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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, CO_2, 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 12	PM	Outline		Mr. Tanabe, ECCJ Mr. Fukushima, ECCJ
May 31	AM/PM	Boiler	16	Mr. Ishibashi, Tokyo Gas
June 7	AM	Transformer, Lighting	19	Mr. Kanao, Mitsubishi Electric Corporation
June 9	AM	Blower, Pump, Compressor	20	Mr. Horikawa, Sumikin Management Co., Ltd.
June 1	AM	Air conditioner	17	Mr. Yamaguchi, Obayashi Corporation
June 14	AM/PM	Energy management	(at factory)	Mr. Kanao, Mr. Kobayashi, Fukuyama Works, Mitsubishi Electric Corporation
June 16–17	AM/PM	Heat recovery of condensate	(at factory)	Mr. Hayafune, TLV Co., Ltd.
June 28	AM	Dyeing machine, Drying machine	27	Mr. Sato, Gunze Development Co., Ltd.
June 28	PM	Heat insulation	28	Mr. Hoshi, Shinagawa Furnace
June 29	AM/PM	Heat furnace	29	Mr. Ikeda, Chugai-ro Co., Ltd.
June 30	AM/PM	Group work		Mr. Fukushima, ECCJ Mr. Yamaguchi, Obayashi Corporation
July 1	AM/PM	Group work		Mr. Kanao, Mitsubishi Electric Corporation Mr. Horikawa, Sumikin Management Co., Ltd.
July 2	AM/PM	Group work		Mr. Fukushima, ECCJ
July 5	AM	Group work		Mr. Fukushima, ECCJ
	PM	Presentation		Mr. Ikeda, Chugai-ro Co., Ltd. Mr. Kanao, Mitsubishi Electric Corporation Mr. Horikawa, Sumikin Management Co., Ltd. Mr. Yamaguchi, Obayashi Corporation Mr. Hoshi, Shinagawa Furnace Mr. Sato, Gunze Development Co., Ltd. Mr. Fukushima, ECCJ Mr. Shibuya, 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

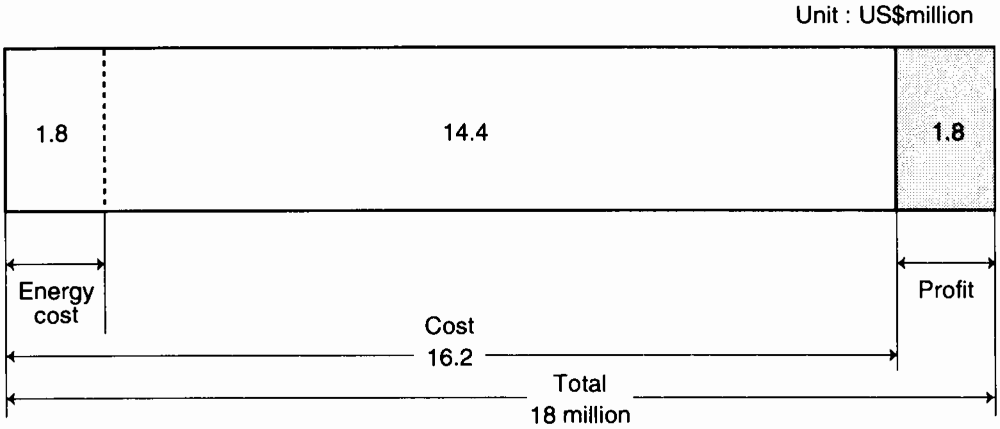
4. Factory Organization

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

- Factory Director
  - General Affairs Dept. : 20 persons
  - Technology Dept. : 10 persons
  - Manufacturing Dept.(A) : 50 persons
  - Manufacturing Dept.(B) : 50 persons
  - Energy Dept.
    - Electric Power Section : 3 persons
    - Boiler & Utility Section : 5 persons
  - Equipment Dept.
    - Building and Civil Works Section : 7 persons
    - Maintenance & Improvement Section : 10 persons

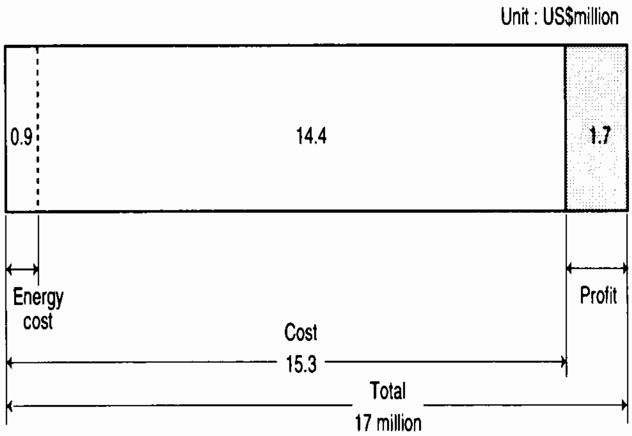
3) Factory scale (Fuji)

Turnover : US$18



4) Factory scale (Sakura)

Turnover : US$11 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: Diesel oil or Gas oil

1) Components : C = 86%, H = 13%, O = 0.7%, N = 0.2%, S = 0.1%
2) Calorific value : 42,119 kJ/kg
3) Theoretical combustion air (Ao) : 11.09 Nm^3/kg
4) Theoretical exhaust air (Go) : 11.82 Nm^3/kg
5) Specific heat : Air : 1.30 $kJ/Nm^3\,°K$
: Exhaust gas : 1.38 $kJ/Nm^3\,°K$
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 CO_2 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 = $(1500 \times 14 \times (1.85 - 0.87) + 22252.67 \times 0.17 \times 25) / (22252.67 \times 25)$
= 0.207 $/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 = $(1500 \times 7 \times (1.85 - 0.87) + 22252.67 \times 0.08 \times 25) / (22252.67 \times 25)$

$= 0.098$ $/kWh

2) Fuel charge

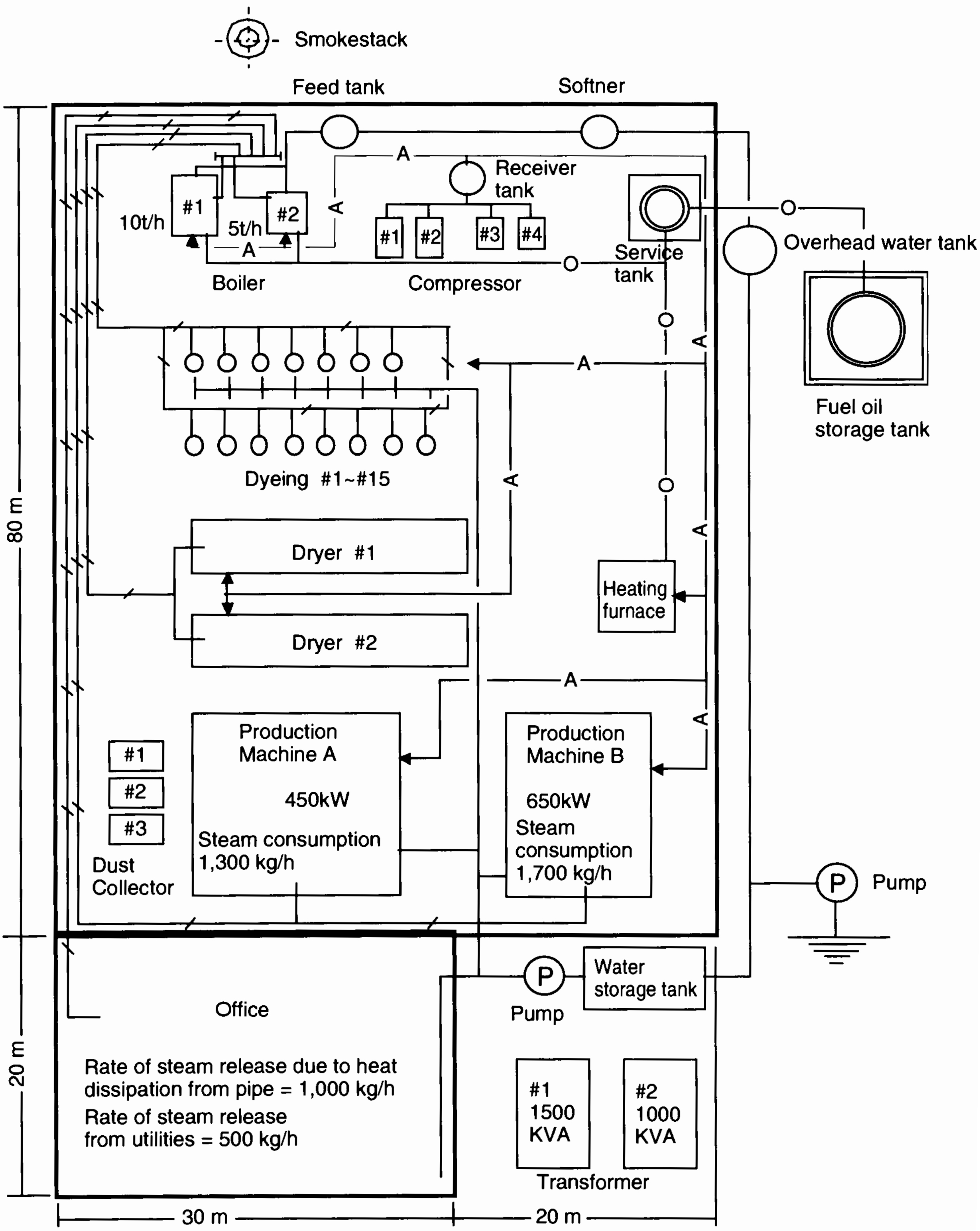
0.1 $/kg

(6) Others

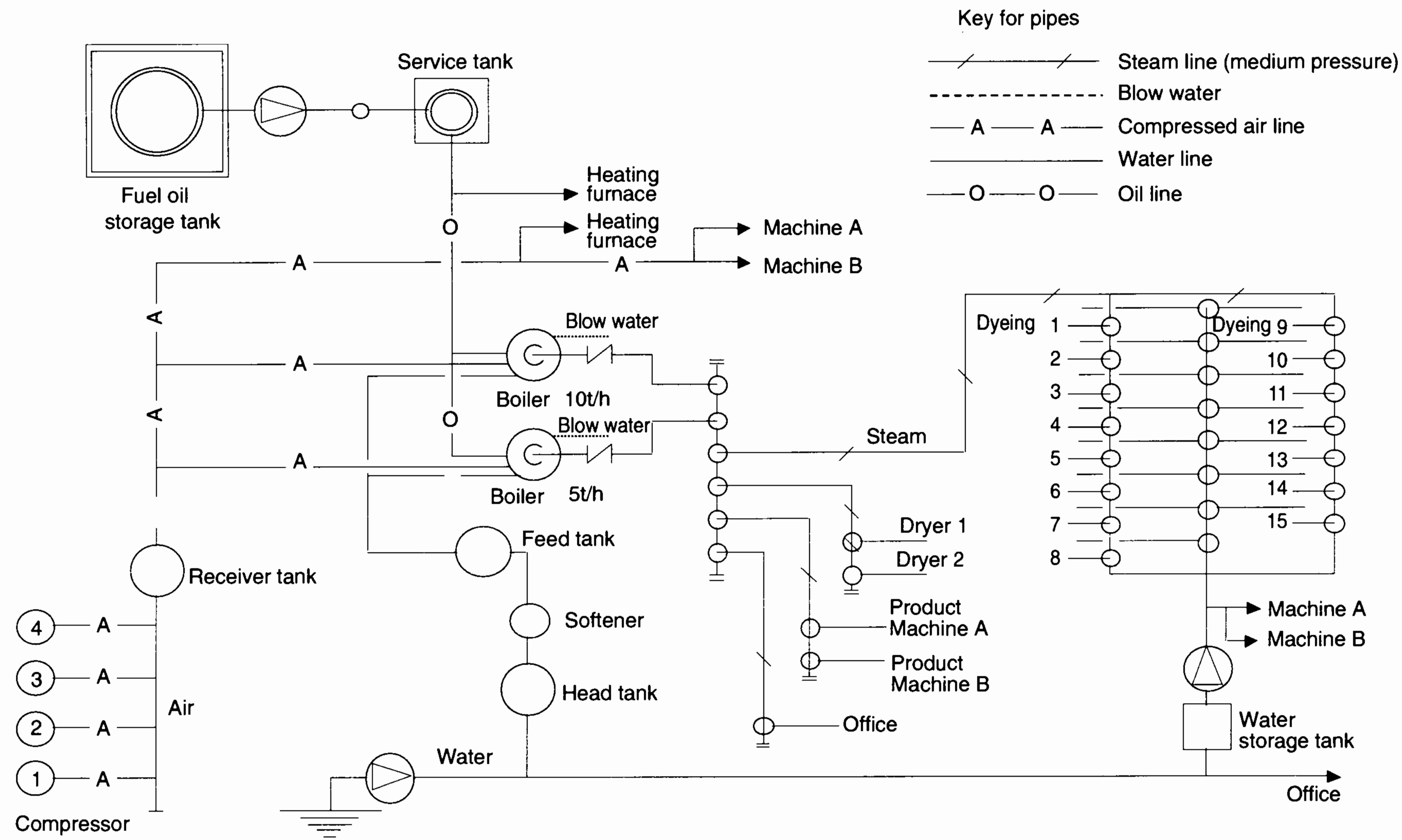
1) Ambient temperature : 33°C

2) Water temperature : 20°C

6. Factory Layout



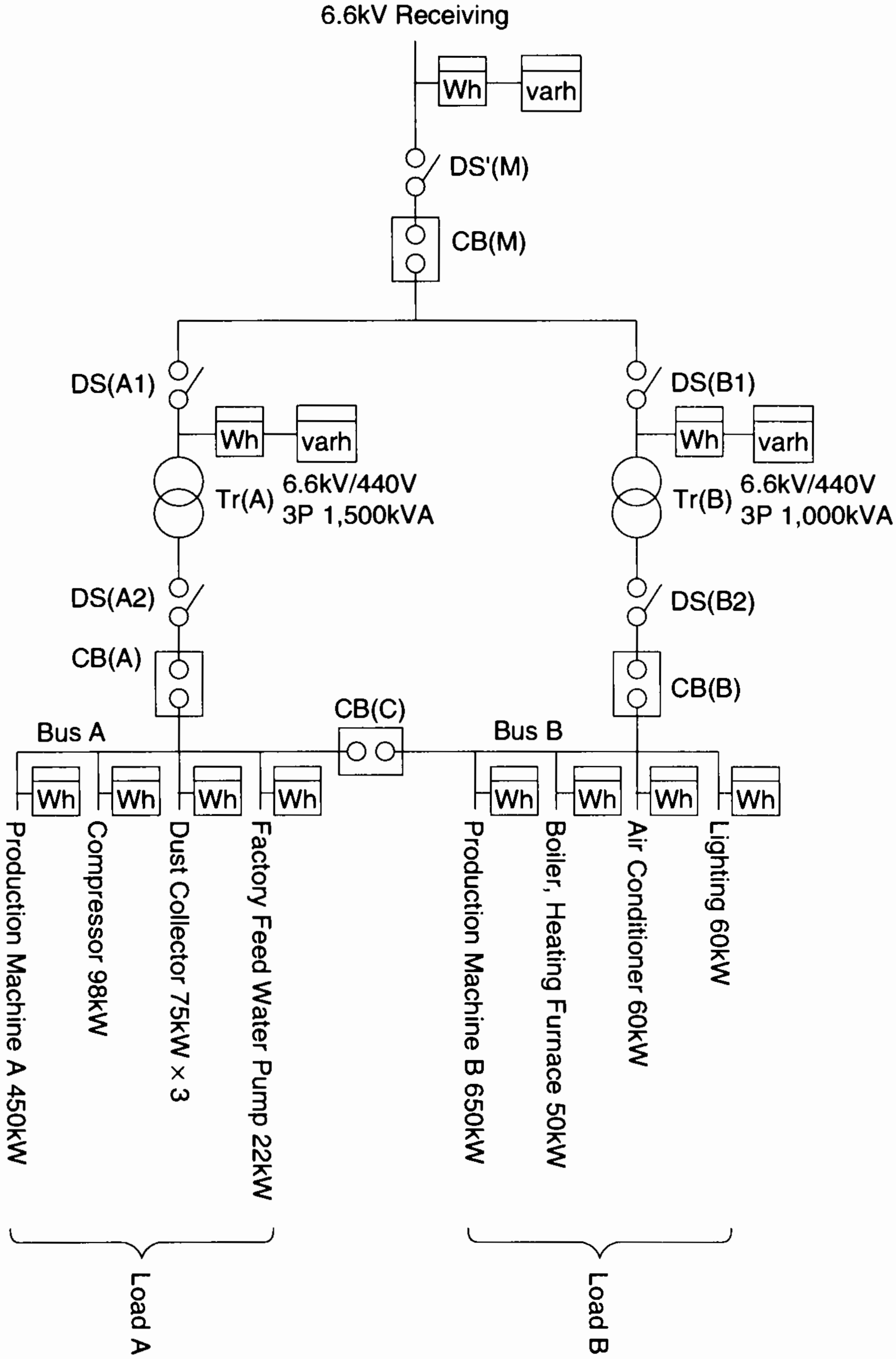
7. Utility Flow Sheet



8. Installation of Measuring Instruments

Item	Name of apparatus	Quantity	Utilities					No. of meters	
			Elec-tricity	Fuel	Water	Steam	Com-pressed air	Watt-meter	Amme-ter
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	
Environ-mental 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

Tr(A) and Tr(B) are possible to make parallel operation.
Their primary and secondary connections are same and their phase rotations are same.
Their % impedance are inverse proportional to their capacities.

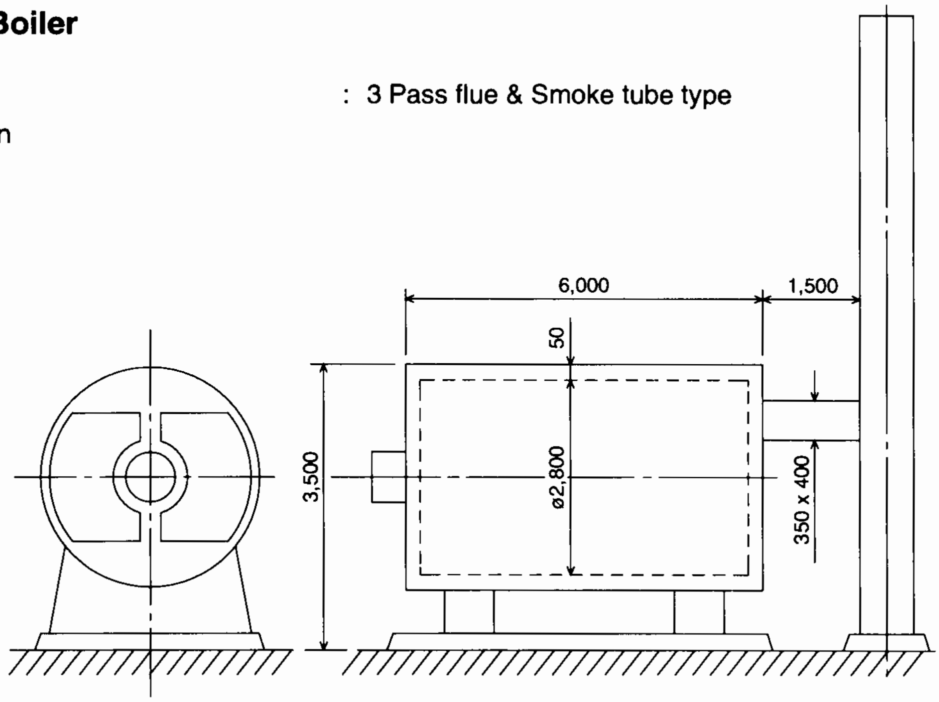
CB(M), CB(A) and CB(B) are close and CB(C) is open.

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) O_2% in exhaust gas : 8%
3) NOx% in exhaust gas : 250 ppm
4) Surface temp. of body : 150°C
5) Water quality

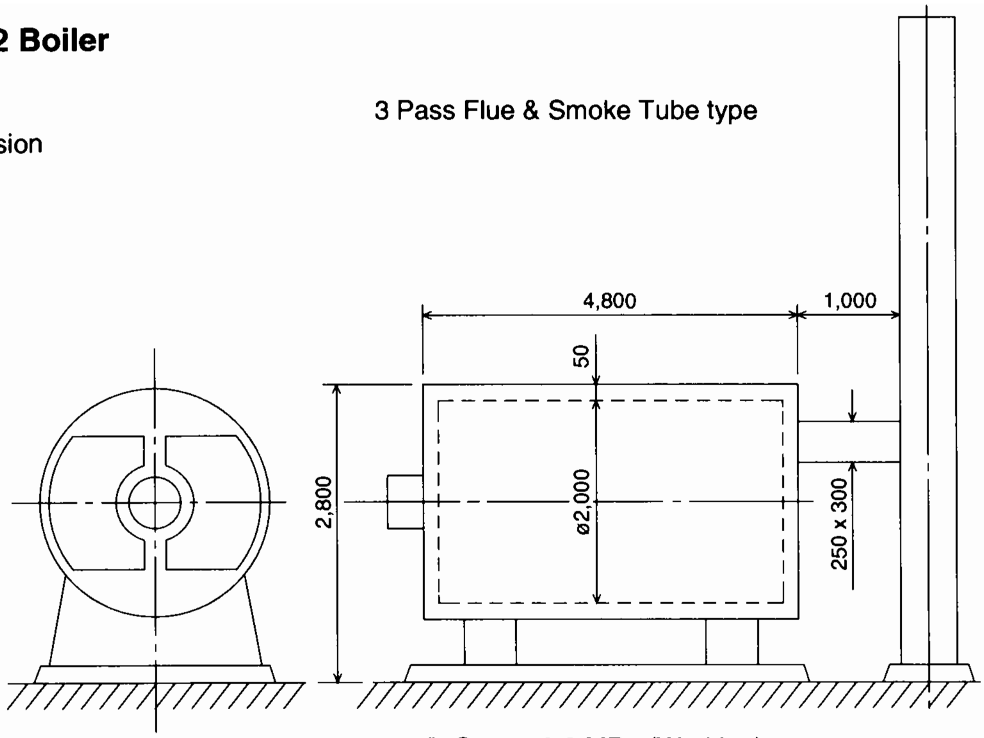
	Feed water	**Boiler water**
pH	7	9
Conductivity	200 μS/cm	2,000 μS/cm
Hardness	200 $mgCaCO_3$/l	

6) Air preheater : Nothing
7) Economizer : Nothing
8) Condensate recovery : Nothing
9) Fuel consumption : 750.5 kg/h
10) Water consumption : 10.6×10^3kg/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: 3 Pass Flue & Smoke Tube type

(2) Dimension



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

(4) Analysis Data

1) Exhaust gas Temp. : 350°C
2) O_2% in exhaust gas : 8%
3) NOx% in exhaust gas : 250 ppm
4) Surface temp. of body : 150°C
5) Water quality :

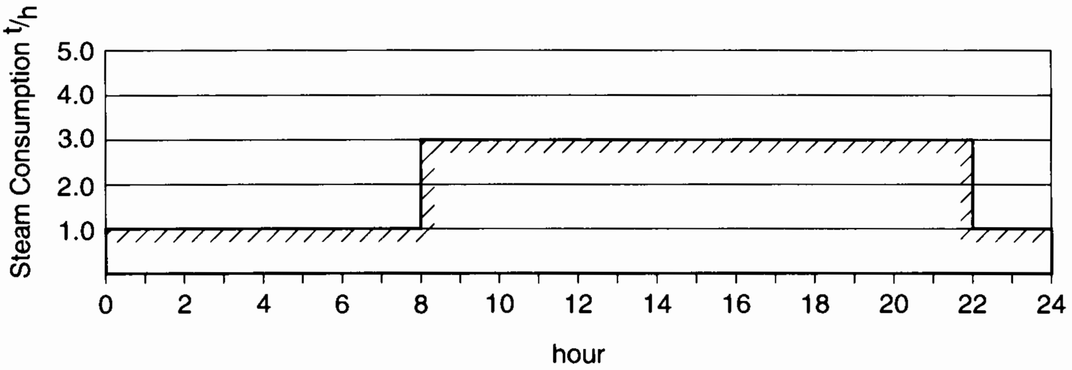
	Feed water	Boiler water
pH	7	9
Conductivity	200 μS/cm	2,000 μS/cm
Hardness	200 $mgCaCO_3/l$	

6) Air Preheater : Nothing
7) Economizer : Nothing
8) Condensate Recovery : Nothing
9) Fuel consumption : 394.7 kg/h
10) Water consumption : 5.2×10^3kg/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 Curve of Steam

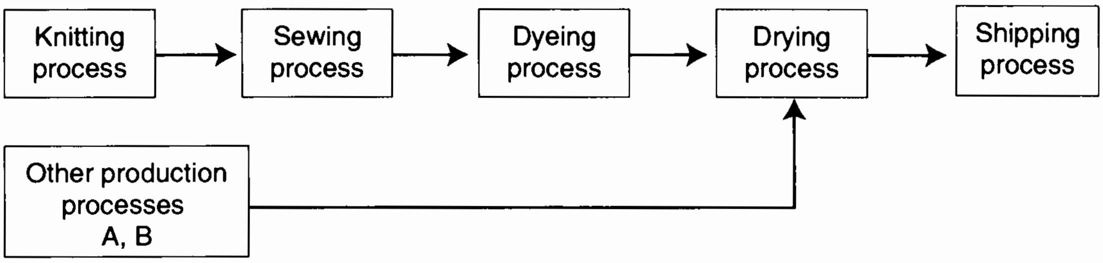
0:00–8:00 : 1t/h
22:00–24:00 : 1t/h
8:00–22:00 : 3t/h

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 and 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

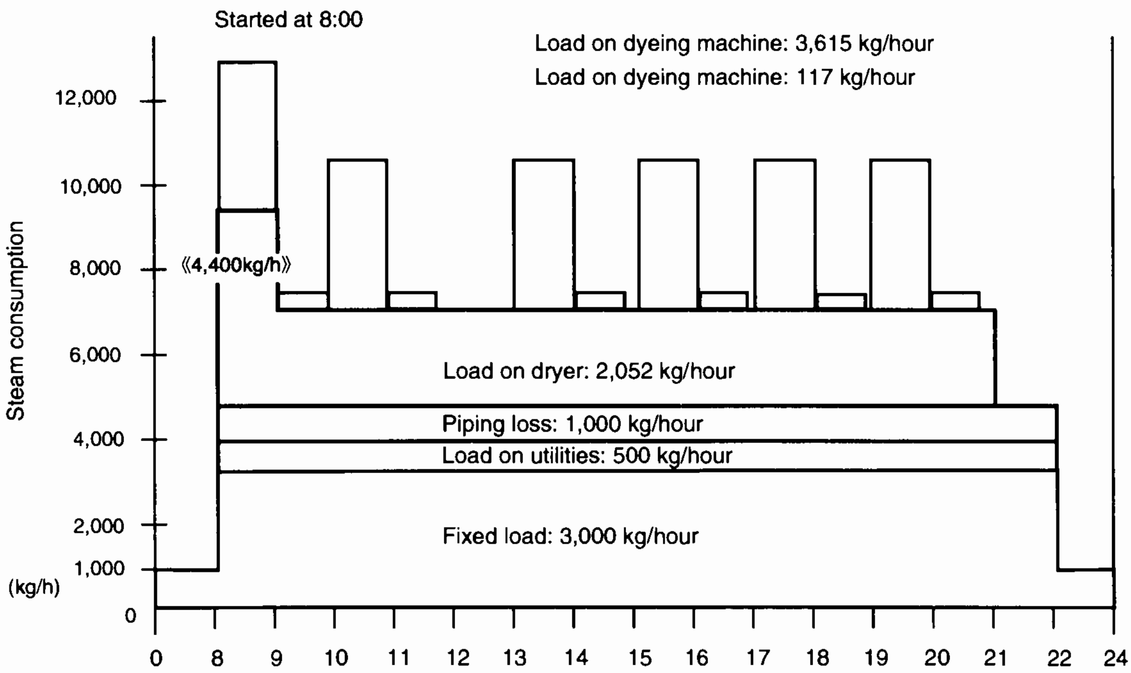
(3) Piping conditions

In the steam piping, 60% of the pipe is not properly heat-insulated. The effect of insulation is assumed to be zero for that section of the pipe. Steam is leaking from some disk type steam traps and pipe flanges.

No.	Item	Steam piping for Production A & B	Steam piping for Dyeing and drying
1	Pipe size	4" (outer dia. 114 mm)	6" (ouer dia. 165 mm)
2	Pipe length	130 m	100 m
3	Steam flow hour	24 h/d	14 h/d
4	Heat insulation	20 mm thickness of glass wool	20 mm thickness of glass wool
5	Radiation heat of insulated part	1,250 kJ/m^2h	1,250 kJ/m^2h
6	Not-insulated part	60%	60%
7	Radiation heat of not-insulated part	11,540 kJ/m^2h	11,540 kJ/m^2h
8	Steam trap with leakage	4 sets	2 sets
9	Steam leakage per trap	30 kg/h	30 kg/h
10	Pipe flang with leakage	10 sets	0
11	Hole eauivalent to leaked flange gap	1.5 mm diameter	—

(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

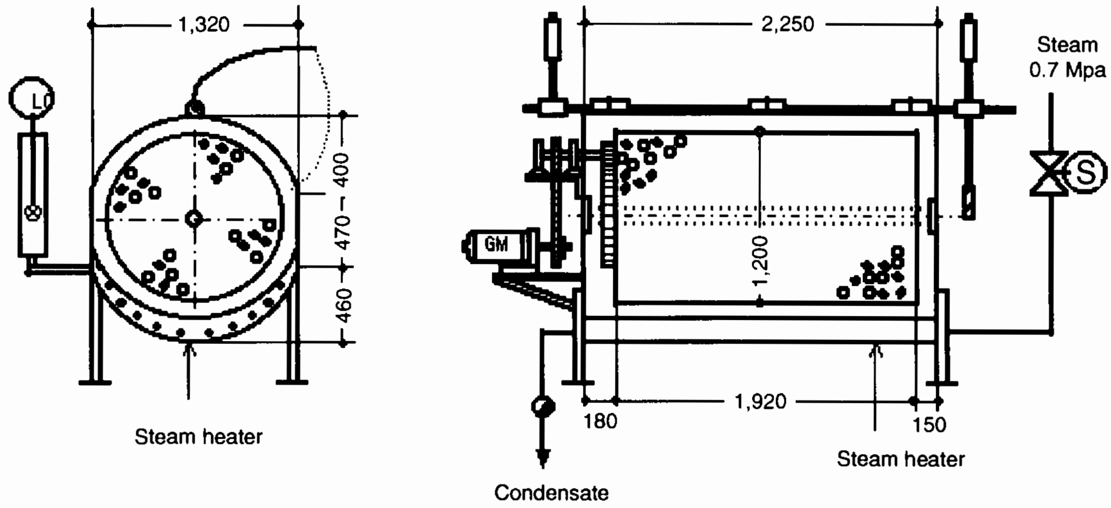
3) Steam pipe

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 m^2 (cylindrical part: 9.3 m^2, vertical part: 2.8 m^2)

(6) Heat insulation conditions : Not insulated

(7) Dyeing machine material : SUS 304 (Emissivity $\varepsilon = 0.35$)
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	γ = 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 :

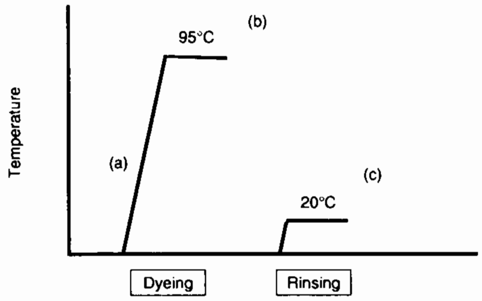
Solution temperature	95°C assumed
Solution contact surface	90
Atmosphere contact surface	90

(14) Water feeding volume : 1,300L/ cycle
Dyeing solution volume per cycle =1,300L for dyeing + 1,300L for rinsing = 2600L/cycle
2,300L × 6 cycles/day × 15 units = 207 m^3/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

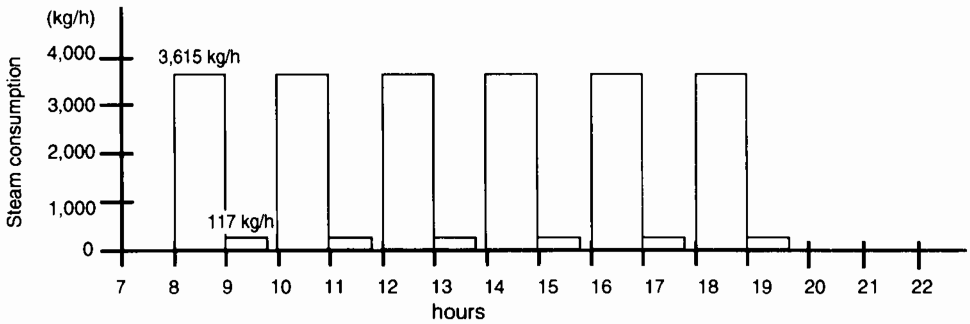
(17) Dyeing heat pattern (Only dyeing is performed in the dyeing process.)



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

	(a)	(b)	(c)
Water feeding & product charging: 10	Heating up to dyeing temperature: 60	Retention for dyeing: 40	Water feeding, rinsing, drainage: 10

(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^2h)	Hours/cycle (h)	Dissipation (kJ/cycle)
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 kJ/cycle × 6 cycles/day × 300 days = 45.9108×10^6 kJ

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

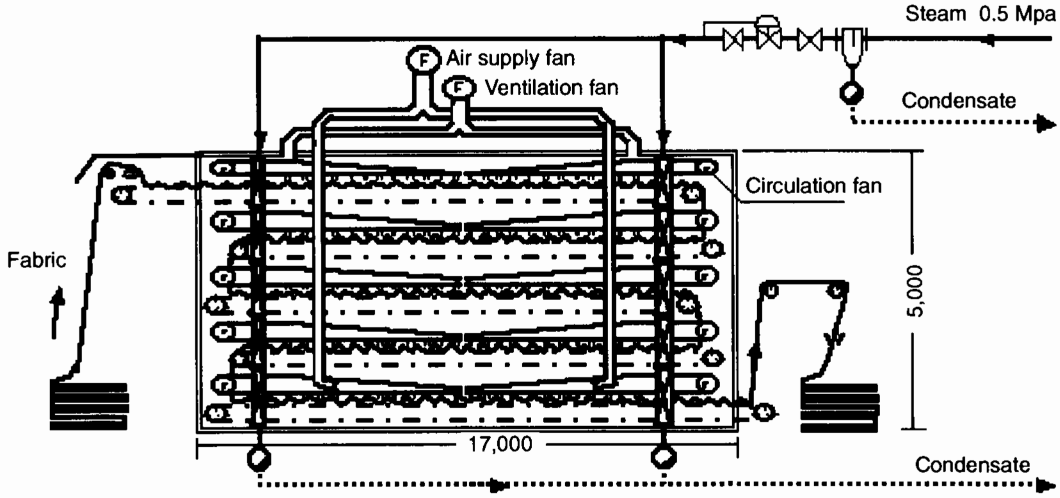
Process	Part	Surface temp. (°C)	Surface area (m^2)	Heat release (kJ/m^2h)	Hours/cycle (h)	Dissipation (kJ/cycle)
Heating	Cylindrical part	42	9.33	188	60/60	1,757
	Vertical part	42	2.74	192	60/60	527
	Total	—				2,284
Dyeing	Cylindrical part	51	9.33	410	40/60	2,553
	Vertical part	50	2.74	430	40/60	787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

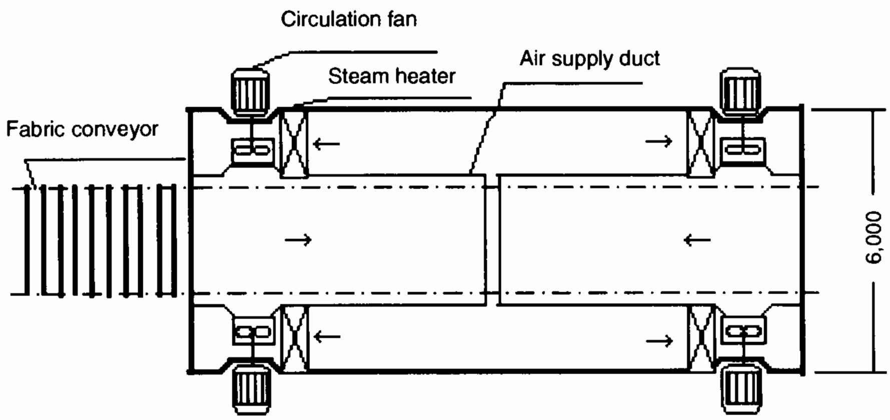
The dyeing machine is operated six cycles per day and 300 days per year. The heat loss per unit is calculated as follows:
5,624 kJ/cycle × 6 cycles/day × 300 days = 10.1232×10^6 kJ

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 m^2 (roof = 105 m^2, vertical wall = 230 m^2, bottom = 102 m^2)
(6)	Heat insulation conditions	: Glass wool 20 mm layer λ = 0.052 W/m^2k, ε = 0.23
(7)	Dry product	: Cotton 100% Specific heat C =1.30 kJ/kg·K
(8)	Heating steam	: Pressure p = 0.5 MPa

(9) Properties of steam for heating : p = 0.5 Mpa

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

(10) Production rate : Cotton fabric 570 kg/h

570 kg/h × 13 h/d = 6,840 kg/d·unit

6840 × 2 units/day = 13,680 kg/day

(11) Conditions of the drying machine

Steam consumption per product (kg)	: 1.80 kg/kg·fabric
Power consumption per product (kg)	: 0.23 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 kJ/kg
Exhaust air	: DB 70°C WB 42°C Enthalpy h = 184 kJ/kg
Exhaust air volume	: 238 Nm³/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

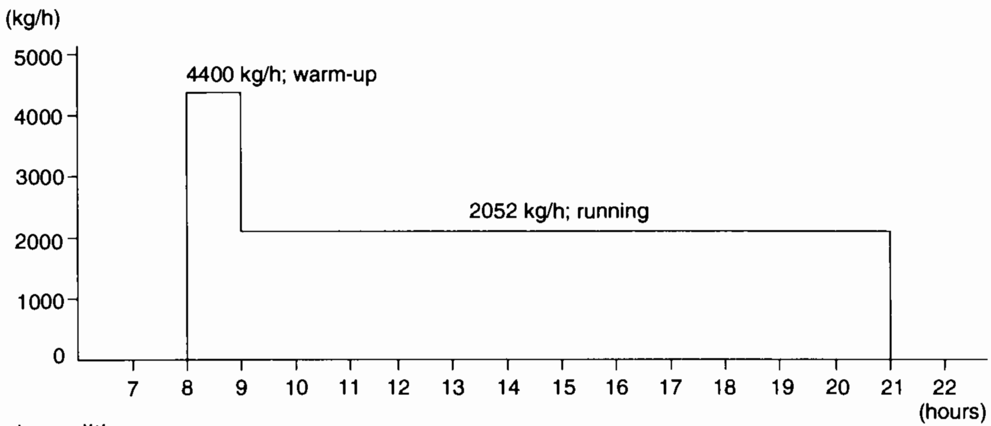
Heat-insulated surface temperature : 43°C

(13) Steam consumption : 1,026 kg/h × 2 units = 2,052 kg/h

(2,052 × 12 h) + 4,400 kg/h = 29,024 kg/day

(4,400 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.

	Psesent	Heat exchanger	Heat exchanger + VVVF control
Exhaust air DB°C	70	50	50
Exhaust air WB°C	42	40	44
Exhaust air enthalpy (h = 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 (Nm³/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 kg/kg × 570 kg/h × 2,712.2 kJ/kg	2,782,717	60.2
Heat of electricity	0.23 kWh × 570 kg/h × 3,600 kJ/kWh	471,960	10.2
Heat of supplied air	238 Nm^3/min × 1.3 kg/Nm^3 × 60 min × 68.2 kJ/kg	1,266,065	27.4
Heat of fabric	570 kg/h × 1.30 kJ/kg· K × 33°C	24,453	0.5
Heat of fabric moisture	570 kg/h × 1.019 × 4.186 kJ/kg · K × 33°C	80,235	1.7
Total		4,625,430	100.0

(Heat output)

Item	Calculation	kJ/hour	%
Heat of waste gas	238 Nm^3/min × 1.3 kg/Nm^3 × 60 min × 184.1 kJ/kg	3,417,632	73.9
Heat of fabric	570 kg/h × 1.30 kJ/kg · K × 70°C	51,870	1.1
Heat of fabric moisture	570 kg/h × 0.045 × 4.186 kJ/kg · K × 70°C	7,516	0.2
Heat of condensate	1.8 kg/kg × 570 kg/h × 666.8 kJ/kg	684,137	14.8
Heat dissipation	510 m^2 × [convective dissipation (kJ/m^2) + 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 (VVVF 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^2h)	Dissipation (kJ/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 kJ/h × 13 hours × 300 days = 5.538×10^8 kJ

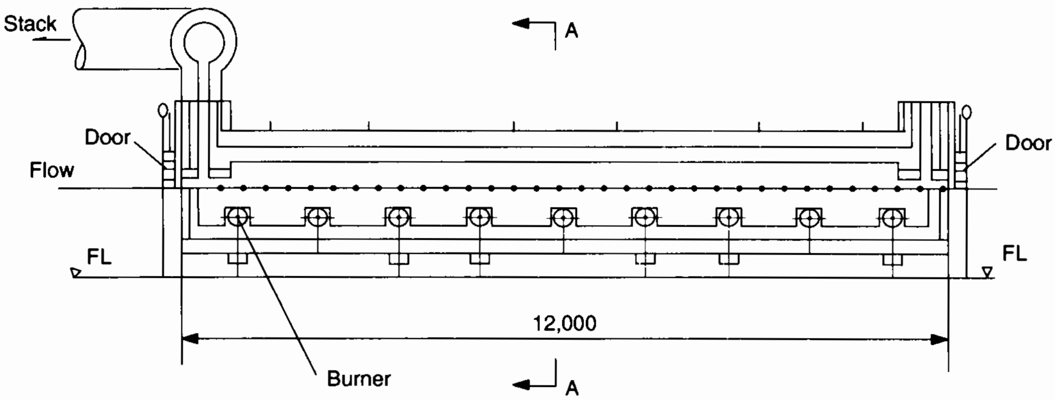
(2) Heat dissipation after improvement (glass wool 50 mm)
The insulation thickness is increased to improve the insulating performance of the dryer.
As in the existing dryer, glass wool is used as insulation material, and the insulation thickness is increased up to 50 mm which is the economically optimum 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.

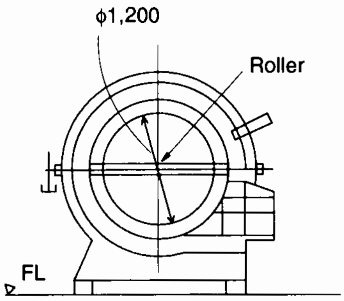
Part	Surface temp. (°C)	Surface area (m^2)	Heat release (kJ/m^2h)	Dissipation (kJ/h)
Top	40	102	159	16,218
Side	41	230	155	36,650
Bottom	42	102	150	15,300
Total/unit		—		67,168

The heat loss per unit is calculated as follows:
67,168 kJ/h × 13 hours × 300 days = 2.6195×10^8 kJ

16. Heating Furnace

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





View A–A

3) Capacity : 1000 kg/hr
4) Fuel : Fuel A oil H_L = 42,119 kJ/kg
Theoritical air quantity 11.09 Nm^3/kg
Quantity of the waste gas (air ratio = 1) 11.82 Nm^3/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 m^3/h 30°C → 40°C
furnace pressure : 49 Pa

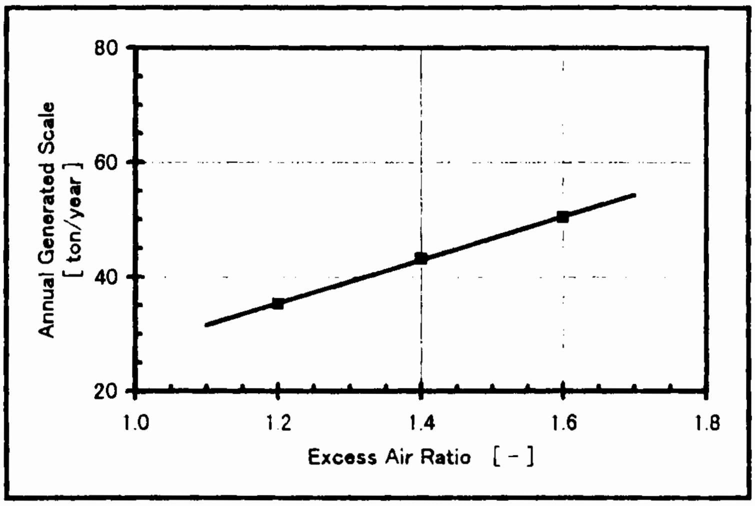
16) Generated scale : 7 kg/ton of raw material
17) Average specific heat at constant pressure
    air : 1.298 kJ/m^3NK
    waste gas : 1.381 kJ/m^3N K
    specific heat of iron : 0.699 kJ/kgK
    scale : 0.900 kJ/kg K
18) Heat of oxydizing reaction (Fe)
    : 5,588 kJ/kg
19) Total Fe in scale : 0.755
- 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

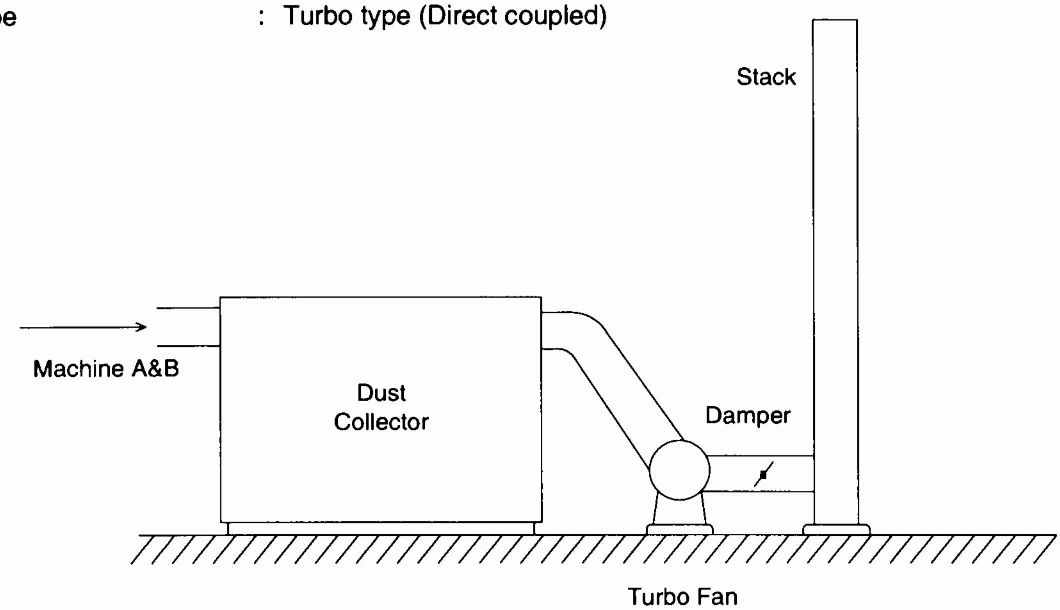
Excess Air Ratio	Generated Scale	Annual Generated Scale
-	kg/ton	ton/year
1.6	7.0	50.4
1.4	6.0	43.2
1.2	4.9	35.3

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 m^3/min – 300 m^3/min
Controlled by discharge damper (damper opening 100% at 800 m^3/min)

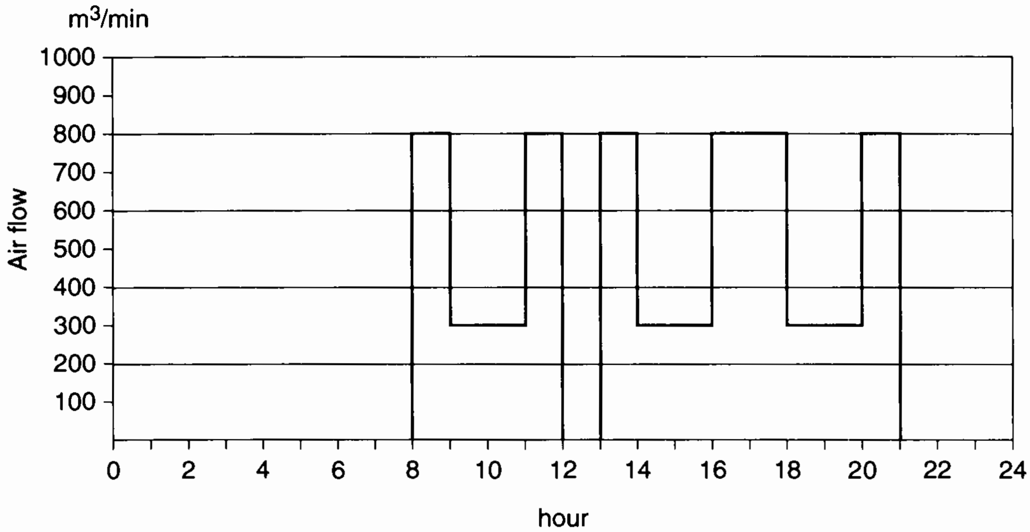
(4) Blower efficiency : 0.7

(5) Motor type : Induction motor

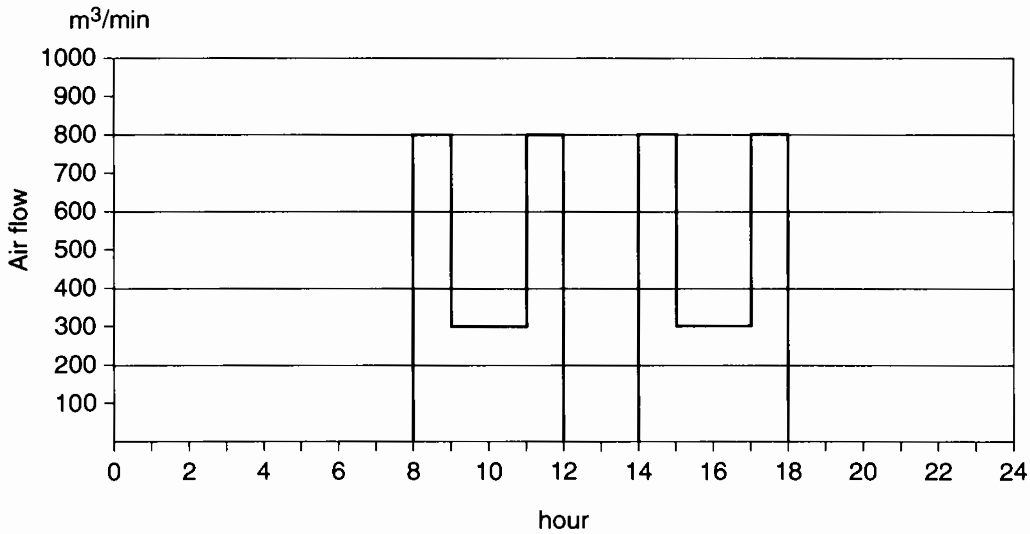
(6) Motor capacity : 75 kW × 3 unit

(7) Load curve

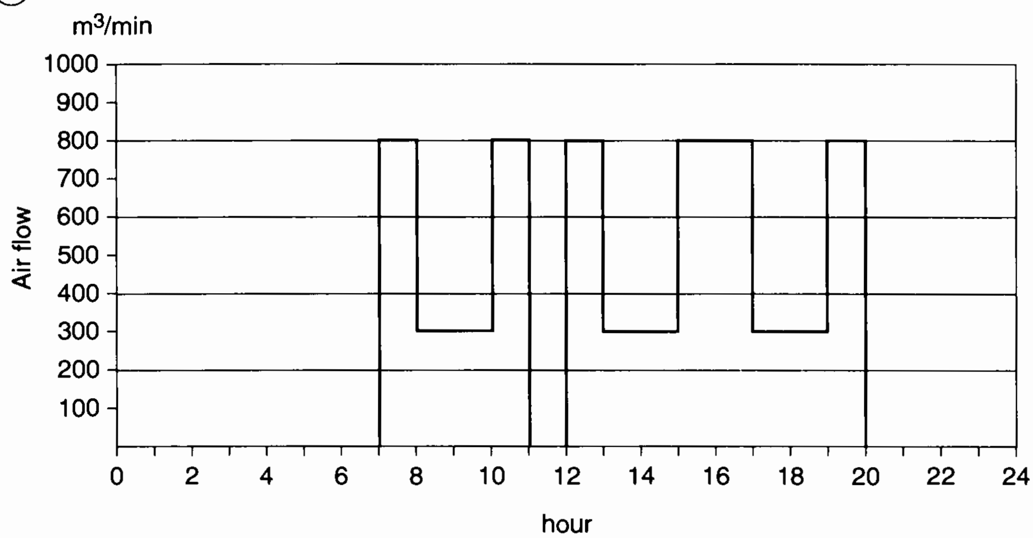
① Unit No. 1



② Unit No. 2

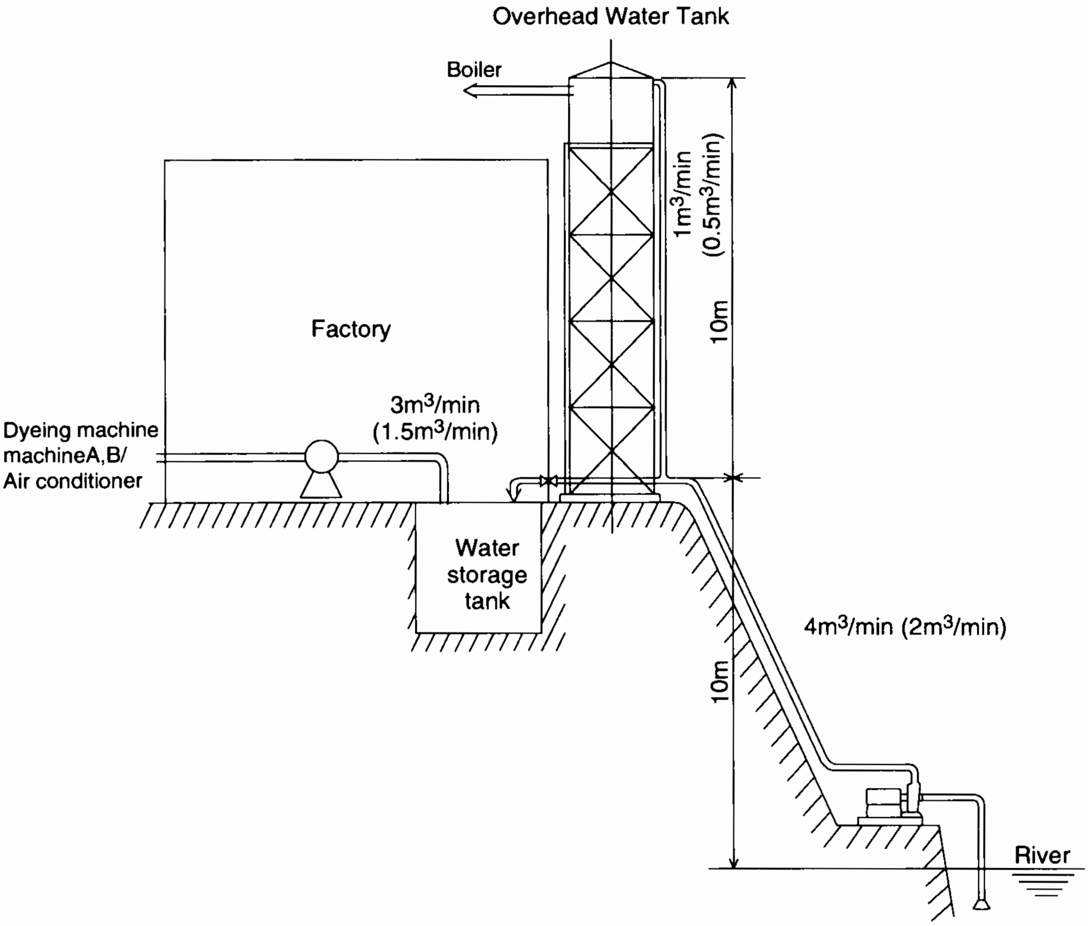


③ Unit No. 3



18. Pump

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



(2) Motor capacity : 22 kW

(3) Flow rate : 4 m^3/min × 20 mH_2O

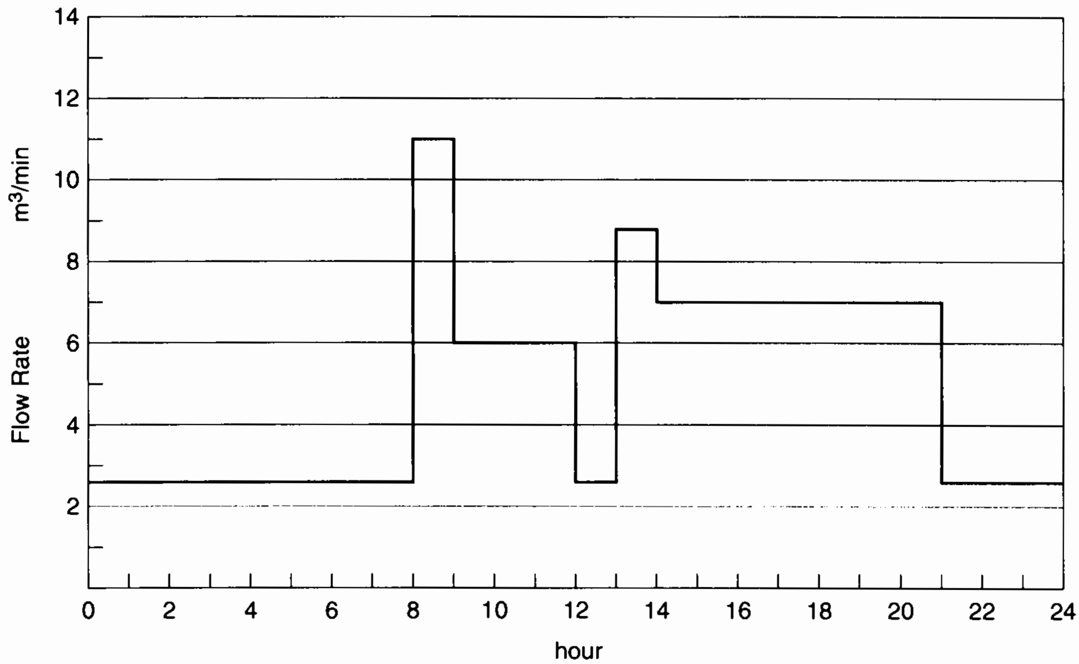
(4) Water temp. : 20°C

(5) Water consumption by working hour : 8:00–20:00 4 m^3/min
20:00–8:00 2 m^3/min Data in parentheses

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 — Δp = 0.05 ~ 0.1 MPa



Load Curve

Compressor Operation Pattern

h Load (m³/min) / No	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
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.

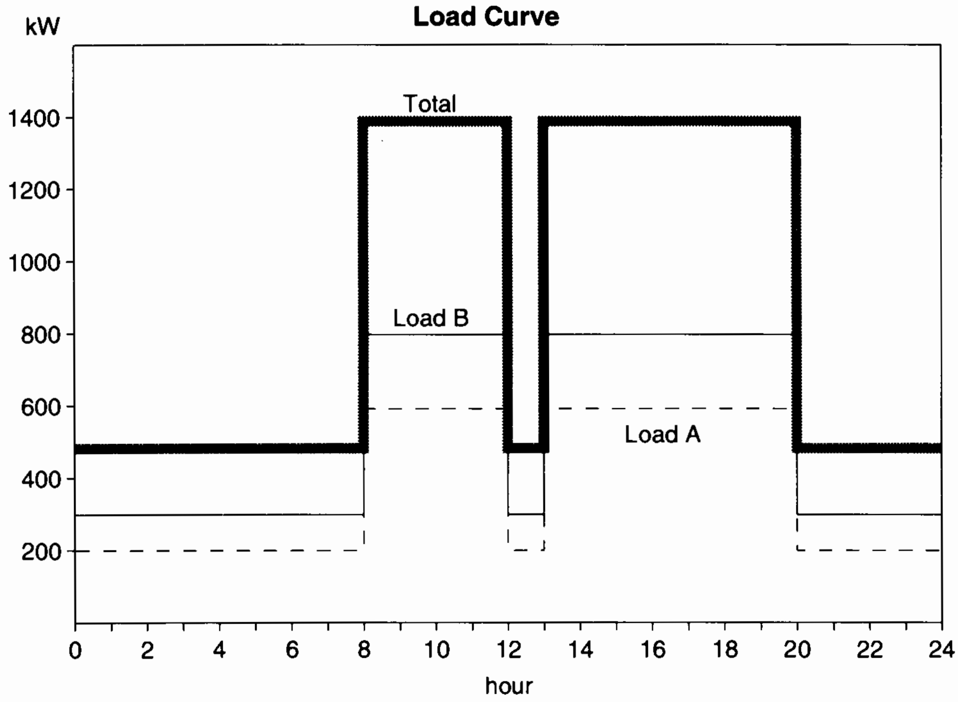
The combined daily electric energy consumption of the compressors was measured to be 1,250 kWh.

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 m³/min	11.0 m³/min	6.0 m³/min	2.5 m³/min	9.0 m³/min	7.0 m³/min	2.5 m³/min	
SCREW TYPE No.13		intermittent	Unload		intermittent	Unload		
Flow rate 4.0 m³/min Load 30 kW Unload 18 kW		3.0 m³/min 27 kW	0 m³/min 18 kW		1.0 m³/min 21 kW	0 m³/min 18 kW		
SCREW TYPE No.14		continuous	intermittent		continuous	intermittent		
Flow rate 3.2 m³/min Load 25 kW Unload 13 kW		3.2 m³/min 25 kW	1.2 m³/min 17.5 kW		3.2 m³/min 25 kW	2.2 m³/min 21.3 kW		
RECIPRO TYPE No.15	intermittent	continuous	continuous	intermittent	continuous	continuous	intermittent	
Flow rate 3.0 m³/min Load 25 kW Unload 5.0 kW	2.5 m³/min 21.7 kW	3.0 m³/min 25 kW	3.0 m³/min 25 kW	0.7 m³/min 9.7 kW	3.0 m³/min 25 kW	3.0 m³/min 25 kW	2.5 m³/min 21.7 kW	
RECIPRO TYPE No.16		continuous	continuous	continuous	continuous	continuous		
Flow rate 1.8 m³/min Load 18 kW Unload 3.6 kW		1.8 m³/min 18 kW	1.8 m³/min 18 kW	1.8 m³/min 18 kW	1.8 m³/min 18 kW	1.8 m³/min 18 kW		
Average Power	21.7 kW	95.0 kW	78.5 kW	27.7 kW	89.0 kW	82.3 kW	21.7 kW	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

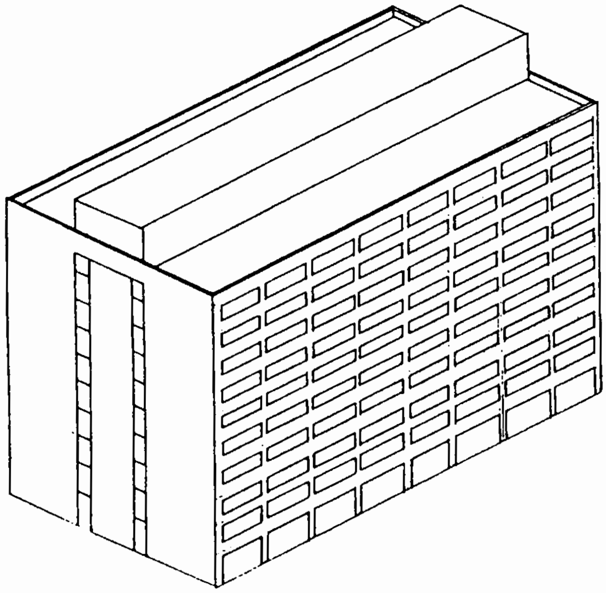
(3) Transformer Loss

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

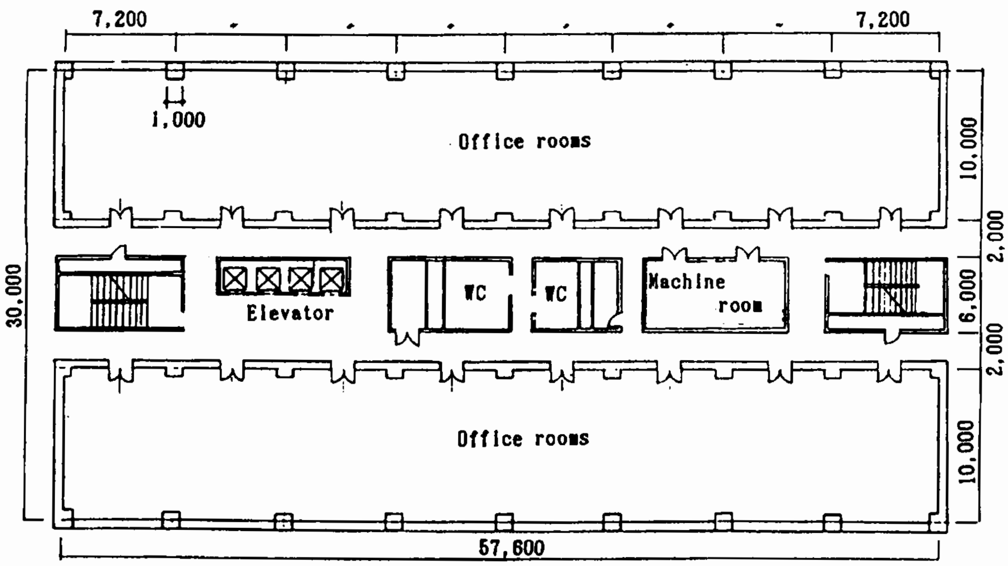
Air-conditioning

1. Outline of building

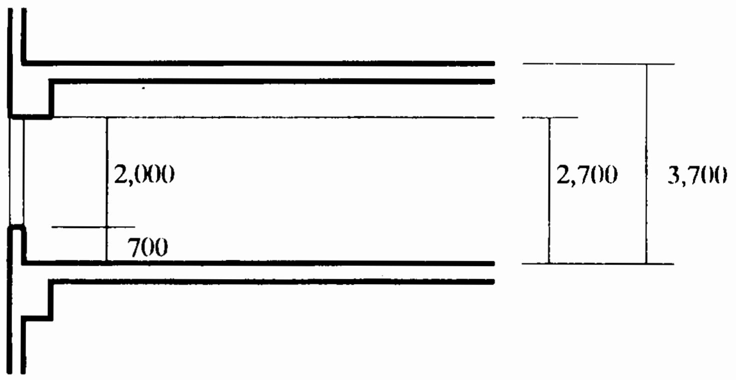
Name	:	ECCJ Office building
Location	:	Areas where only cooling is required throughout the year
Total number of stories	:	10 above ground (No underground floors)
Structure	:	Steel structure
External appearance	:	As shown below
Working hours	:	8:00–18:00



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 [W/m²K]
Roof	: Heat transmission coefficient	K = 0.83 W/m²K]
Window glass	: Heat transmission coefficient	K = 6.29 [W/m²K] (with the blind open) K = 4.95 [W/m²K] (with the blind closed)
	: Shading coefficient	SC = 0.96 [ND] (with the blind open) SC = 0.53 [ND] (with the blind closed)

3. Air-conditioning load calculation conditions

Room temperature & humidity	: 24°C (DB) 50% (RH)	
Air-conditioning hours	: 8:00–18:00	
Lighting hours	: 8:00–18:00	
Room occupants	: 0.1 [person/m²]	(per air-conditioned area)
Heat generation from human body	: 62.8 [W/m²] 55.8 [W/m²]	(sensible heat) (latent heat)
Lighting	: 20 [W/m²] • 40 W × 3 flueorescent lamps/unit • 127.5 W/unit • 1,800 units/building	(per air-conditioned area) (energy consumption)
Heat generation from office equipments	: 10 [W/m²]	(per air-conditioned area) (sensible heat only)
Fresh air intake	: 30 [m³/h/person]	(minimum 20 [m³/h/person] by building code)
Air infiltration	: 0.2 [times/h]	

4. Assumption for annual cooling load calculation

Annual cooling load [kWh/Y] = Peak cooling load [kWh/h] × 1000 [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)

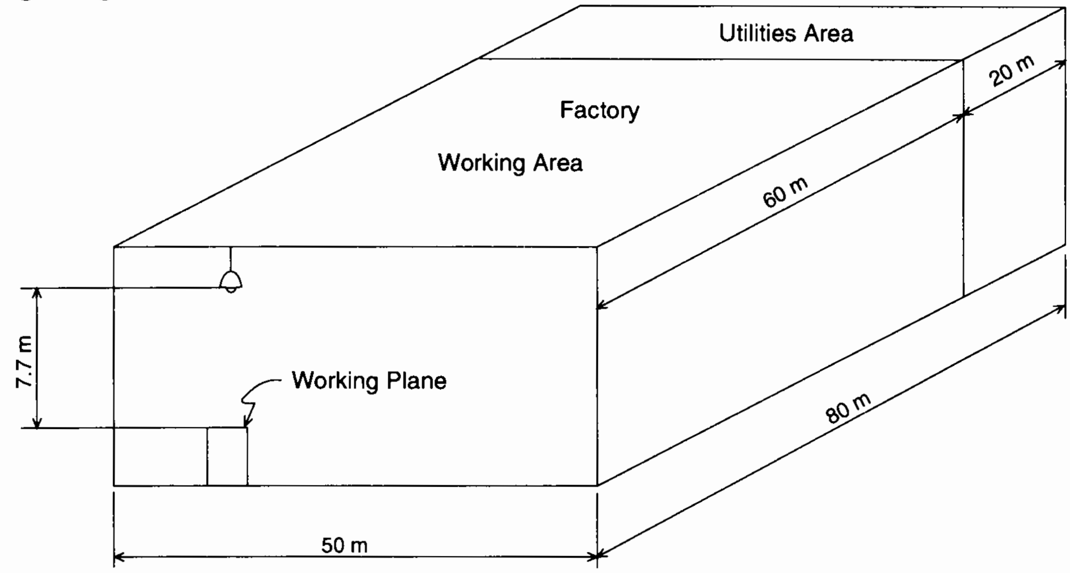
Time (O'clock)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
θo		2	1	1	1	1	1	2	3	5	6	7	7	7	7	7	6	6	5	4	3	3	2	2	2
θe	Roof	3	2	2	2	1	2	4	9	14	19	25	29	32	33	32	30	26	21	16	11	8	6	4	3
	N	3	2	2	2	1	2	3	4	5	5	6	7	8	8	8	9	9	9	9	7	6	4	4	3
	E	2	2	2	2	1	3	9	14	18	19	19	16	14	12	11	10	9	8	7	6	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 θr is not equal to 26℃, add $(26-\theta r)$ to each value in the Table.

Solar heat gain with standard glass : Sn [W/m^2]

Time (O'clock)		5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sn	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 m × 50 m = 4,000 m^2
(2) Height of light source from working plane : 7.7 m
(3) Lamp : Fluorescent mercury lamp 400 W (60 *l*m/W) × 150
(4) Illumination standard : 500 lx (at Working area)   300 lx (at Utilities area)
(5) Reflecitivity : Floor 10%
Ceiling 30%
Wall 20%

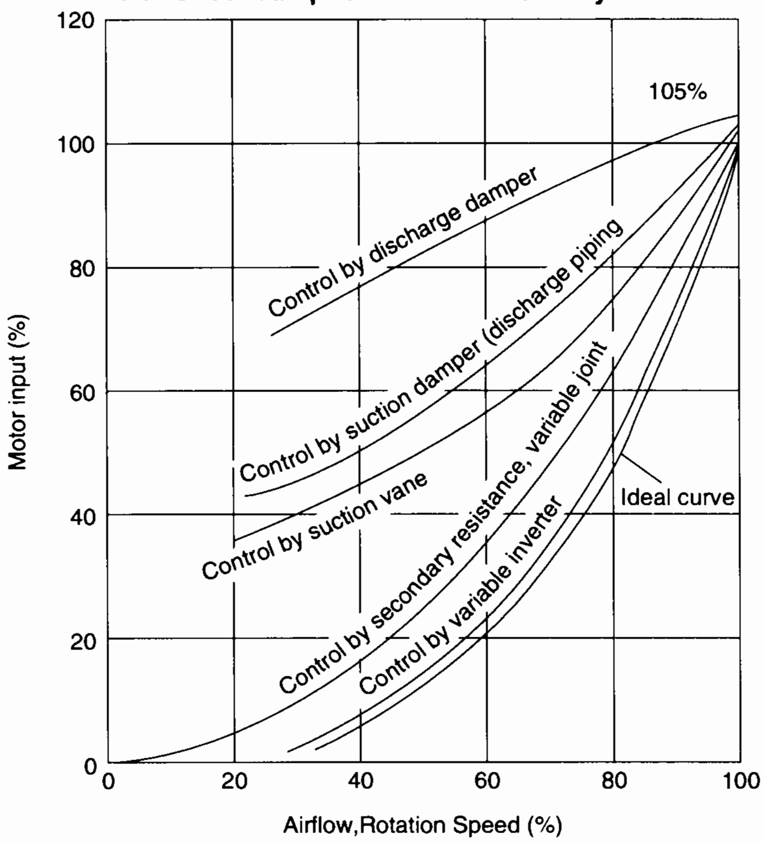
(6) Utilization factor

Reflectivity from floor %		10							
Reflectivity from ceiling %		70		50			30		
Reflectivity from wall %		40	20	60	40	20	60	40	20
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
(8) Room index = RI = Width × Length / (Height × (Width + Length))

22. Reference

Power consumption curve of motor by Airflow



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

23. 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 (2) Storage tank unit (3) Water pump unit (VVVF control)	 40 mm × 90 m @80 pipes/90 m 20 m^3 tank Pump with VVVF	 7,200 5,000 7,000
		2. Drainage waste-heat recovery system (1) Heat exchanger (2) Piping including installation (3) Water tank including installation	 Plate-type heat exchanger Piping complete with circulating pump 60 m^3, double-chamber type	 40,000 10,000 24,000
		3. Heat insulation work Polyethylene heat insulator	Thickness: 15 mm λ=0.041 W/mk ε=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	3,000 $/set
		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/160 m @$75/m	 20,000 5,000 12,000
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 plywood ring 25 mm 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^3N/h Maximum air volume 1,000 m^3N/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^3N/h Maximum air volume 450 m^3N/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	Lithting 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
13	Steam piping	Disk type steam trap		1/2"	160
		Free float type steam trap		1/2"	170

Appendix 1

Heat insulation (glasswool rockwool and calcium silicate) installation cost for various pipe diameter per unit volume (m^3) in US$

Insulation thickness ~~(mm)~~	Diameter of pipe				
	1/2 to 3/4"	1 to 2"	2-1/2 to 6"	8 to 12"	14" to 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	2614	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.
Insulation cost = $1.2 * (12000 * X^{-K}+100) * 10\$/m^3$
where X = thickness of insulation material in mm
K = constant and selected from following

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

Appendix 2

Heat insulation installation cost for veneering ceramic fiber per unit area (m^2) in US$

Veneering thickness (mm)	Installation cost
25	350
50	500
75	700

(US$/$m^2$)

24. 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 9.80665Å~10^4 9.80665	1.019716Å~10^{-5} 1 10^{-4}		
Energy Work Heat Enthalpy	kJ	kW · h	kcal	
	1 3600 4.1868	1/3600 1 1.163Å~10^{-3}	0.2388459 859.8452 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 · 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 4.1868	0.2388459 1		
Specific heat Specific entropy (Mass entropy)	kJ/(kg · K)	kcal/(kgf · °C)		
	1 4.1868	0.2388459 1		