	

25. Unit Conversion Table

Quantity	SI Unit	Conventional units		Remarks
Force	N	kgf		
	1 9.80665	0.1019716 1		
Torque Moment of force	N·m	kgf·m		
	1 9.80665	0.1019716 1		
Pressure	Pa	kgf/cm ²		
	1 9.80665 × 10 ⁴	1.019716 × 10 ⁻⁵ 1		
	9.80665	10 ⁻⁴		
Energy Work Heat Enthalpy	kJ	kWh	kcal	
	1	1/3600	0.2388459	
	3600	1	859.8452	
	4.1868	1.163 × 10 ⁻³	1	
Power Power rate Power output Heat flow	W	kgf·m/s		
	1 9.80665	0.1019716 1		
Heat flux (heat flow per unit area)	W/m ²	kcal/(m ² ·h)		
	1 1.163	1/1.163 1		
Heat conductivity	W/(m·K)	kcal/(m·h·°C)		
	1 1.163	1/1.163 1		
Heat transfer rate Heat transfer coefficient	W/(m ² ·K)	kcal/(m ² ·h·°C)		
	1 1.163	1/1.163 1		
Heat capacity Entropy	kJ/K	kcal/°K		
	1 4.1868	0.2388459 1		
Specific internal energy Specific enthalpy Mass latent heat (latent heat)	kJ/kg	kcal/kgf		
	1	0.2388459		
	4.1868	1		
Specific heat Specific entropy (Mass entropy)	kJ/(kg·K)	kcal/(kgf·°C)		
	1 4.1868	0.2388459 1		