THE STUDY (AFTER-CARE)
ON THE ENERGY CONSERVATION PROJECT
IN THE KINGDOM OF THAILAND

TEXTBOOK FOR THE ENERGY AUDIT TECHNIQUES WORKSHOP

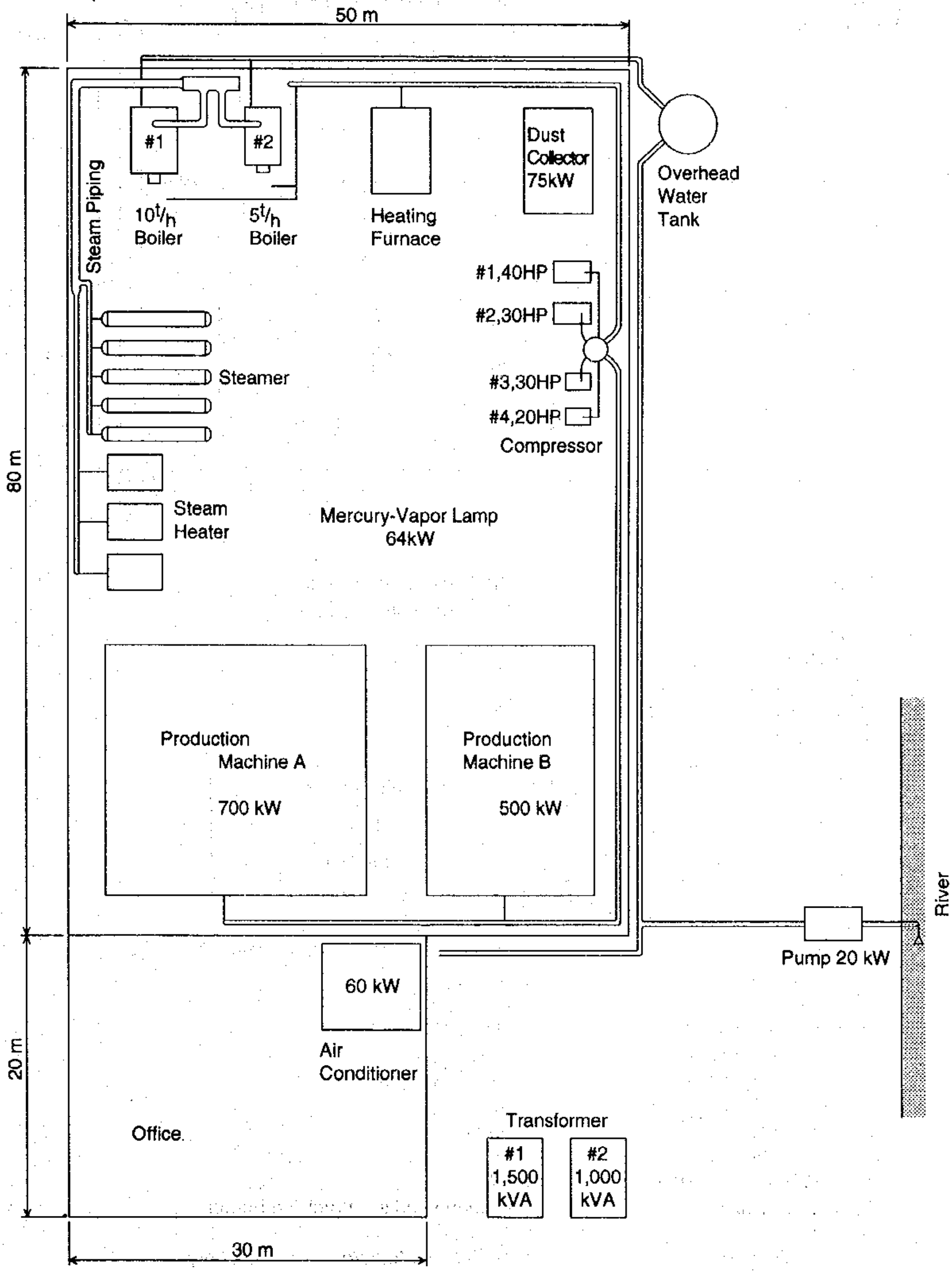
1. Model Factory

March 1994

Japan International Cooperation Agency (JICA)

The Energy Conservation Center, Japan (ECCJ)

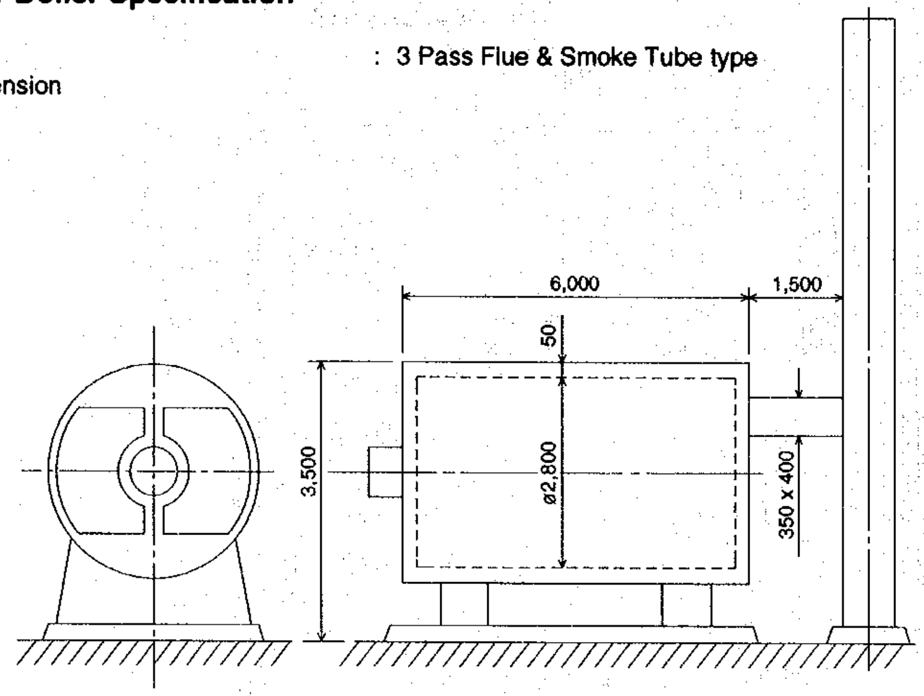
Factory Layout



1. No. 1 Boiler Specification

(1) Type : 3 Pass Flue & Smoke Tube type

(2) Dimension



(3) Capacity : 10t/h 8kg/cm^{2}G (Working)
10kg/cm^{2}G (Design)

(4) Analysis Data

1) Exhaust gas Temp. : 300°C
2) O_2% in exhaust gas : 8%
3) Surface temp. of body : 150°C
4) Water quality :

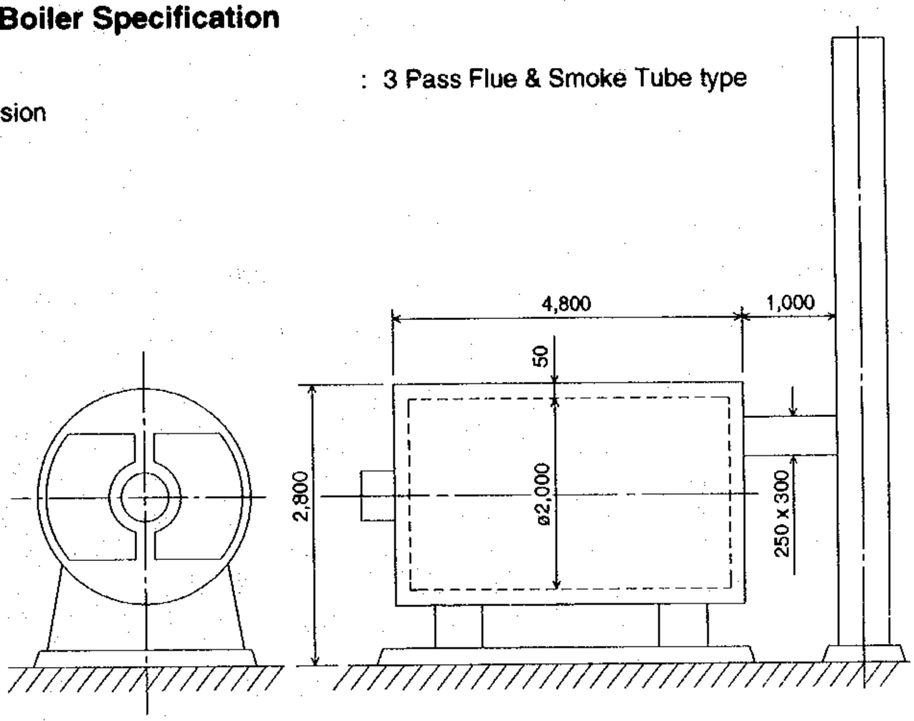
	Feed water	Boiler water
pH	7	10
Conductivity	200μS/cm	6,000μS/cm
Hardness	200mgCaCO$_3$/l	

5) Fuel : Heavy A Oil Hl = 9,700 kcal/kg S = 0.5wt%
6) Air preheater : Nothing
7) Economizer : Nothing
8) Condensate recovery : Nothing
9) Fuel consumption : 811.7 kg/h
10) Water consumption : 11.1 × 10^{3}kg/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 : 10%
17) Operation hour : 10h/day × 25day/m × 12 = 3,000h/y
18) Scale thickness on boiler tube : 1mm
19) Dryness of steam : 98%

2. No. 2 Boiler Specification

(1) Type : 3 Pass Flue & Smoke Tube type

(2) Dimension



(3) Capacity : 5t/h 8kg/cm^{2}G (Working)
10kg/cm^{2}G (Design)

(4) Analysis Data

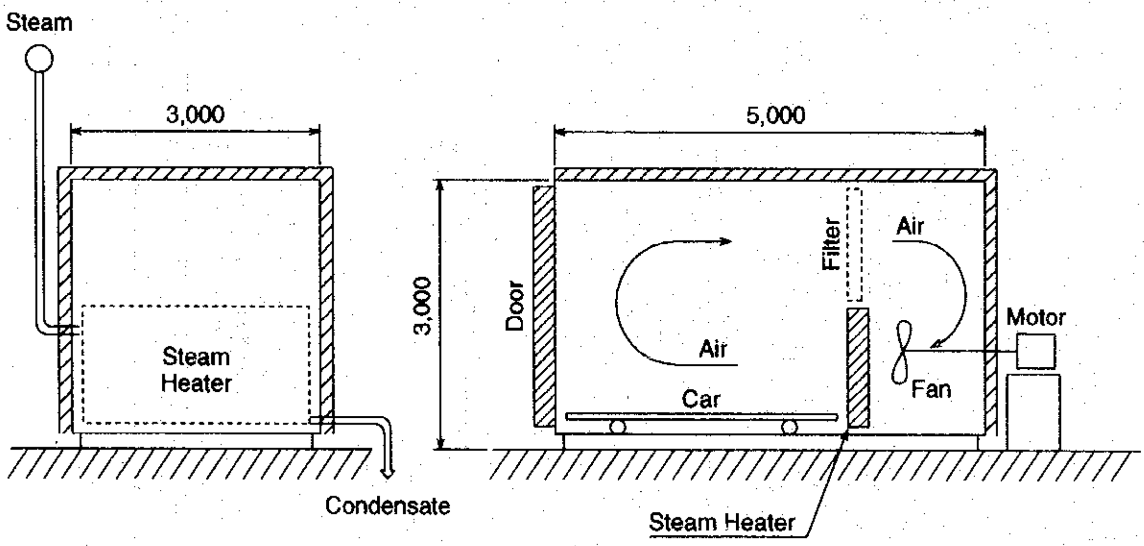
1) Exhaust gas Temp. : 300°C
2) O_2% in exhaust gas : 8%
3) Surface temp. of body : 150°C
4) Water quality :

	Feed water	Boiler water
pH	7	10
Conductivity	200µS/cm	6,000µS/cm
Hardness	200mg$CaCO_3$/l	

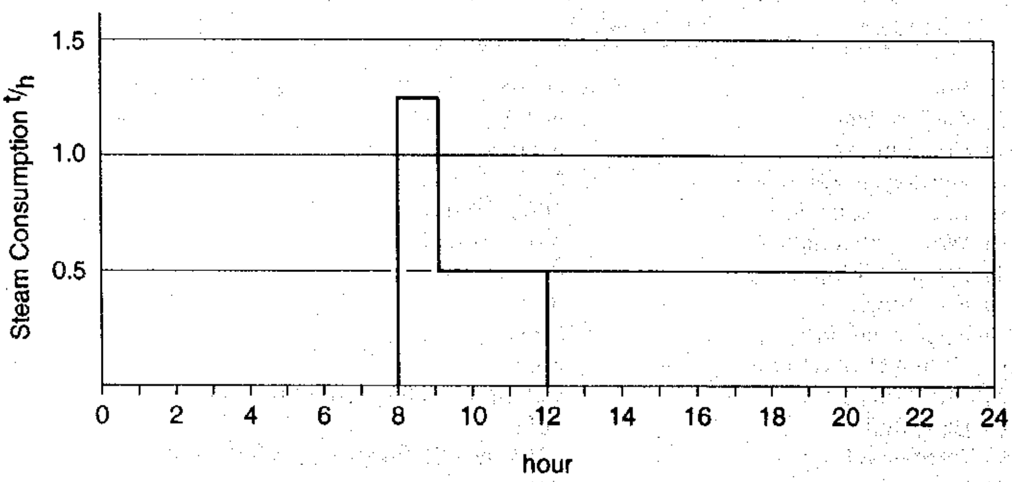
5) Fuel : Heavy A Oil Hl= 9,700 kcal/kg S = 0.5wt%
6) Air Preheater : Nothing
7) Economizer : Nothing
8) Condensate Recovery : Nothing
9) Fuel consumption : 406.2 kg/h
10) Water consumption : 5.6 × 10^{3}kg/h
11) Ambient temp. : 33°C
12) Fuel temp. : 33°C
13) Feed water temp. : 20°C
14) Combustion air temp. : 33°C
15) Burner type : Compressed air atomizing burner
16) Blow rate : 10%
17) Operation hour : 10h/day × 25day/m × 12 = 3,000h/y
18) Scale thickness on boiler tube : 1mm
19) Dryness of steam : 98%

3. Steam Heater

(1) Type : Hot air circulation
(2) Dimension



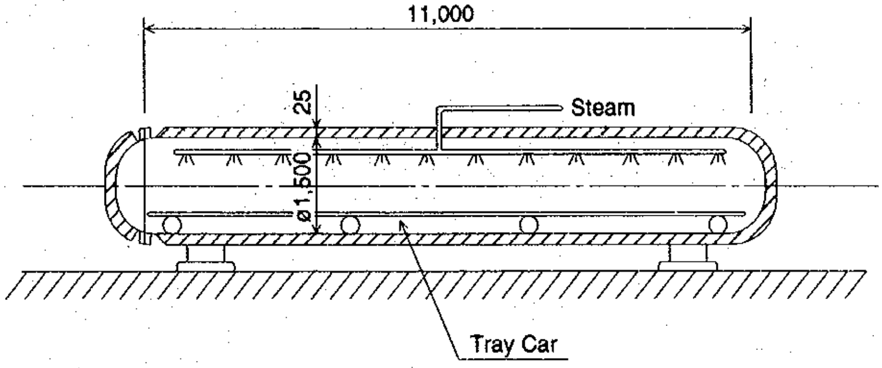
(3) Steam consumption : 0.5t/h × 3units (Peak consumption 1.3t/h/unit at start up)
(4) Heating material temp. (rubber) : 33°C →130°C
Weight 2.5t
Specific heat 0.5
(5) Car (steel) : Weight 4t
Specific heat 0.1
(6) Ambient temp. : 33°C
(7) Steam Pres. : 6.0 kg/cm^{2}G
(8) Insulation : 15 mm Glasswool
(9) Recirculated air temp. : 145°C ± 5°C
(10) Heating hour : 4 hours
(11) Load curve



4. Steamer

(1) Type : Direct steam heating

(2) Dimension



(3) Steam consumption : 1.4t/h per 5units (Peak consumption 4.3t/h per 5unit)

(4) Heating Material temp. (rubber) : 33°C →150°C
Weight 2.5t
Specific heat 0.5

(5) Car (steel) : Weight 2t
Specific heat 0.1

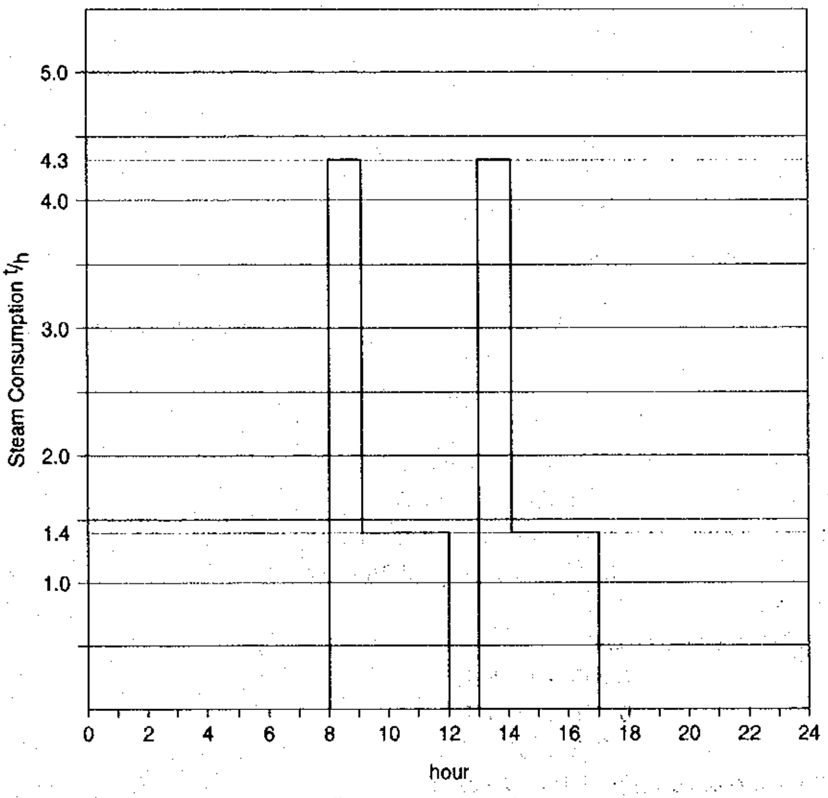
(6) Ambient air temp. : 33°C

(7) Supplying steam pressure : 5.5kg/cm^{2}G

(8) Insulation : 25mm Glasswool

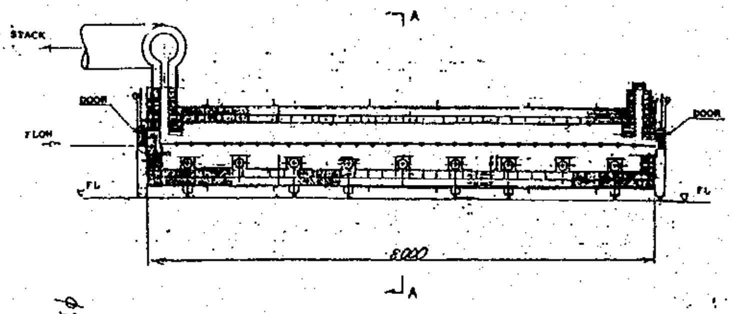
(9) Heating hour : 4hour

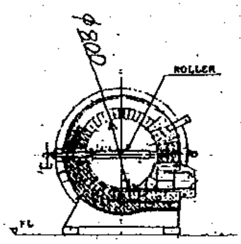
(10) Load curve



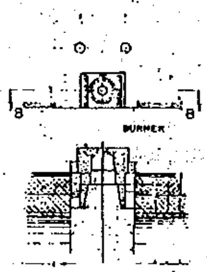
5. Heating Furnace

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





VIEW A-A



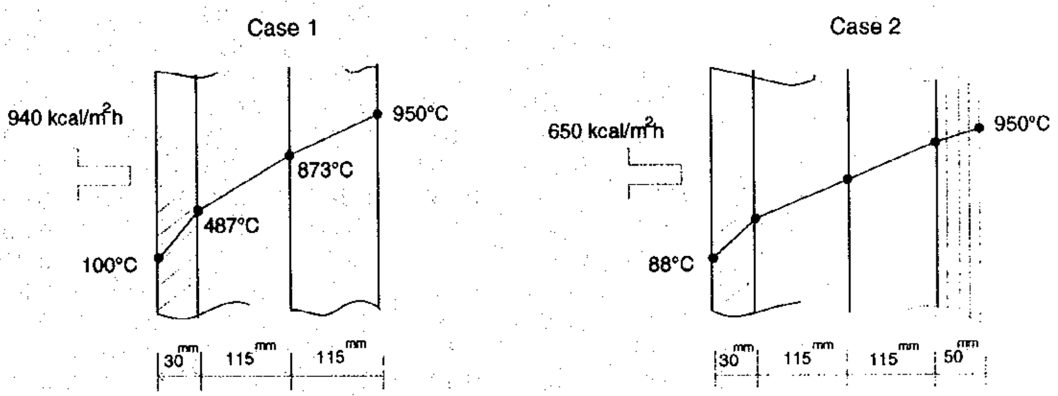
VIEW B-B

3) Capacity : 400kg/hr
4) Fuel : heavy A oil H_{ℓ}=9,700 kcal/kg
theoritical air quantity 10.65m^{3N}/kg
quantity of the waste gas (air fuel ratio=1) 11.37m^{3N}/kg
5) Fuel consumption : 28.8kg/h
6) Combustion air temp. : 33°C
7) Fuel temp. : 33°C
8) Air fuel ratio : 1.6
9) Waste gas temp. : 1000°C
10) Furnace temp. : 950°C
11) Material temp. : 33°C → 950°C
12) Surface temp. of body : 100°C
13) Furnace wall structure
fire brick : SK 33-----115mm refer to the hint attached
insulating brick : B6 ---------115mm
silica boad--------------------------------30mm
14) Other heat loss
through roller : 200kcal/hr × 30 sets
cooling water : 1m^3/hr 30°C → 40°C
waste gas blow out : furnace pressure 5mmH_2O
opening 800mm × 200mm × 2
15) Generated scale : 7kg/t
16) Average isopiestic spesific heat
air : 0.31kcal/m^3N°C
waste gas : 0.33kcal/m^3N°C
scale : 0.215kcal/kg°C
17) Heat of oxidizing reaction (Fe): 1,335kcal/kg

— **HINT** —

Effect of veneering

<Example>



	Case 1	Case 2
Ceramic fiber	—	0.15
Fire brick SK33	1.4	1.4
I brick B6	0.28	0.25
Silica board	0.072	0.066

- Air fuel ratio could be reduced to 1.2
- Damper control will make furnace pressure from 5 mm H_2O to 2 mm H_2O.
- Scale less at air fuel ratio 1.2 would be 70% of air fuel ratio 1.6
- Quantity of blow out is

$$13{,}990\sqrt{\frac{273}{273+t_g}} \times \sqrt{P\,mmH_2O} \times C_p$$

where t_g = waste gas temperature (°C)
p = furnace press (mm H_2O)
C_p = Specific heat (kcal/m^3N°C)

Table Average specific heat at constant pressure of gas

Temperature (°C)	H_2	N_2	O_2	CO	H_2O	CO_2	SO_2	Air
0	0.305	0.311	0.312	0.311	0.341	0.387	0.424	0.310
100	0.307	0.311	0.315	0.312	0.344	0.412	0.445	0.311
200	0.309	0.312	0.320	0.313	0.348	0.432	0.464	0.312
300	0.309	0.313	0.325	0.315	0.352	0.450	0.481	0.315
400	0.310	0.316	0.330	0.318	0.357	0.466	0.494	0.318
500	0.311	0.319	0.334	0.321	0.363	0.480	0.507	0.321
600	0.312	0.321	0.339	0.325	0.369	0.493	0.518	0.324
700	0.313	0.325	0.343	0.329	0.375	0.504	0.527	0.328
800	0.314	0.329	0.347	0.332	0.381	0.515	0.535	0.331
900	0.316	0.331	0.351	0.335	0.387	0.523	0.542	0.334
1,000	0.317	0.334	0.351	0.338	0.393	0.532	0.548	0.338
1,100	0.319	0.338	0.356	0.341	0.400	0.540	0.554	0.340
1,200	0.321	0.340	0.359	0.344	0.406	0.547	0.559	0.343
1,300	0.323	0.342	0.362	0.346	0.411	0.553	0.563	0.345
1,400	0.325	0.345	0.361	0.348	0.418	0.559	0.567	0.348
1,500	0.326	0.347	0.366	0.351	0.423	0.565	0.570	0.350
1,600	0.328	0.350	0.368	0.353	0.428	0.570	0.573	0.353
1,700	0.330	0.351	0.370	0.355	0.433	0.575	0.576	0.354
1,800	0.332	0.353	0.372	0.357	0.439	0.579	0.579	0.356
1,900	0.334	0.354	0.374	0.358	0.443	0.583	0.581	0.358
2,000	0.336	0.356	0.376	0.360	0.448	0.587	0.583	0.359

Furnace price

1.	Casing, door, flue, stack, deck, etc.	4,500,000
2.	Combustion equipment	3,500,000
3.	Roller & driving system	10,000,000
4.	Refractory	7,500,000
5.	Instrumentation	10,000,000
6.	Erection	12,000,000
	Total	¥47,500,000

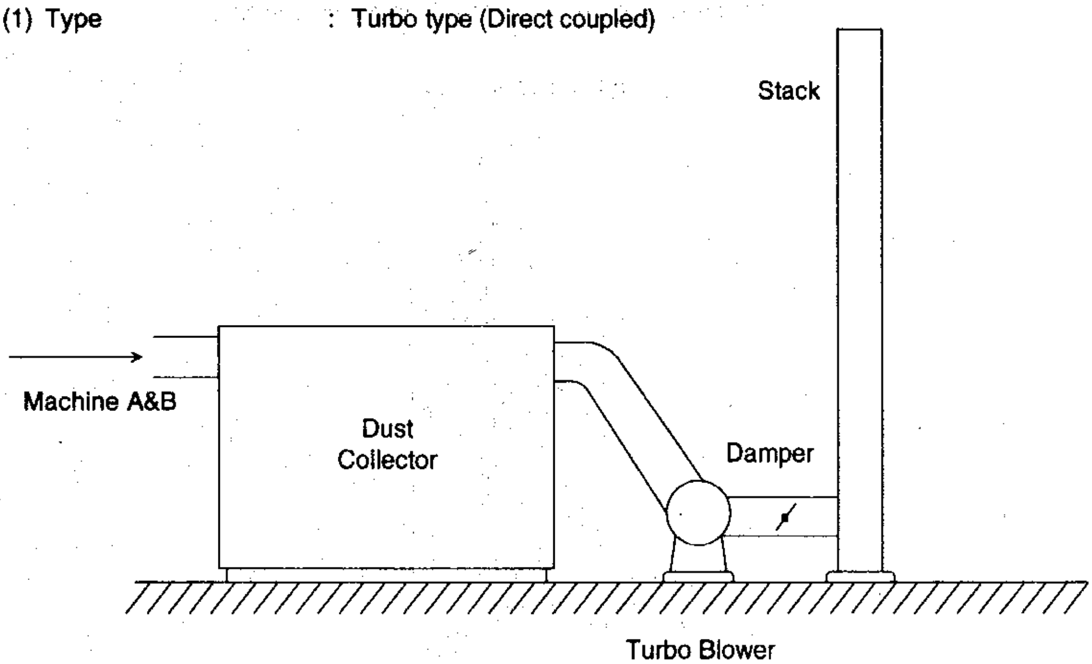
Capital cost for energy conservation

1.	Requperator (including dilution fan)	3,000,000
2.	Damper control	2,000,000
3.	Burner system for hot air	2,000,000
4.	Veneering	2,000,000
5.	Insulation for hot air duct	800,000
6.	Man cost 10 men • 10 days	4,000,000
	Total	¥12,000,000

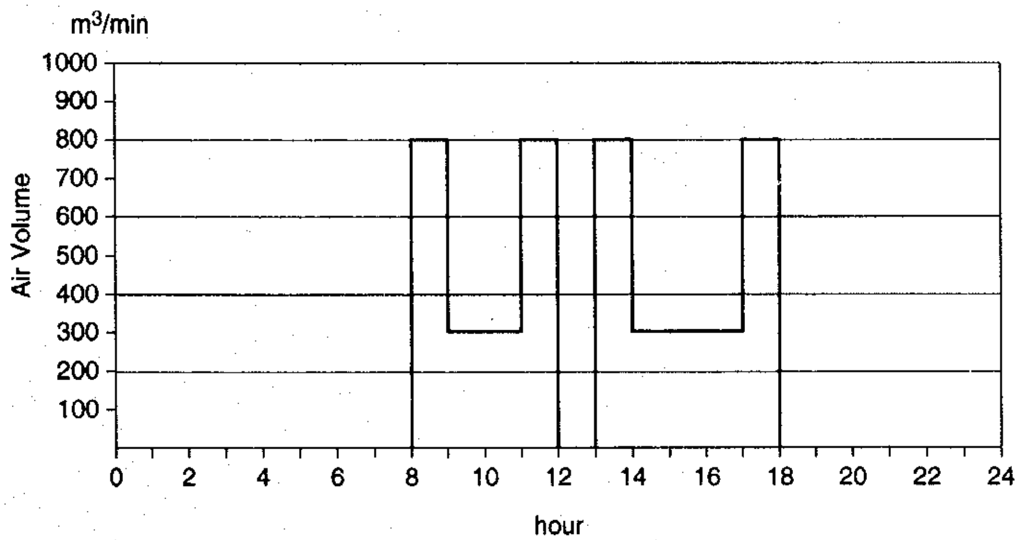
Payback
(33.3 – 18.0) × 7,010 h/year = 107.253 h/year
12,000,000/107.253 × ¥40.7 = 2.74 years

6. Blower for Dust Collector

(1) Type : Turbo type (Direct coupled)

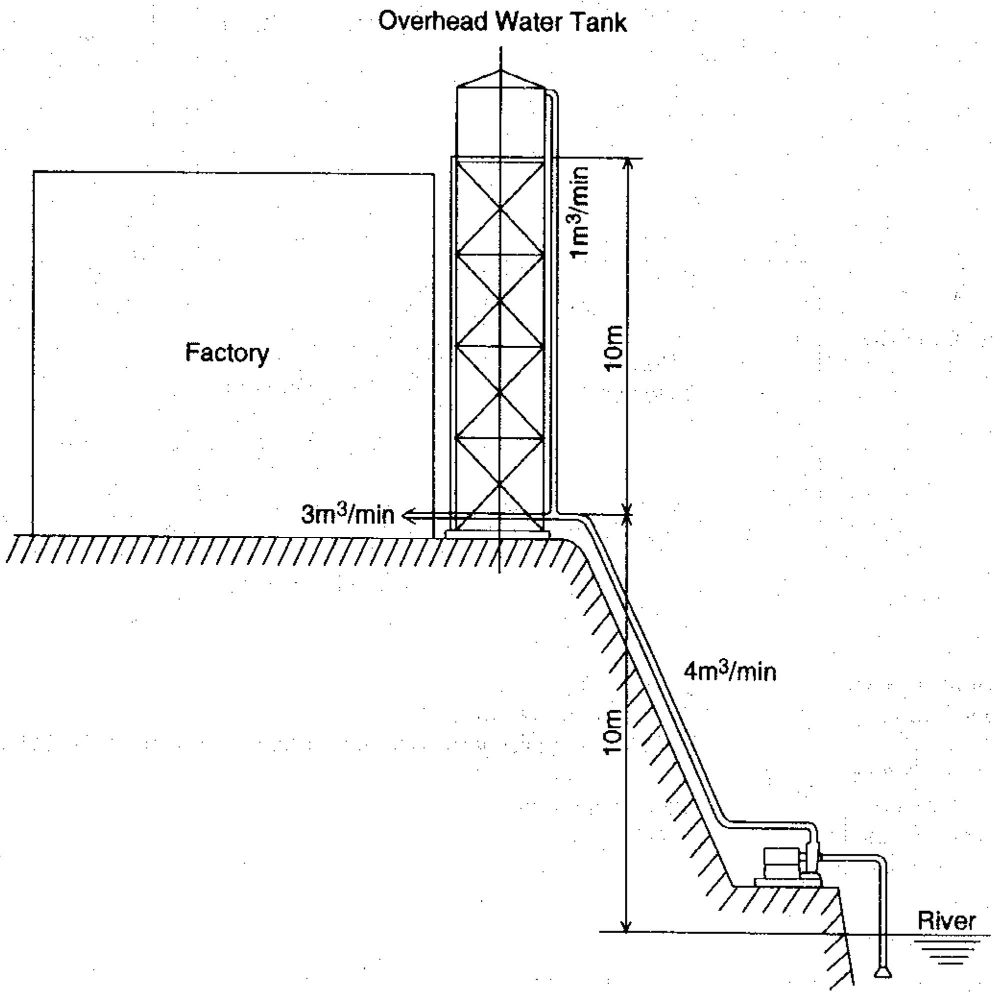


(2) Static pressure : 150 mmAq
(3) Air volume : 800 m^3/min - 300m^3/min
controlled by discharge damper (damper opening 100% at 800m^3/min)
(4) Blower efficiency : 0.7
(5) Motor type : Induction motor
(6) Motor capacity : 75 kW
(7) Load curve



7. Pump

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

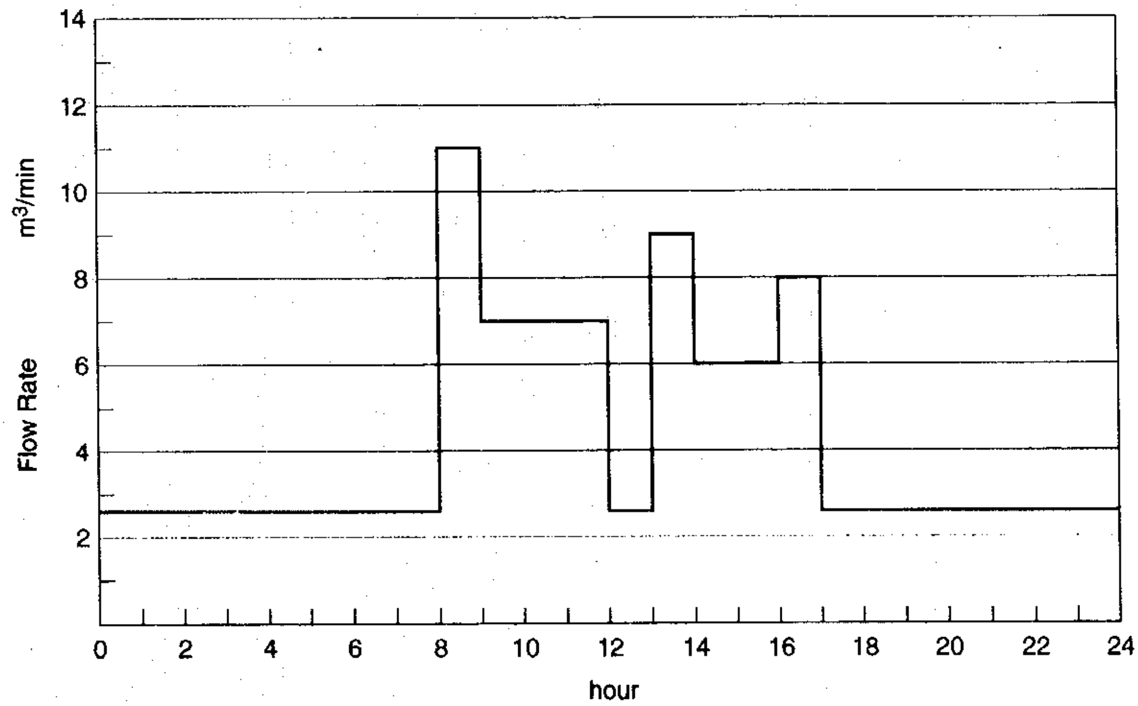


(2) Motor Capacity : 22 kW continuous operation
(3) Flow rate : 4 m^3/min × 20 mAq
(4) Water temp. : 20°C

8~11. Compressor

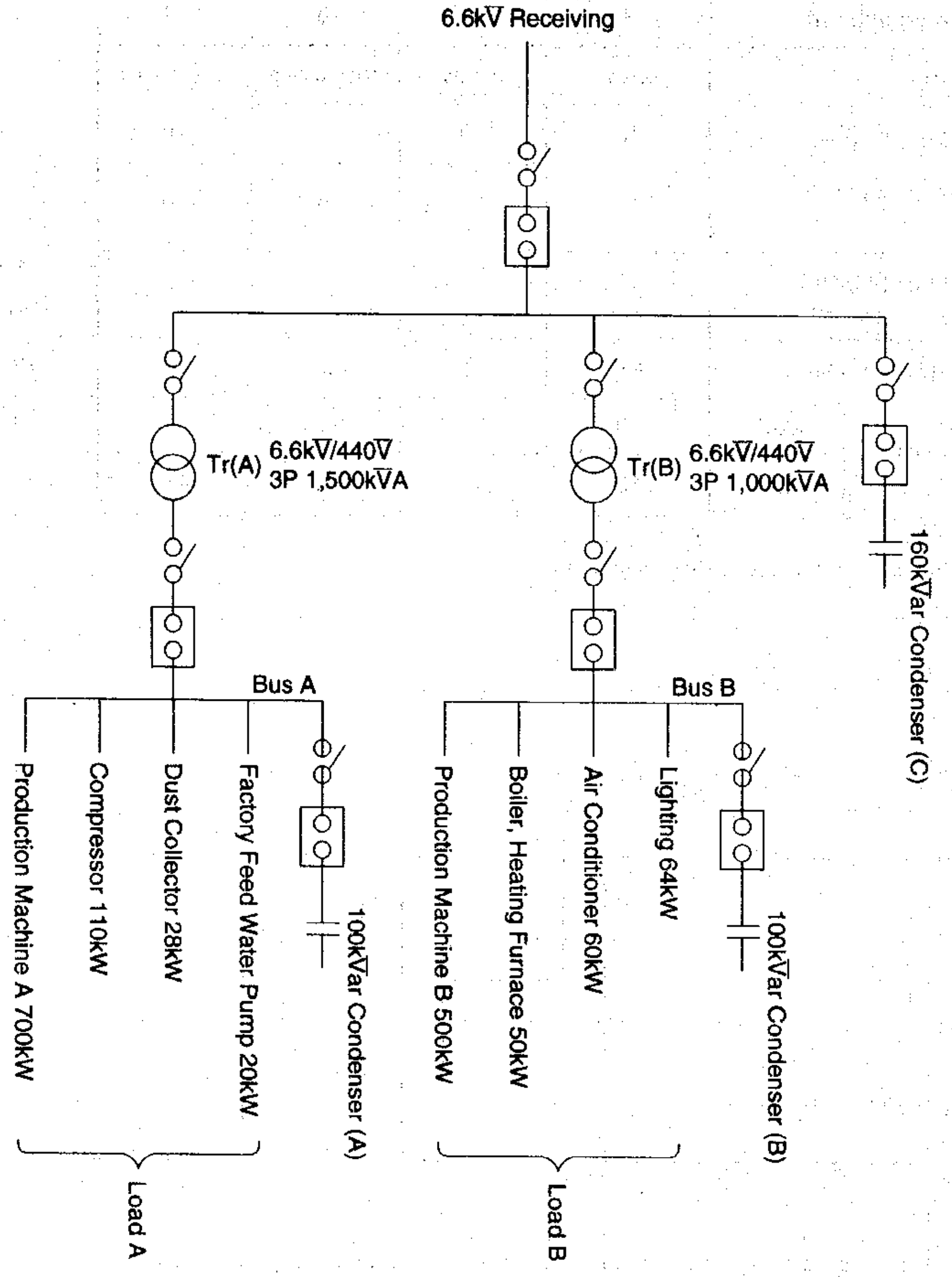
No. of equipment		8	9	10	11	Total
Type		screw	screw	reciprocating	reciprocating	
Capacity [PS]		40	30	30	20	
Temp. of intake air [°C]		50	50	50	50	
Discharge pressure [kg/cm^2]		7	7	7	7	
Flow rate [m^3/min]		4.0	3.2	3.0	1.8	12
Power [kW]	load	30	25	25	18	98
	unload	15	13	6.0	4.0	38

Maximum pressure of user side 5 kg/cm^2g

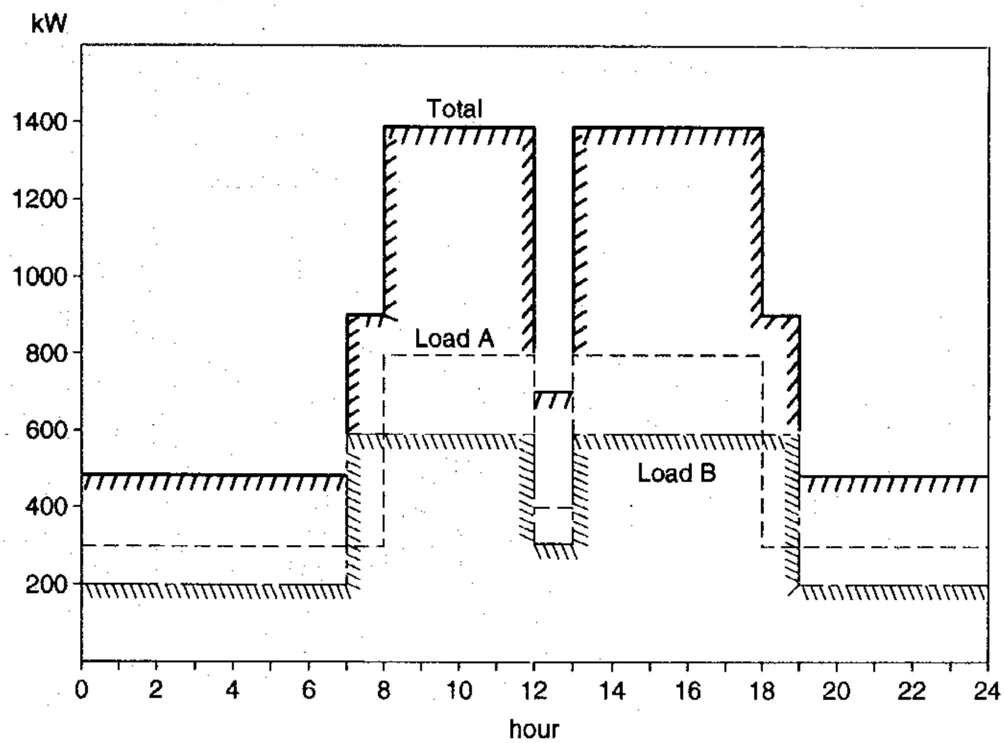


Load Curve

12. Transformer



13. Load Curve



(1) Load of A

Hour	0-8	8-12	12-13	13-18	18-24
kW	300	800	400	800	300
p.f.%	83	85	85	85	83

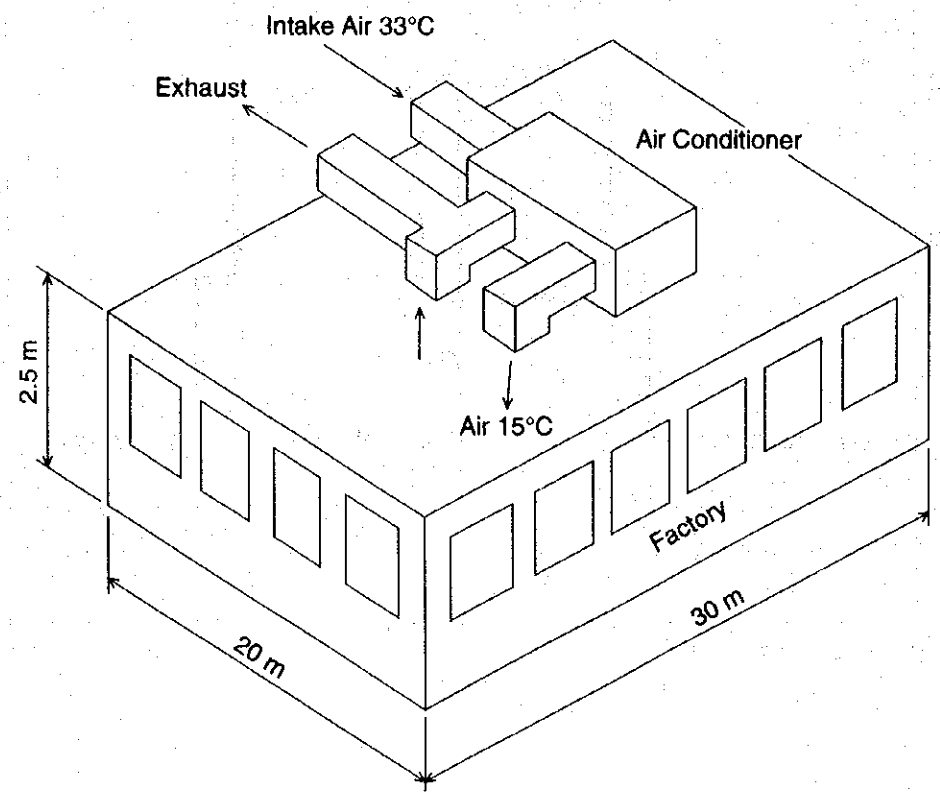
(2) Load of B

Hour	0-7	7-12	12-13	13-19	19-24
kW	200	600	300	600	200
p.f.%	89	86	88	86	89

(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

14. Air conditioner



(1)	Room area	: $600m^2$
(2)	Room height	: 2.5m
(3)	Room volume	: $1{,}500m^3$
(4)	Outdoor temp.	: 33°C (R.H 70%)
(5)	Indoor temp.	: 23°C (R.H 50%)
(6)	Air conditioner outlet air temp.	: 15°C
(7)	Blower for air circulation	: 20kW
(8)	COP of refrigeration	: 3.0

15. Data for calculation of heat capacity

1) Heat transfer through wall & roof

K	: $2.5kcal/m^2.h.°C$	K	Overall heat transfer coefficient
Aw	: $800m^2$	Aw	Area of wall & roof
Δte	: 12°C (Δte is proportional to Δ to)	Δte	Difference temp. of effective

2) Heat transfer through glass

K	: $5.5kcal/m^2.h.°C$	K	Overall heat transfer coefficient
Ag	: $56m^2$	Ag	Area of window
Δto	: 10°C	Δto	Difference temp. between outdoor and room

3) Infiltration

n	: 1/h	n	Number of times for ventilation
V	: $1,500m^3$	V	Room volume

4) Lighting

q_L	: 6,000kcal/h	q_L	Lighting power

5) Indoor appliances

q_{AS}	: 30,000kcal/h	q_{AS}	Sensible heat load from appliances
q_{AL}	: 0	q_{AL}	Latent heat load from appliances

6) Fresh air
20% to total cool air

7) Duct leakage, others
15% of RL — RL Room load

16. Electric Charge

(1) Electric charge per month (Baht/m) = Demand charge + Energy charge + Power factor charge

Demand charge = Contract demand (kW) × Demand charge (Baht/kW.m)

Energy charge = Power consumption per month (kWh/m) × Energy charge (Baht/kWh)

Power factor charge = 15.00Baht/Portion of measured reactive power demand in kVar which is numerically in excess of 63% of contract demand in kW

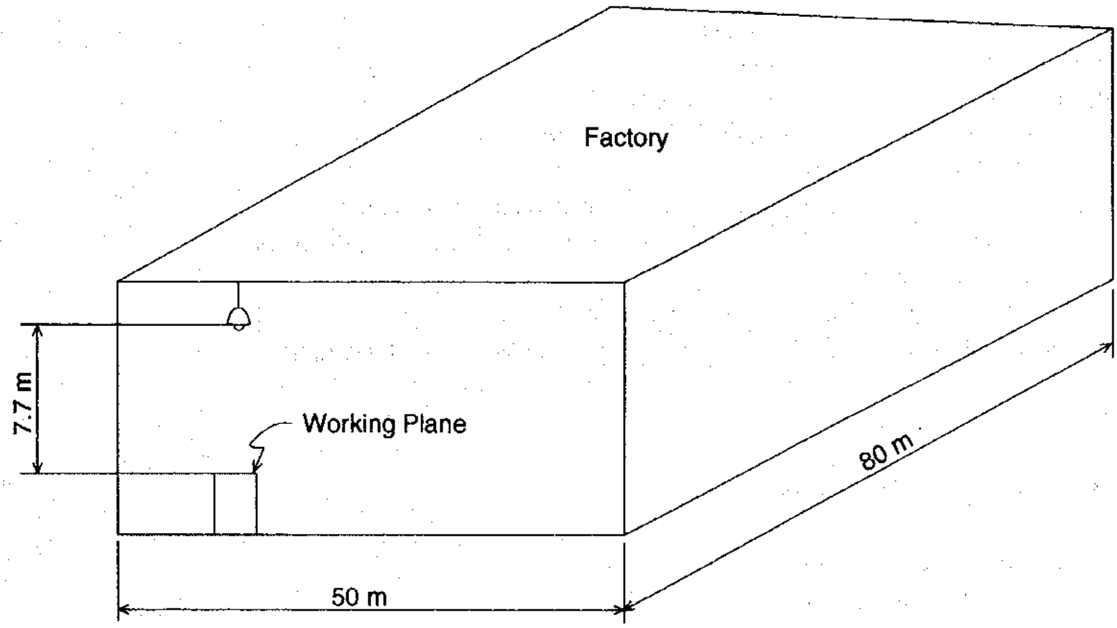
Ex. (Metropolitan Electricity Authrity)

Voltage kV	Demand charge Baht/kW	Energy charge Baht/kWh
3.1.1 69kV and Over	188.00	1.03
3.1.2 12-24	210.00	1.07
3.1.3 Below 12	237.00	1.10

(2) Calculate the electricity charge that will be incurred by a factory under the following electricity consumption conditions, as well as identifying any charge reduction measures. Assume a 15 minute demand and use the above table to calculate the electricity charge. Distribution voltage is assumed to be a variable which can be changed as desired.

Case	Contract classes Voltage kV	Contract demand (real power) kW	Monthly electricity consumption kWh	Max demand (reactive power) kvar
1	3.1.3 Below 12	250	125,000	183
2	3.1.3 Below 12	500	250,000	300
3	3.1.2 12-24	500	250,000	300
4	3.1.2 12-24	750	250,000	400
5	3.1.2 12-24	1,200	330,000	550

17. Lighting



(1) Lighting area : 80 m × 50 m = 4,000m^2
(2) Height of light source from working plane : 7.7m
(3) Lamp : Fluorescent mercury lamp 400 W (601m/w) × 150
(4) Illumination standard : 500 lx
(5) Reflection factor : 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	KR=0.60	0.36	0.32	0.41	0.35	0.31	0.40	0.35	0.31
	KR=0.80	0.45	0.41	0.50	0.44	0.40	0.48	0.43	0.40
	KR=1.00	0.52	0.48	0.56	0.51	0.48	0.54	0.50	0.47
	KR=1.25	0.57	0.53	0.60	0.56	0.52	0.58	0.54	0.51
	KR=1.50	0.62	0.58	0.64	0.60	0.57	0.62	0.59	0.56
	KR=2.00	0.67	0.64	0.68	0.65	0.62	0.66	0.63	0.61
	KR=2.50	0.70	0.67	0.71	0.68	0.66	0.68	0.66	0.64
	KR=3.00	0.72	0.70	0.72	0.70	0.68	0.70	0.68	0.67
	KR=4.00	0.75	0.73	0.75	0.73	0.71	0.72	0.71	0.69
	KR=5.00	0.77	0.75	0.76	0.74	0.73	0.73	0.72	0.71
	KR=7.00	0.79	0.77	0.77	0.76	0.75	0.75	0.74	0.73
	KR=10.00	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.75

(7) Maintenance factor : 0.8

18. Steam Piping

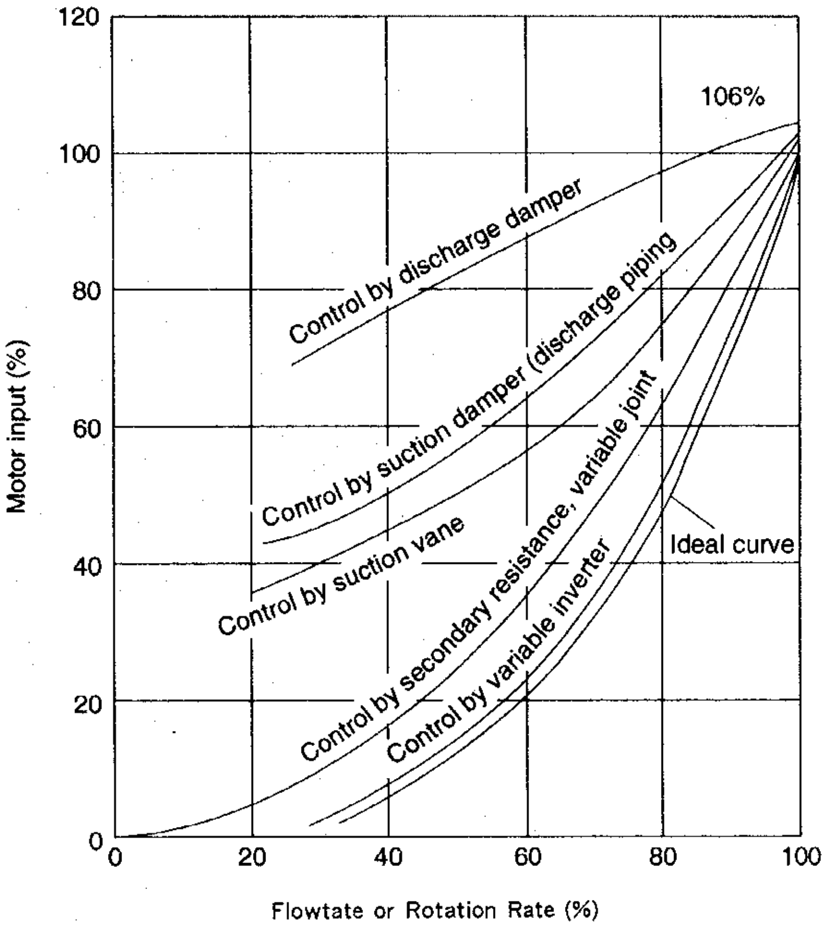
(1) Pipe diameter : 12 inches
(2) Pipe length : 200 m
(3) Insulation : 20 mm glasswool
(4) Steam pressure : 8 kg/cm^2G working pressure
(5) Steam Leakage :
Steam leakage from 10 flanges and screw joints on the pipe lines.
It is almost equivalent to the leakage from 10 holes with 1.5mm in diameter.
(6) Peeling of insulation :
There are some broken insulation parts on pipe lines.
Total length of broken insulation parts on pipe lines is about 10m length.

• Quantity of exhaust steam is

$$1.99 \times A \times \sqrt{\frac{100^{c} \bullet P}{v''}} \times 3{,}600$$

where A : Hole's area (m^2)
P : Steam pressure ($kg/cm^2 \bullet abs$)
v" : Steam specific volume (m^3/kg)

19. Power consumption curve of motor by load



THE STUDY (AFTER-CARE)
ON THE ENERGY CONSERVATION PROJECT
IN THE KINGDOM OF THAILAND

TEXTBOOK FOR THE ENERGY AUDIT TECHNIQUES WORKSHOP

2. Model Building

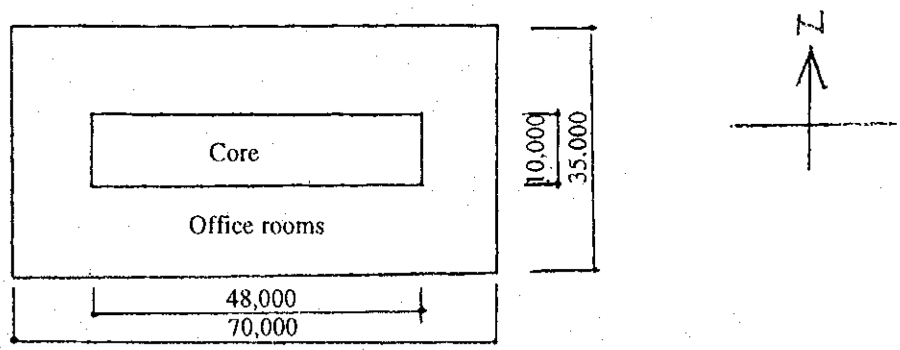
March 1994

Japan International Cooperation Agency (JICA)

The Energy Conservation Center, Japan (ECCJ)

1. Outline of the Building

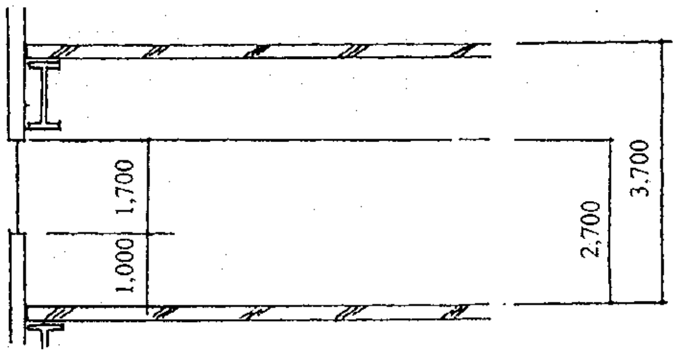
Name:	Building A
Location:	Bangkok, Thailand
Usage:	Office
Total floor area:	24,500 m^2
Number of stories:	10 above ground (No underground floors)
Construction:	Steel skeleton
Typical plan:	As shown below (assumed to be common for all 10 floors)



Story height: 3,700 mm

Ceiling height: 2,700 mm

Window cross section:



Window area ratio: 46% (i.e. window 46% and external wall 54%)

Window glass: Ordinary glass (transparent)

Heat transmission coefficient

K: [kcal/m^2hC] (with the blind open)

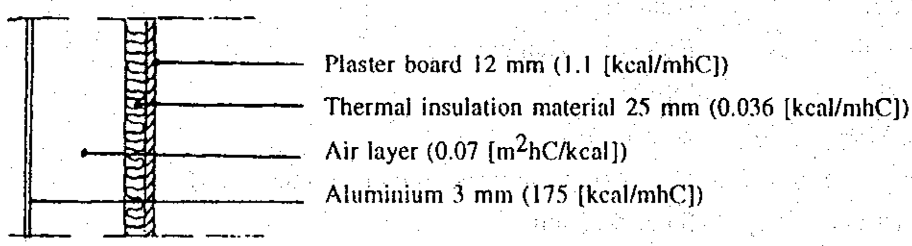
K: [kcal/m^2hC] (with the blind closed)

Solar heat capturing rate

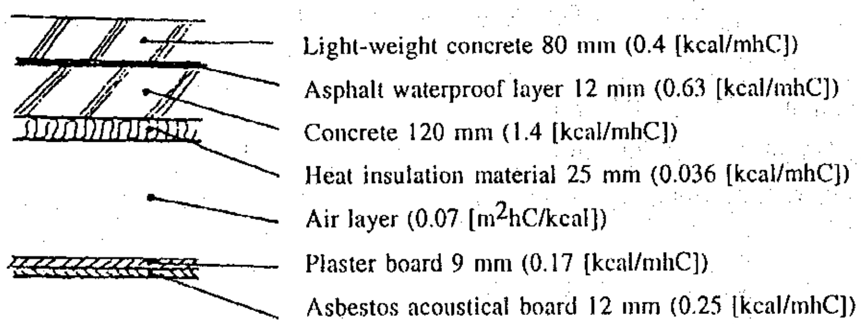
SC: [ND] (with the blind open)

SC: [ND] (with the blind closed)

External wall structure: (solar absorptivity 70%)



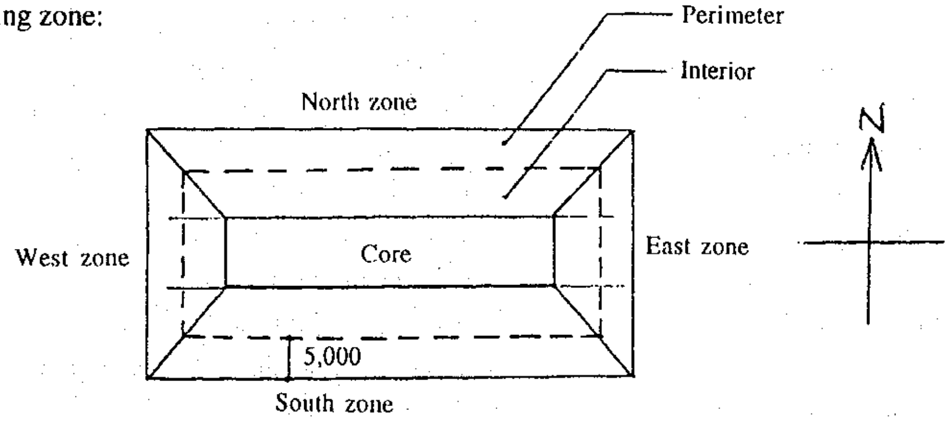
Roof structure: (solar absorptivity 70%)



2. Air-conditioning system outline

Type: Single duct + fan-coil unit
(4 air-conditioning units on each floor)

Air-conditioning zone:



Refrigerating machine: Centrifugal 1 unit

3. Air-conditioning load calculation conditions

Room temperature and humidity:	24°C DB 50% RH
Room usage hours:	Weekdays 9.00 - 18:00
	Saturdays and Sundays Closed
Air-conditioning hours:	Weekdays 8.00 - 18:00
	Saturdays and Sundays No air-conditioning
Room occupants:	0.1 person/m^2 (per air-conditioned area)
Lighting:	20W/m^2 (per air-conditioned area)
Illuminating hours:	Weekdays 9.00 - 18:00 (all lights on)
	Saturdays and Sundays No lighting
Fresh air intake volume:	30 m^3/h/person
Outside air temperature: and humidity	35°C DB 77% RH
Solar radiation intensity:	400 kcal/m^2h Average solar radiation intensity for all directions during peak load (assumed)
Air infiltration:	0.2 times/h
Frequency of blind use:	50% (open) 50% (closed)

I. Reductions in Cooling Load

1. Determination of maximum cooling load

Find the overall value of maximum cooling load by hand calculation and determine the required refrigeration capacity.
(Ignore the effects of special conditions that normally apply to the first floor.)

Results:

Sensible heat load:	Wall structure	[kcal/h]
	Window glass	[kcal/h]
	Human bodies	[kcal/h]
	Lighting	[kcal/h]
	Fresh air	[kcal/h]
	Air infiltration	[kcal/h]
Latent heat load:	Human bodies	[kcal/h]
	Fresh air	[kcal/h]
	Air infiltration	[kcal/h]
Total:	Room cooling load	[kcal/h]
	Fresh air load	[kcal/h]
	Total load	[kcal/h]

Refrigeration capacity: [USRT]

2. Changing temperature and humidity settings

Find the reduction ratio in maximum load that will result from the following change in temperature and humidity settings:

From:	24°C DB	50% RH
To:	26°C DB	50% RH

Reduction in maximum load: %

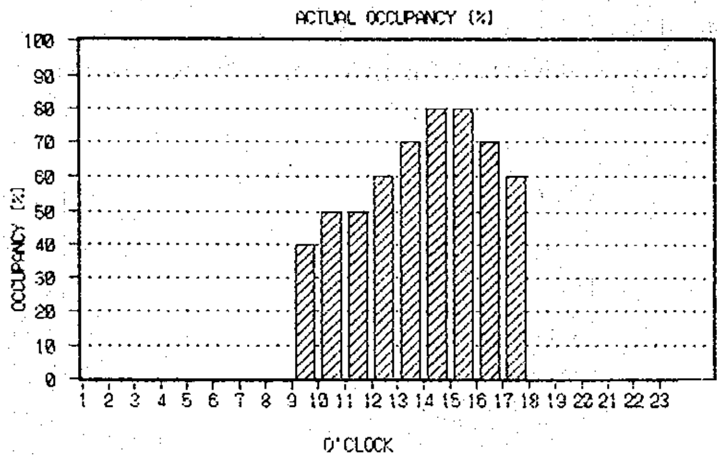
3. Changing fresh air intake volume

Find the reduction ratio in maximum load that will result from the following change in fresh air intake volume:

From: 30 m^3/h/person
To: 20 m^3/h/person
Reduction in maximum load: %

4. Changing the fresh air intake control system

Compare daily fresh air loads in cases where fresh air intake volume is fixed and where CO_2 control is provided. Assume that the number of room occupants changes according to the following pattern:



Temperature and humidity conditions are as follows:

Room:	24°C DB	50%
Fresh air (average):	33°C DB	28°C WB

5. Adopting total enthalpy heat exchangers

Find the reduction ratio in daily fresh air load that will result from the use of total enthalpy heat exchangers. (Assume a heat exchange efficiency of 50%.)

6. Stopping fresh air intake during precooling

Find the reduction ratio in daily fresh air load that will result from stopping fresh air intake during precooling (8.00 - 9.00).

Temperature and humidity conditions are as follows:

Room:	24°C DB	50%
Fresh air (during precooling):	27°C DB	26°C WB

7. Minimizing fresh air load

Find the reduction ratio in daily fresh air load that will result from the combined application of the above techniques.

8. Reducing air infiltration

Find the reduction ratio in maximum load that will result from reducing air infiltration to 50%.

9. Changing illumination intensity

Find the reduction ratio in maximum load that will result from the following change in illumination intensity.

From: 20 W/m^2
To: 15 W/m^2

10. Strengthening exterior wall thermal insulation

Find the reduction ratio in maximum load that will result from an increase in the thickness of the external wall thermal insulation material as shown below:
(Also find the increase in maximum load that will result from removing the thermal insulation.)

From: 25 mm
To: 50 mm
(No thermal insulation material — for reference)

11. Strengthening window glass thermal insulation

Find the reduction ratio in maximum load that will result from the provision of a heat reflecting film over the window panes as follows:

From: ordinary glass (transparent)

Heat transmission coefficient	K:	5.5 [kcal/m^2hC] (with the blind open)
	K:	4.3 [kcal/m^2hC] (with the blind closed)
Solar heat gain coefficient	F:	0.87 [ND] (with the blind open)
	F:	0.47 [ND] (with the blind closed)

To: ordinary glass + thermal reflective film

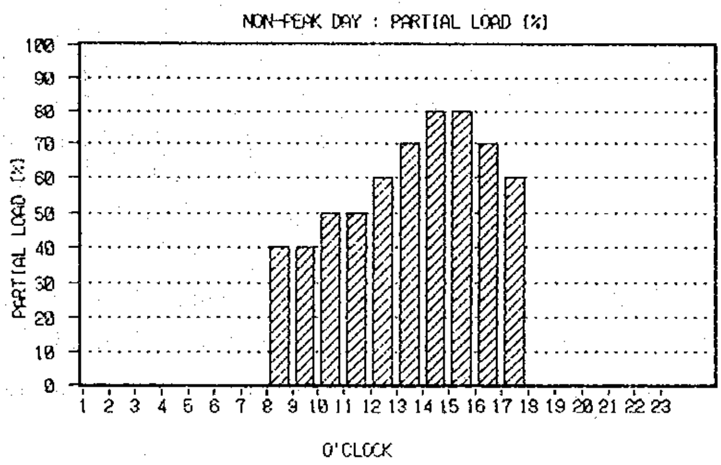
Heat transmission coefficient	K:	5.5 [kcal/m^2hC] (with the blind open)
	K:	4.3 [kcal/m^2hC] (with the blind closed)
Solar heat gain coefficient	F:	0.61 [ND] (with the blind open)
	F:	0.44 [ND] (with the blind closed)

II. Heat Source System

1. Effects of refrigeration output control via the number of units in operation

(1) Calculating hourly loads on a non-maximum load operating day

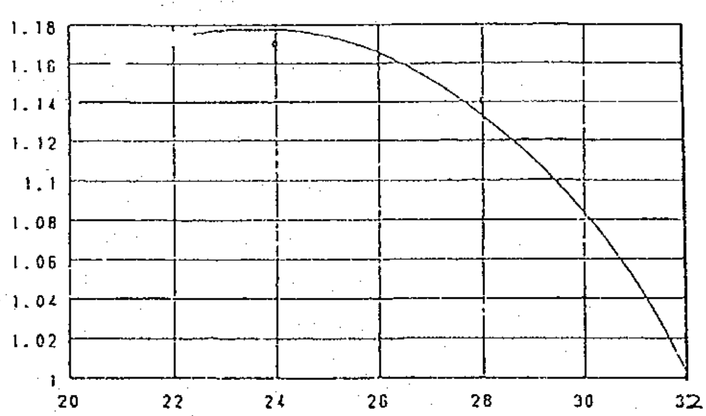
Calculate hourly loads on a non-maximum load operating day, assuming the load fluctuation pattern shown in the following diagram:



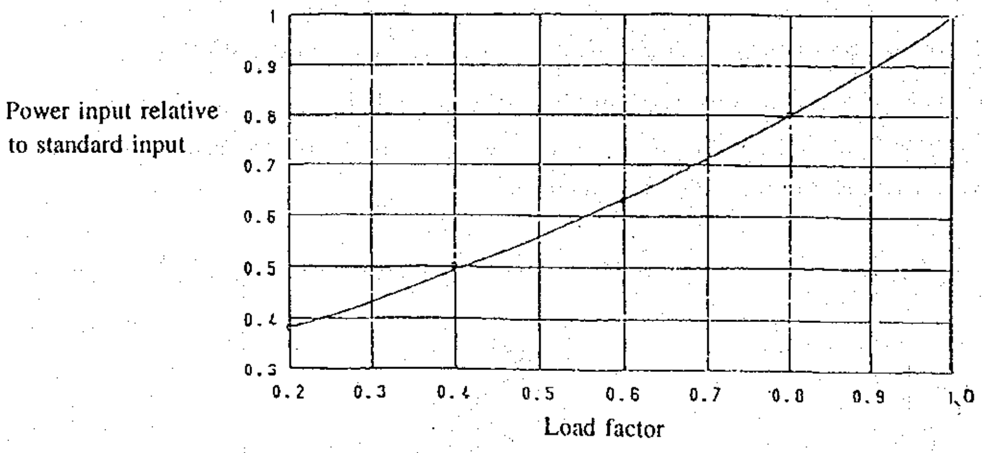
(2) Calculating the refrigerating machine electricity consumption on a non-maximum load operation day. Assume the following refrigerating machine characteristics:

Standard refrigerating capacity:		[kcal/h] (from Part I)
Standard COP:	4.5	
Standard power input:		[kW]
Standard operation conditions:	Cooling water inlet temperature: 32°C	
	Cooling water outlet temperature: 5°C	
	Cold water inlet temperature: 10°C	

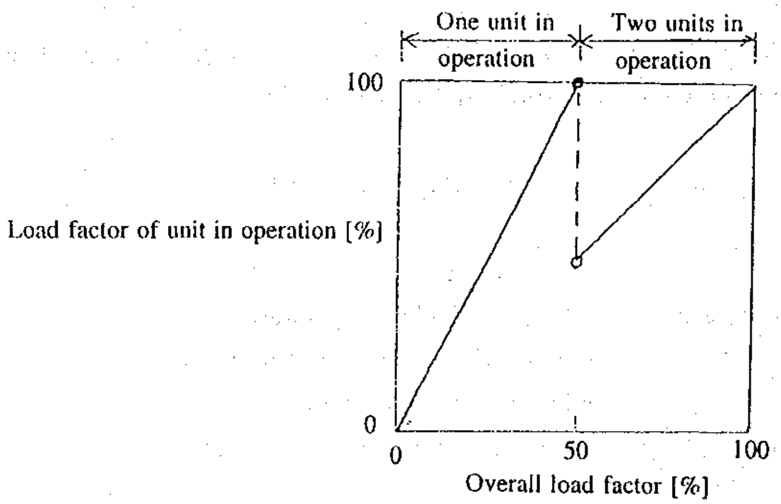
Effects of cooling water temperature: As shown in the following diagram



Effects of load factor: As shown in the following diagram



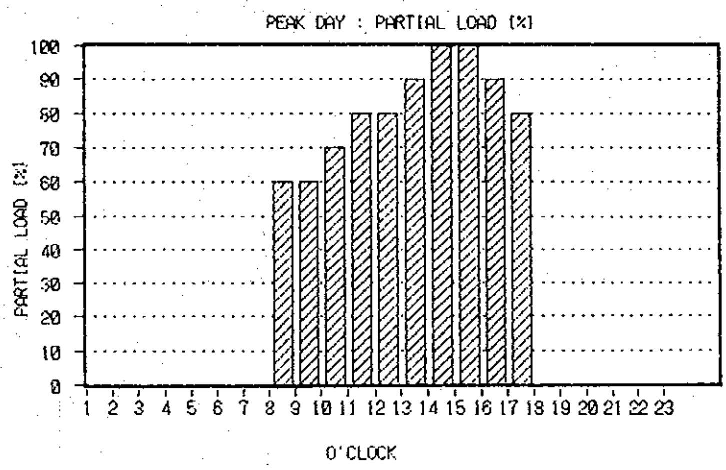
(3) Calculating the effects of refrigeration output control via the number of units in operation
Increase the number of refrigerating units to two and perform a calculation similar to that in (2) above, incorporating refrigeration output control via the number of units in operation.
Apply the following operating method:



2. Examining the heat storage system

(1) Calculating hourly loads on a maximum load operating day

Calculate hourly loads on a maximum load operating day, assuming the load fluctuation pattern shown in the following diagram:



(2) Calculating heat storage tank and refrigerating machine capacities

Calculate heat storage tank and refrigerating machine capacities for the following cases:

(i) Operating the refrigerating machine during the off-peak period (21:30 - 8:00) only

(ii) Not operating the refrigerating machine during the peak period (18:30 - 21:30)

(iii) Operating the refrigerating machine 24 hours a day

(iv) Without a heat storage tank

(3) Comparison of electricity charges

Assuming there were 20 non-maximum load operation days with a load fluctuation curve as described in 1. above, in a particular month, calculate differences in electricity charge in the three cases with a heat storage tank compared to the one without. Use the following electricity rate:

Demand charge:	(Peak)	18:30 - 21:30	305.00 Baht/kW
	(Patial peak)	8:00 - 18:30	63.00 Baht/kW
Energy charge:			1.07 Baht/kWh

III. Distribution system

1. Examining of variable air volume systems (VAV)

Assuming that the cooling load within an air-conditioning zone changes in accordance with the following diagram, calculate daily blower electricity consumption for each of the following air flow control systems, and compare them:

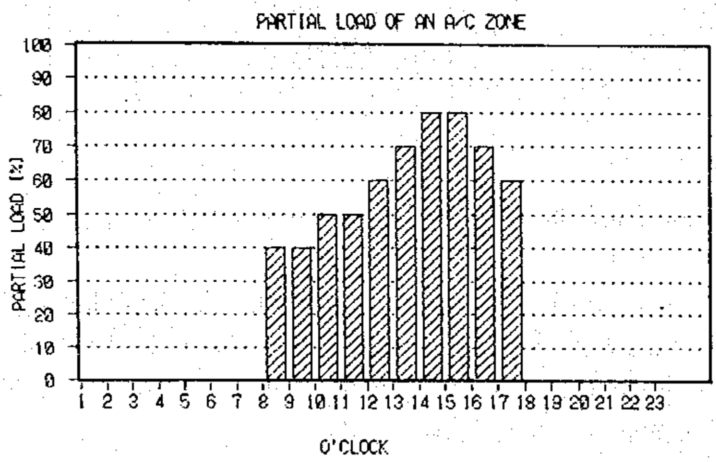
i) Constant air volume (CAV)

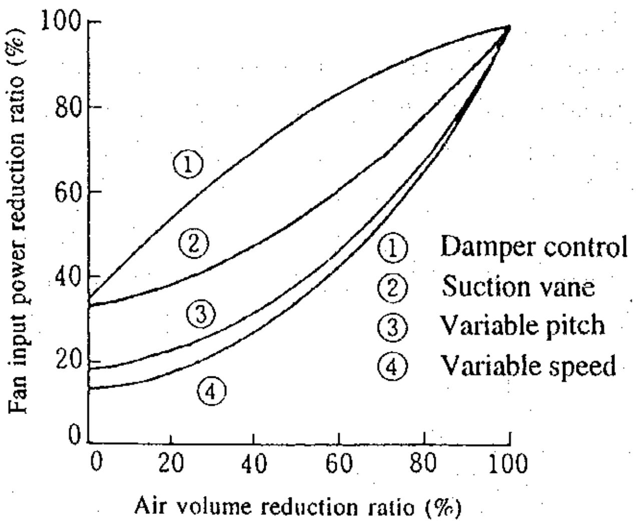
ii) Variable air volume (VAV: damper control)

iii) Variable air volume (VAV: suction vane control)

iv) Variable air volume (VAV: variable pitch control)

v) Variable air volume (VAV: variable speed control)





2. Examination of variable water volume systems

Assuming that the cooling load within an air-conditioning zone changes in accordance with the following diagram, calculate the daily electricity consumption of the cold water pump for this zone for each of the following water flow control systems, and compare them:

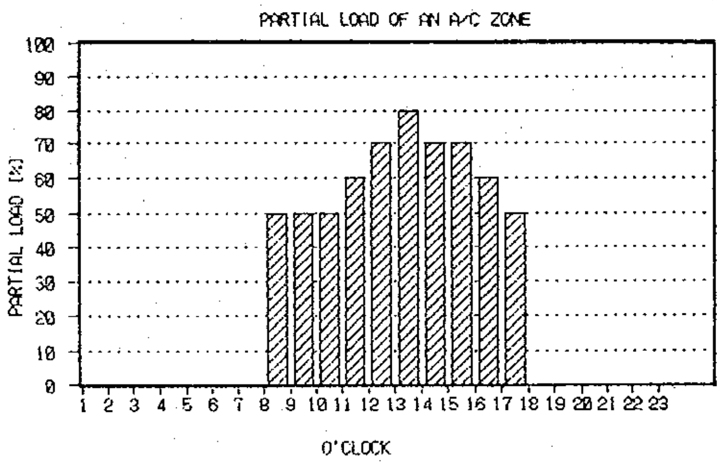
i) Constant water volume (CWV)

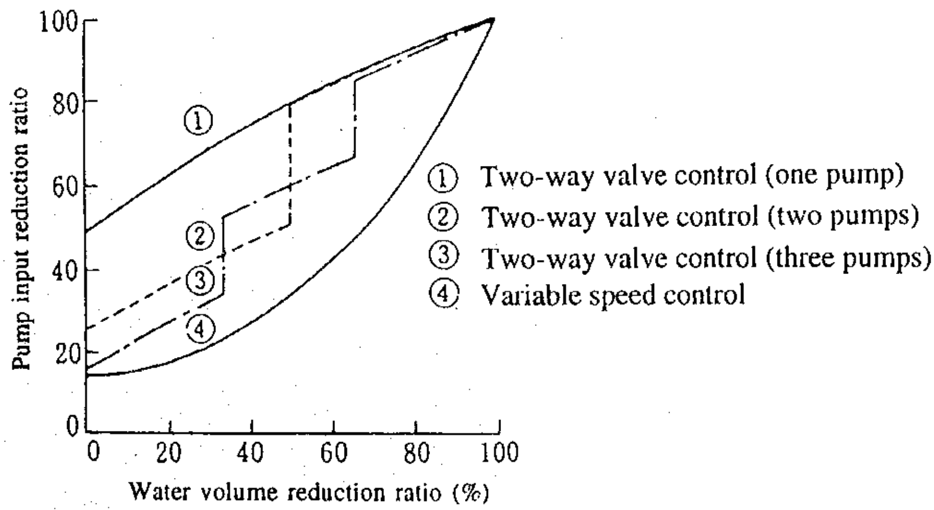
ii) Variable water volume (VWV: two-way valve control: one unit)

iii) Variable water volume (VWV: two-way valve control: two units)

iv) Variable water volume (VWV: two-way valve control: three units)

v) Variable water volume (VWV: variable speed control)





THE STUDY (AFTER-CARE)
ON THE ENERGY CONSERVATION PROJECT
IN THE KINGDOM OF THAILAND

TEXTBOOK FOR THE ENERGY AUDIT TECHNIQUES WORKSHOP

3. Energy Management

March 1994

Japan International Cooperation Agency (JICA)

The Energy Conservation Center, Japan (ECCJ)

1. ENERGY MANAGEMENT

In order to achieve higher efficiency and level in energy consumption as well as productivity and quality, the first requirement is to use the appropriate and well-maintained equipment according to the purpose and to handle them properly. The most effective way for energy conservation is to reduce the number of the equipment troubles and to ensure higher product yields.

The second requirement is to consider if there is any room for improvement in the current equipment and operation method, and to make constant efforts to reach a higher level through repeated studies and factory experiments.

To achieve this, the management people of the factory and the engineers as well as all the operators working in the first front of the site are required to make an concerted effort. It is not too much to say that the success of the campaign depends on the willingness of all the employees of the company, and the factory management to encourage the willingness of these employees is the key to the success. Energy management can be defined as "an organized effort to achieve energy conservation".

(1) Defining the management policy

Because of deeper recognition of the energy situation and requirements for improved factory profit, the factory management and supervising people have come to be greatly interested in energy conservation issues. In order to start the energy conservation activity as a campaign involving all the members of the factory, it is necessary to demonstrate a strong determination of the top management to achieve the goal as a company policy. It is essential to show a quantitative target in terms of percentage of energy to be reduced for each ton of the product, and the deadline by which this target must be achieved, as well as such restrictive items as the upper limit of the annual investment and the investment recovery period. When the top management has defined a direction in which the factory is moving forward, the employees can be convinced that they are working in the direction desired by the top management of the company. Since all the factory members are making efforts in the same direction, cooperation among them will become very smooth.

The target of the top management is shown as an overall goal, so each division in the factory should set up concrete, detailed targets regarding the items for which it can take actions within the scope of their responsibility to achieve the goal set up by the top management, and should make efforts to reach such targets. Since such targets are given in a familiar form which is easily understandable, they will be effectively conveyed to every member of the factory to get positive cooperation.

When the targets broken down for each division are to be set up, they will be studied in the committee (discussed later) to see if such individual targets meet the overall goal or not. It is also important to bring up rivalry in a good sense in the factory so that each division should set up higher level to make further efforts in challenging it.

(2) Setting up the organization to promote the energy conservation campaign

In the campaign such as energy conservation campaign where a great number of people pertaining to different classes join, it is necessary to appoint some persons who will take care of the overall progress of the activities. In the case of a small-sized factory, individuals may take up this responsibility. However, in the case of a large-sized factory, a special-purpose section may be organized for this purpose.

In any case, this section, as staff members of the plant manager, is required to pay attention to the progress of energy conservation campaign. If there is any delay in the progress, it should check the causes for such delay and should make efforts to remove such causes.

To be concrete, the duties of this section comprises having a correct information on the energy consumption situation, comparison with the original schedule, collection and checking of improvement proposals, distribution of improvement budgets, progress control of the improvement works, evaluation of the results, working out of the education and training program, and preparation for the meeting of the committee.

The committee is effective in ensuring a smooth communication and deep understanding among various divisions such as production, sales, material purchase, equipment maintenance, accounting so that the effective actions will be taken. In this meeting, impact of the energy conservation measures upon each division should be discussed, and it should be confirmed that energy conservation measures do not adversely affect the profits of the entire factory.

The committee should be headed by the factory manager having authority and responsibility for production, or a person having an equivalent authority and responsibility. Otherwise, the meeting will end up determining nothing and implementing nothing.

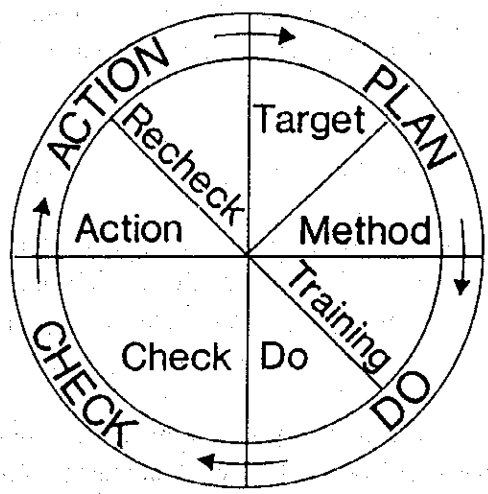
No matter how excellent an idea for the energy conservation countermeasures are based on, it will not lead to good results, unless the operators have a deep understanding of the meaning and put it into practical use in the daily works. In some cases, the QC circle (a small circle for activities) is effectively used for energy conservation with good results. The QC circle is to improve the human relations at the job site and to provide a joy of positive works by making use of the positive willingness which is essentially built in humans. Until workers recognize that the QC activities are useful and necessary for each of them, however, it is necessary to take some means as education or incentives which will facilitate promotion of the activities. It should be noted that the workers in the front line are always in contact with the energy-consuming equipment, and are in a position to feel most sensitively the phenomena which may occur according to changes of operating conditions. It will be very effective if it is possible to use information of these people and to pick up improvement actions from them.

(3) Scientific and organized activities

To go ahead with the energy conservation campaign, it is essential to have correct information on the energy consumption. It will be impossible to work out an effective strategy if there is no data showing the change of the unit consumption rate to production volume, and the differences according to the equipment, product types and material types. It is not too much to say that the factory data contains a huge amount of suggestions for improvement. If the data are checked with awareness to solve problems , it is possible to find out ways for improvement. Install measuring instruments at the required positions, and record readings. Analyze the information on a periodic basis, and try to find out meaning in the information. In this case, the data should be processed in a statistical method, and be careful to detect significant differences.

When the improvement program is implemented, be sure to follow up the results. Efforts should be made to improve the work quality according to PDCA circle advocated by Dr. Deming. As shown in Figure 1, the PDCA circle comprises the following processes; to determine a method regarding an improvement item (PLAN), to train oneself in that method and to put it into practice (DO), to confirm the result (CHECK), and to evaluate the result and to standardize it if satisfactory, and to take corrective actions if not satisfactory (ACTION). If the goal in one step has been achieved, PDCA efforts will be made to achieve the goal in the next step. This method is useful in improving the work quality in every aspect including energy conservation activities.

Figure 1 PDCA Circle



In the first stage of selection of the theme in the PLAN phase, the items which should be improved can be easily found out. The improvement proposal system must be effectively used. Proposals may be given by any of the individual workers, QC circles, or staff members. The proposals should not be left unchecked. Immediately they must be brought to the meeting of the committee for review. Advice may be given to some proposals or may be partially modified; in this way, they should be taken up for implementation if possible. Some award should be given to the proposals. It is important to give official commendation to the proposal which has been adopted with excellent results, thereby encouraging the employees to take greater interest in the energy conservation campaign. For proposals which could not be adopted, it is necessary to explain the reason and to lead them for better proposal.

In the DO phase, it is necessary to explain the purpose of the improvement and concept of improvement program to all the factory people and to call for their cooperation to achieve the goal. Lead them so that they will report even minor abnormalities, and fine adjustment can be made smoothly in order to ensure successful activities.

The results should be checked on a periodic basis and reported to the committee or superiors, as well as to the workers in order to encourage them to take greater interest in the activities. In this case, it is important to define the criteria from the beginning, which should not be changed easily on the way.

In the ACTION phase, if the excellent results can be expected by executing the improvement plan, it should be incorporated in work standards to make sure. The required measures should also be taken for the equipment. This procedure is intended not to give much load to the operator in the normal operation, and is essential to ensure continued improvement activities.

If the considerable results can be obtained on a continued basis, the process should be described and should be made public to serve as a good example for other groups. At the same time, official commendation should be given to the related persons, thereby encouraging their further efforts.

(4) Providing education and information

Even if the employees are willing to cooperate, the improvement program cannot be implemented smoothly without information on how to solve the problem. Their interest in the activities will be increased if they can make proposal in addition to pointing out problems.

For this purpose, intra-company education is very important. Seminars are held and guideline manuals are distributed. Even if the staff members are sent to seminars sponsored by external organizations, the results will be much reduced if the information gained from such an event is restricted to these participants, without being conveyed to the other staff members and general operators.

The participants in the external seminars should convey the knowledge in the intra-company seminars when they have come back to their own factory. This will raise the general level of the factory, and will also confirm their knowledge.

The improvement movement will also be encouraged by active exchange of information with the employees of rival companies, material suppliers and product vendors. Of course, it is necessary to compete among companies. Exchange of technical information on the give-and-take basis to some extent will raise the level of the industry and strengthen international competitiveness, thereby contributing to mutual benefits. For example, to disclose the unit consumption rate will motivate competition. Furthermore, problems can be picked up from different angles by getting advice and diagnostic comments from public organizations, consultants and university professors.

THE STUDY (AFTER-CARE)
ON THE ENERGY CONSERVATION PROJECT
IN THE KINGDOM OF THAILAND

TEXTBOOK FOR THE ENERGY AUDIT TECHNIQUES WORKSHOP

4. Method of Energy Management in Industry

March 1994

Japan International Cooperation Agency (JICA)

The Energy Conservation Center, Japan (ECCJ)

1. Energy Conservation in the Industrial Sector

Energy conservation in the industrial sector can be defined as "promotion of more efficient energy use by elimination of energy waste without lowering the production level or the living standard and without impairing the environment and safety".

The following three items can be named as the purpose of industrial energy conservation activities.

(1) Decreased consumption of energy like electricity and fuel is directly effective reduction of production costs and various other costs.

(2) Enterprises are responsible for stable supply of products even with limited energy supply, and in preparation for such a situation, they must make daily efforts to establish a system for meeting the user needs with less energy.

(3) Cooperation in energy conservation as an important national policy also is a social responsibility for enterprises.

Table 1 shows an outline of the energy conservation measures of industries with large energy consumption, as well as representative energy-saving equipment.

Table 1 The present state of energy conservation measures inindustries with large energy consumption

Industry name	Outline of the energy conservation measures	Representative energy-saving equipment, etc.
Iron and steel	(1) Improvement of operation technology (2) Recovery of waste energy (3) Improvement of the production process (4) Increased energy-use efficiency	(1) Improved continuous-casting equipment (2) Blast furnace top pressure recovery and power generation equipment (3) Coke dry quencher
Petrochemicals (ethylene sector)	(1) Intensification of waste-heat recovery (2) Process rationalization (3) Reduction of the reflux ratio in distillation systems	(1) Equipment for recovery of waste heat from the exhaust gas of heating furnaces (2) Equipment for waste heat recovery from decomposition products (3) Highly efficient compressors
Cement	(1) NSP (2) Improvement of raw material mills, finishing mills, etc. (3) Utilization of waste heat (4) Optimization of fuel control	(1) SP, NSP kiln (2) Vertical mills (3) Power generation using medium- and low-temperature waste heat
Paper and pulp	(1) Change to a continuous production process (2) Recovery of waste heat (3) Improved efficiency for the production process (4) Expanded use of waste paper (5) Improved operation control	(1) Continuous digesters (2) Falling film type vacuum evaporators (3) Plane press dewatering equipment
Dyeing	(1) Thorough maintenance control (2) Recovery and use of waste hot water and waste heat (3) Introduction of energy-saving equipment like low bath ratio dyeing machines, etc. (4) Improvement of the processing conditions, etc.	(1) Heat exchangers (liquid to liquid) (2) Energy-saving washing equipment (3) Low bath ratio dyeing machines
Sheet glass	(1) Thermal insulation with heat-insulating materials (2) Improved furnace sealing (3) Improved regenerator efficiency (4) Installation of waste heat boilers	(1) Waste-heat boilers

2. Energy Management Organization

Appropriate energy management in a plant lowers the production costs, and permits maintaining and intensifying the competitiveness.

Expert energy management in enterprises requires full development of management systems for the activation and organization of energy-conservation activities, with participation by all levels from management down.

2.1 Conditions for successful energy-conservation activities

The following conditions definitely must be fulfilled for successful energy-conservation activities.

(1) The top management must lead the activities

The top managers must clearly state promotion of energy conservation, and set concrete target values to ensure that continuous efforts are made with contributions by all.

(2) A full-time organization must be established

A task force, which can execute energy-conservation measures, and a system for this must be established. At this time it is important to clarify the person responsible and the scope of responsibility. It is also very important to deepen the understanding of all employees, to establish a system for improvement proposals, to set up an energy conservation campaign month, and to promote the activities of small circles.

(3) The plan must be followed

Energy conservation must not end at the stage of improvement studies and planning, but from the planning stage on, themes must be recorded, the progress during the execution stage must be reported, and the results must be announced at all times to make them known to all employees.

Themes for which good results have been obtained should be investigated positively by all sections of the company, so that the same kind of improvement can be realized effectively also by other sections, and arrangements permitting such improvements should be standardized.

(4) Preferential budgeting

Energy conservation measures should receive preferential investments at present, and improvements with an investment recovery period within two years should be started with first priority. The scope of energy conservation measures in a plant should be within the technologically and economically possible range.

2.2 Organization of the promotion nucleus

There are no fixed rules in regard to the organization of energy conservation activities, and in each case the organization should fit the characteristics of the respective company.

(1) Participation by all

The call by the top management for energy conservation should be followed by all employees, thus aiming not only for substantial results, but also for increased morale in the enterprise.

As this is a somewhat motivational approach, enthusiastic progress takes place during the initial stage of the activities, and considerable results can be obtained in a short time. It is important to maintain this enthusiasm for a long time.

(2) Meetings

The representatives of the various sections should meet periodically, and with smooth coordination between sections, the scale of improvements will be large.

The key to success is the selection of the members.

(3) Forming project team

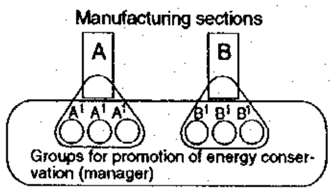
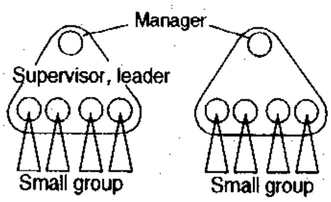
The representatives of the various sections and specialists should be combined to form project teams for energy conservation, with these project teams concentrating on energy conservation activities until the set target has been reached. This permits planned activities, so that energy conservation can be researched in depth and wide. It is important to establish a system for energy conservation activities involving the entire enterprise, to gather competent members, and set limit on objects and period for the energy conservation measures and to execute them in a short time in order to prevent them from becoming token.

(4) Establishment of a special section

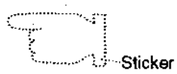
A special section in charge of energy conservation should be established within the organization of the enterprise, as well as a person in charge of energy conservation assigned to each section, so that problems can be taken up easily by cooperation with these persons. The person in charge of energy conservation at each section should execute his energy conservation function concurrently with his main work.

This method has the advantage of allowing the present conditions in each section and any problem points to be grasped easily by the respective person in charge, while the section for energy conservation is connected to the workplace via the person in charge at each section, so that all employees can feel that they are participating in energy conservation.

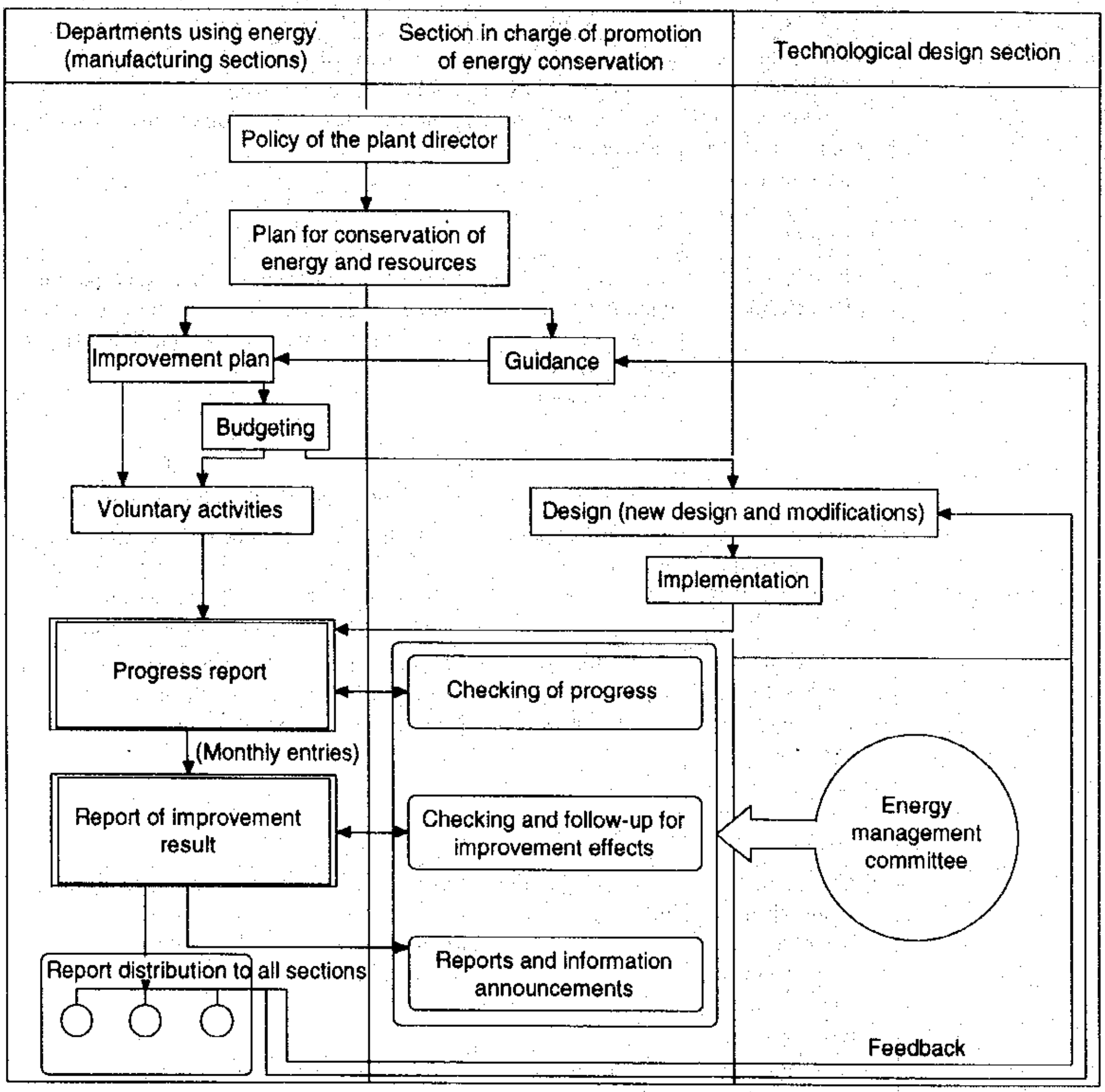
Consolidation and Strengthening of the Energy Management Organization

Theme	Projects	Aim	Concrete project contents
1. Reform of the energy management organization	Expansion of management scope and objects	Increased consciousness of energy conservation	Heat management organization ⇨ Energy management organization Energy (fuel, electricity) ⇨ Fuel (steam), electricity, air, water, oil, solvents, waste matter
	Establishment of an self-active energy management system	Improvement by self-active management, increased consciousness	Energy management section (supply department) leadership type ⇨ Energy use department (manufacturing department) leadership type
2. Organization for participation by all	Establishment of energy conservation promotion groups	Self-active improvement activities, increased consciousness	All managers of the manufacturing sections should be members of groups for promotion of self-active activities, and activities with 100 percent participation should be promoted. 
	Organization of small circles for improvement activities	Furthering of circle activities	
3. Organization of a specialized energy conservation section	Establishment of a special section for promotion of energy conservation	Strengthened activities by specialization	A special organization with the main purpose of promotion of energy conservation should be formed directly under the plant director in order to strengthen the energy management system.
4. Organization of specialist meetings	Establishment of specialist group meetings	Strengthening of the technological power for improvement of energy conservation	Organization with mutual cooperation and influence among the small groups for promotion of energy conservation and specialists to advance improvement measures.

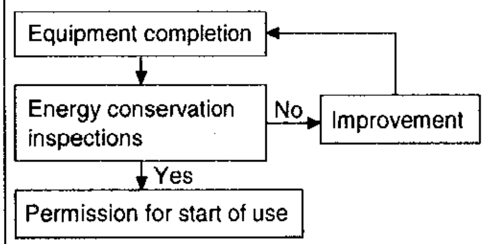
Education and instruction activities for energy conservation

Theme	Projects	Aims	Concrete project contents
1. Instruction activities	(1) Publication of "A handbook for conservation of resources" as an aid for energy conservation	Awakening of consciousness by means of written instructions	Distribution of "An easy visual handbook." holding of study meetings (Improvement effect: Money conversion table) OO kcal= ¥
	(2) Instruction and PR activities	Improvement of employees consciousness of energy and resource conservation	Creation and distribution of stickers and symbol marks, creation of slogans and posters, indication of the bulletin board responsibility division  Switch off unnecessary lighting ← Sticker
	(3) Instruction activities using inner-company VTRs	A consistent policy and improved consciousness	Transmission of the policy of the plant director via the VTR equipment installed in the plant, in offices, and in rest areas; transmission of instruction VTR's; secretariat notifications
	(4) Providing "mini-information" in regard to energy conservation in internal house organs	Heightening of the improvement consciousness	Printing of ideas and improvement information in the weekly company publication News publication by the secretariat
	(5) Campaign for proposals in regard to conservation of energy and resources	Heightening of the improvement desire	Execution of a theme proposal campaign over a given period, evaluation, and granting of prizes for excellent proposals by individuals, groups, and processes
	(6) General meeting for promotion of energy conservation	Instructions and training	Training meetings and lectures with speakers from outside the company for promotion of energy-conservation mindedness of managers and general employees
2. Education and training	(1) Study meetings, visits to other plants	Consciousness raising and improvement	Planning of example announcement meetings inside and outside the company, as well as plant visits, and aiming for positive participation by the employees of the manufacturing sections
	(2) Inner-company study meetings and technological instructions	Level-up	Use of the "Handbook for energy conservation " for training of the leader class Execution of practical instructions for energy conservation technology

Energy conservation improvement follow-up system



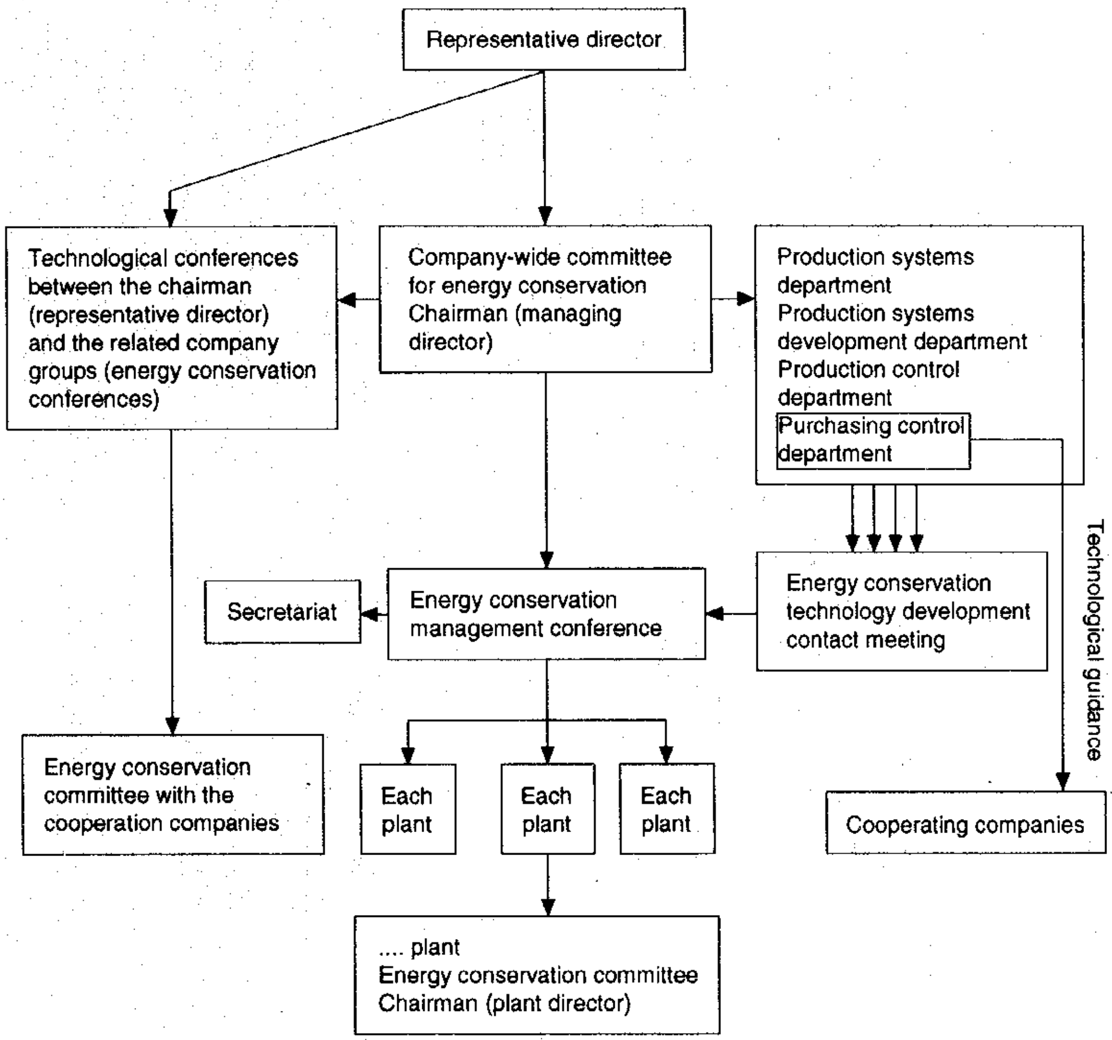
Standardization of energy conservation design and introduction of an inspection system for energy conservation

Theme	Project items	Aims	Concrete project contents
1. Standardization of design and management	(1) Standardization of energy conservation design	Aiming for design for conservation of energy and resources	<Examples> • Checking manual for energy conservation design • Design standard for effective use of steam • Design standard for rationalization of electric power use • Standard for thermal insulation design and work execution • Standard for appropriate steam trap selection • Collection of energy conservation improvement examples • Collection of energy conservation design ideas
	(2) Introduction of an approval system for energy use	Management of energy use quantities and use places Aiming for energy conservation design	• Introduction of a system for approval of energy (fuel, steam, electric power, water, and air) use (quantity and place) • Consolidation of energy flow management diagrams
2. Checking system for energy conservation design	Introduction of an energy conservation inspection system	Public relations and feedback of improvement information to the related sections	Establishing of rules for energy conservation inspections at the time of installation of new equipment, equipment modification, and manufacturing acceptance for improvement at the time of equipment introduction and finding of problem points  Note: Inspections are executed by the section in charge of promotion of energy conservation
3. Improvement information feedback system	Introduction of cards for improvement information in regard to conservation of energy and resources		A system for information feedback with progress report (monthly entries) and improvement report drawn up at the time of completion

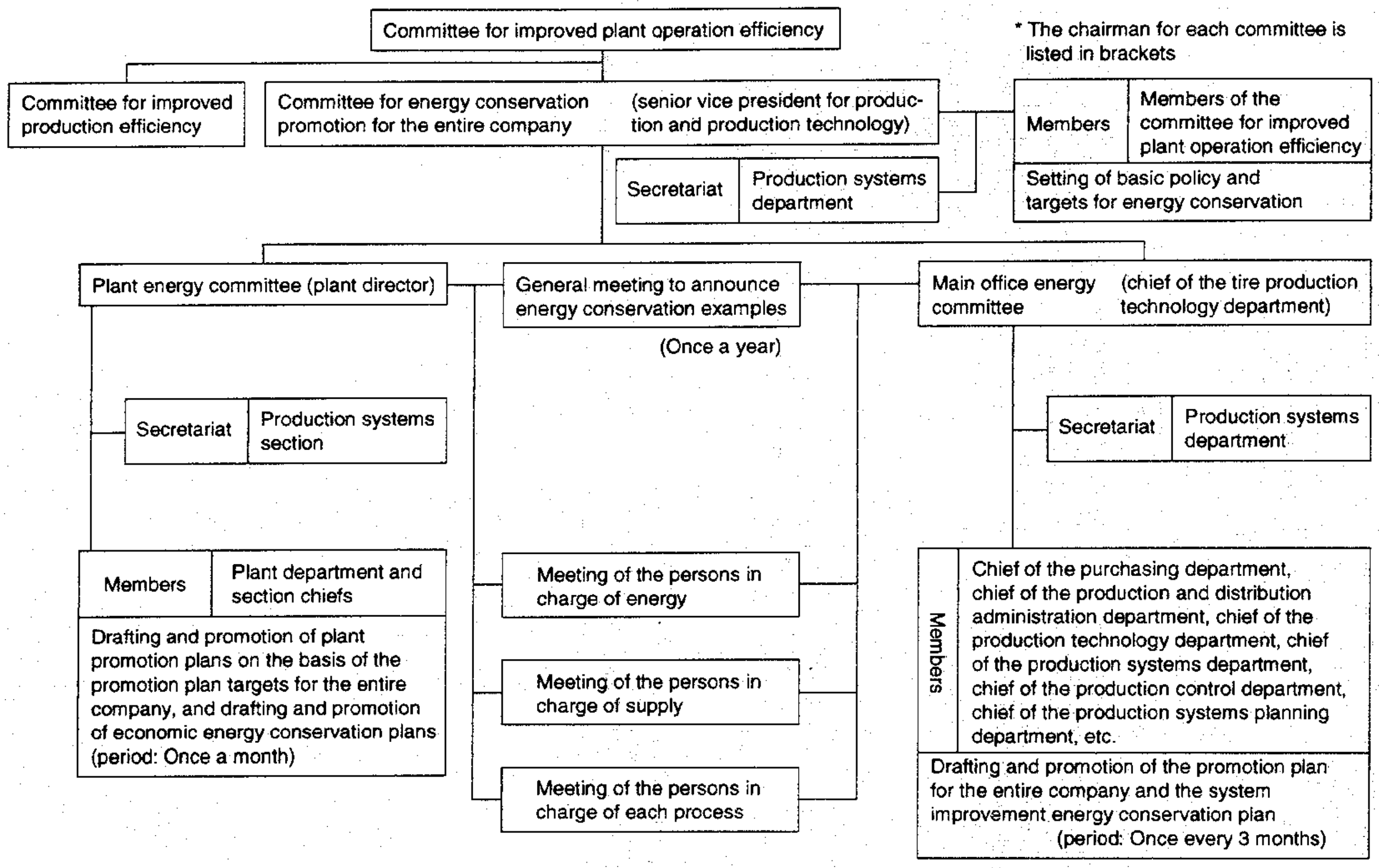
Energy conservation evaluation system

Theme	Project items	Aims	Concrete project contents
Systematization of the improvement evaluation	(1) Patrols for conservation of energy and resources	Site diagnosis	Site patrols by officials in order to check the management conditions and the conservation status for energy and resources for each section, and later follow-up.
	(2) Meetings for announcement of improvement examples	Heightening of the will for improvements, morale boosting	Convening meetings to announce improvement examples at each plant by representatives from each workplace (at least once a year) or convening announcement meetings for all plants of the company (once a year).
	(3) Contests for conservation of energy and resources	Heightening of the will for improvements by evaluation of the improvement activities with participation of the entire personnel	Evaluation of the management conditions and the improvement situation for each workplace in the form of contests for conservation of energy and resources for each process, announcement of the best and worst workplaces in terms of energy efficiency, and aiming for overall level-up. Simultaneous top diagnosis by the plant director.

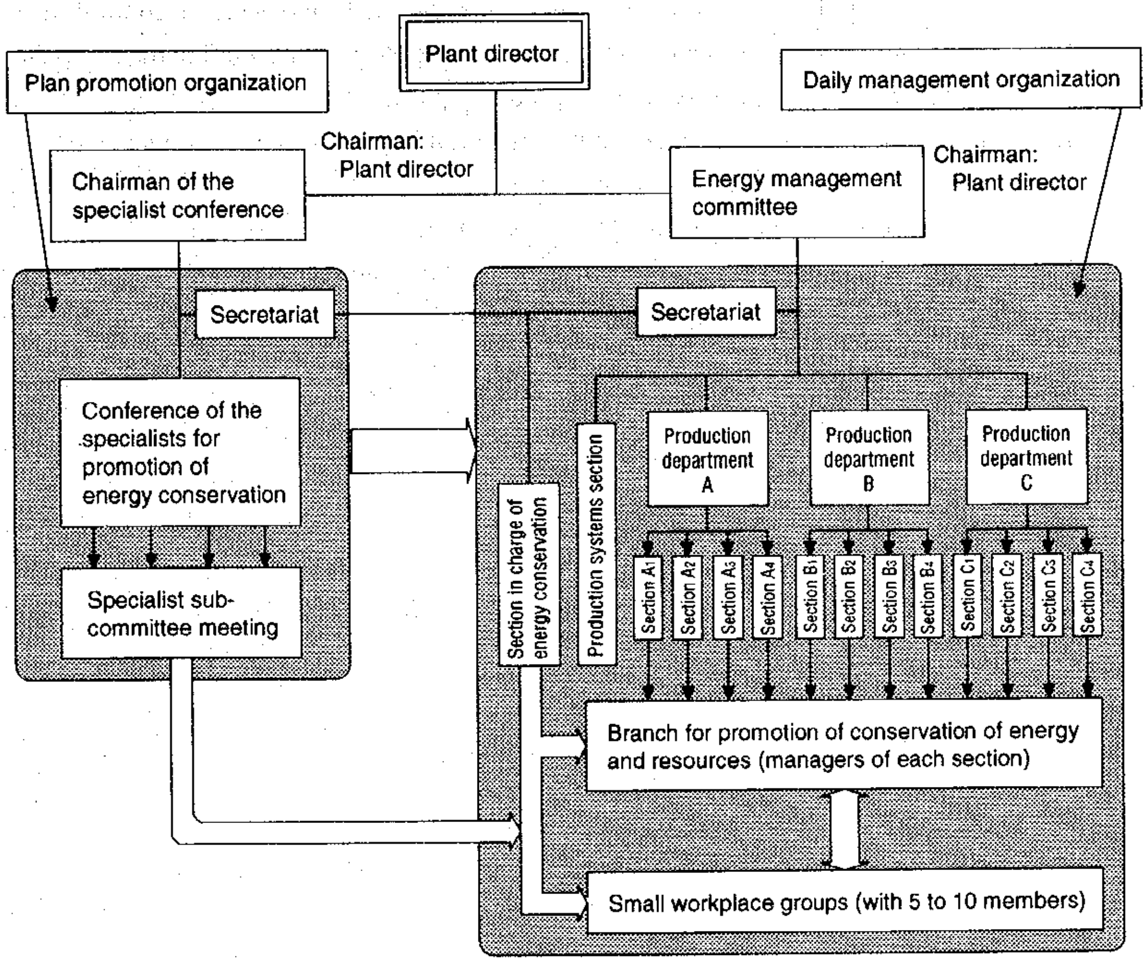
Company organization for promotion of energy conservation measures (example)



System for energy conservation promotion (example)



Plant energy management organization (example)



2.3 Items to be taken into consideration for promotion of energy conservation

I. The most important point is the enthusiasm of the top personnel.
No results will be obtained if the top personnel do not display genuine commitment.

II. The second most important point is that results for energy conservation measures can be expected only with 100 percent employees participation.

III. Energy conservation measures require some funding, as well as personnel and time exclusively for these conservation measures.

IV. It is important to start with simple and easy steps.

V. Horizontal development (positive promotion in the entire company) by standardization and full employees participation is required.

3. Practical Energy Management

In the same way as quality control, etc., energy management also must be carried out faithful to the basics of management and with application of the respective management techniques.

3.1 Understanding the present situation

An accurate understanding of the present situation is a precondition for good management. Energy management requires sufficient measuring instruments, so that the actual energy consumption can be grasped accurately, and the evaluation standard for energy efficiency must be made clear. For reference, Table 2 shows an example for the evaluation table normally used by the rationalization advisors for energy use by medium and small enterprises in their diagnoses and site investigations.

Specified energy management plants must record the conditions for the previous month by the end of each month in a provided ledger. The concrete entry items are shown below.

Designated heat management plants

(1) Purchased quantities, by-product quantities, sold quantities, and used quantities for fuels, etc. by type and grade

(2) Actual conditions in regard to new installation, modification, and removal of equipment consuming fuel, etc., as well as operation conditions

(3) Fuel use quantities by type and grade for each equipment

(4) Actual conditions in regard to new installation, modification, and removal of equipment in connection with rationalization of the use of fuel, etc., as well as operation conditions

(5) Measures executed for the rationalization of fuel use, etc.

Designated electricity management plants

(1) Purchased, generated, sold, and used electricity

(2) Actual conditions in regard to new installation, modification, and removal of equipment using electricity, as well as operation conditions

(3) Actual conditions in regard to new installation, modification, and removal of equipment in connection with rationalization of the use of electricity, as well as operation conditions

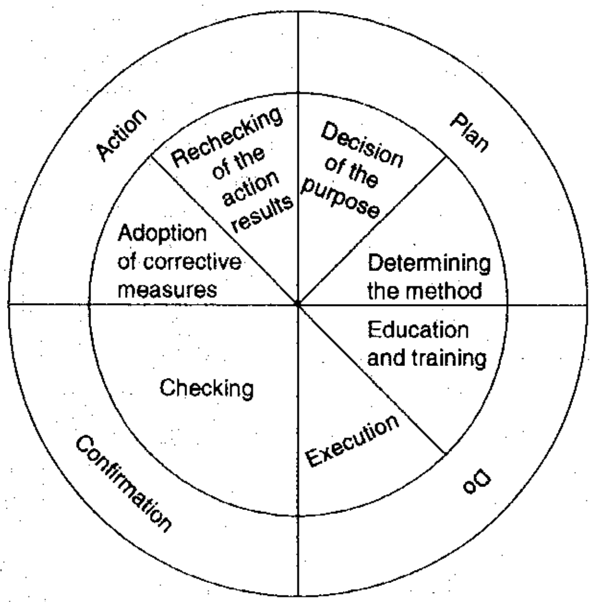
(4) Measures executed in regard to rationalization of the use of electricity

Table 2 Typical Assessment Table for Action on Improvement Suggestions

	Check items	Content
Grasping Energy Consumption Situation	(i) Measuring equipment installation	A. Sufficient to monitor energy consumption B. Allows limited monitoring, though not sufficient C. Lacks essential instruments
	(ii) Measuring equipment maintenance and management	A. Excellently maintained and free of faulty instruments B. Satisfactory C. Poorly maintained and contains faulty instruments
	(iii) Monthly energy consumption (fuel, electricity, etc.)	A. Always well recorded and maintained B. Well recorded but poorly maintained C. Not monitored
	(iv) Daily energy consumption (fuel, electricity, etc.)	A. Always well recorded and maintained B. Well recorded but poorly maintained C. Not monitored
	(v) Energy consumption for each major energy consuming facility (fuel, electricity, etc.)	A. Well recorded and maintained B. Well recorded but poorly maintained C. Not monitored
	(vi) Examination of reasons for an increase or decrease in energy consumption	A. Carried out with improvement measures identified B. Carried out C. Not carried out
	(vii) Calculation of unit energy consumption rates (fuel, electricity, etc.) for major products (calculation in monetary units also acceptable)	A. Always carried out B. Carried out as necessary C. Never carried out
	(viii) Examination of unit energy consumption rate improvement measures	A. Always carried out B. Carried out as necessary C. Never carried out
	(ix) Calculation of daily load factor of electric power	A. Carried out as necessary B. Under consideration C. Never carried out
	(x) Examination of daily load factor improvement measures	A. Have been carried out with improvement measures taken or examination under way B. Under positive consideration C. Never carried out
	(xi) Power factor used as a basis of determining the latest electricity charge (contractual power factor)	A. 95% or more B. less than 95% but not less than 90% C. less than 90%

3.2 Management of the promotion situation

Generally, TQC is executed here. A plan is drawn up and executed, the results are evaluated, corrective or preventive measures are executed on this basis, and then the entire sequence is repeated with entry into the planning stage at a higher level to close the PDCA circle as shown in Figure. Here, it is important that investigations are executed on the basis of facts and data, and for improvement of the data quality, sufficiency of mesuring instruments and application of applicable analysis methods is required.



Deming circle

3.3 Comprehensive energy evaluation

For consideration of energy management, it is not sufficient to consider only the quantitative aspect of the specific energy consumption, but attention also must be paid to the type and the quality of the energy (Table 3). The price differences between the energy types influence not only the direct costs, but transport, storage, environment, and other characteristics. The future demand and supply and the price tendencies also must be taken into consideration.

Table 3 Characteristics of energy

<table>
<tr><th></th><th>Transport</th><th>Storage</th><th>Influence on the environment</th><th>Ease of handling</th><th>Use efficiency</th><th>Safety</th></tr>
<tr><td>Coal</td><td rowspan="3">Normally, freight transport routes can be used.
The transport time is long, but the loss from transport is small.</td><td>Mass storage is possible.</td><td>SOx, NOx, dust, ash, and heat</td><td>Adjustment is required for quality and grain size.</td><td rowspan="3">Indirect heating (70%)
Direct heating (pool heater) (90%)</td><td></td></tr>
<tr><td>Petroleum</td><td>Mass storage is possible.</td><td>SOx, NOx</td><td>Excellent operationality</td><td rowspan="2">Flammable, explosive</td></tr>
<tr><td>Gas</td><td>Mass storage is possible.</td><td>NOx, heat</td><td>Excellent operationality</td></tr>
<tr><td>Electricity</td><td>Transmission loss (6 to 7%).
Continuous transmission is possible.
There is no time loss.</td><td>The storage quantity per unit weight is small.
Batteries (the energy density is small)
Pumped storage power generation</td><td>Heat</td><td>Excellent operationality</td><td>Generation efficiency (thermal power) (35 to 40%)
Heater (100%)
Electric motor (85 to 95%)</td><td></td></tr>
<tr><td>Heat</td><td>Short distances because of large loss from thermal conduction and convection.</td><td>The storage quantity per unit weight is small.
Storage in the form of latent heat or sensible heat</td><td>Heat</td><td>A heat source is required at a short distance.
Effective as a low-temperature heat source</td><td></td><td></td></tr>
</table>

Source: "For Realization of an Industrial Structure Vision" by the Industrial Structure Council (1977).

4. Economic Evaluation of Energy Conservation

Various methods have been proposed for evaluation of the economy of investments, and the methods used relatively often are described below.

4.1 Funds recovery period method

$$\text{Funds recovery period} = \frac{\text{Investment amount}}{\text{Annual profit before depreciation}} \text{(years)} \quad (2.1)$$

The above formula does not take into consideration the change of the profit with the passage of time, but it is used often because of its simplicity.

4.2 Method for calculating the present value of the profit

With

$P_1, P_2, ..., P_n$ as the profit before depreciation for the respective year,

i as the interest rate,

V as the present value of the profit,

S as the remaining value, and

I as the investment amount,

the following formula applies.

$$V = \frac{P_1}{1+i} + \frac{P_2}{(1+i)^2} + \frac{P_3}{(1+i)^3} + \ldots\ldots + \frac{P_n}{(1+i)^n} + \frac{S}{(1+i)^n} \quad (2.2)$$

When i is given and n is obtained so that $V = I$ applies, the number of years required to repay the interest is found.

For $P_1 = P_2 = \ldots P_n$ and $S = 0$, the following applies:

$$I = V = P \times \frac{(1+i)^n - 1}{i(1+i)^n} \quad (2.3)$$

$$n = \frac{\log\left(\frac{P}{P - Ii}\right)}{\log(1+i)} \quad (2.4)$$

When the service life n of equipment is given and i is calculated, the investment profit ratio is obtained.

When this value exceeds the present interest rate, the investment can be considered as advantageous.

4.3 Simple investment profit ratio

$$\text{Simple investment profit ratio} = \frac{\text{Annual profit before depreciatioı}}{\text{Investment amount}} \qquad (2.5)$$

Future price increases should be taken into consideration for the energy as the basis for the profit calculation. Also, the energy conservation profit should receive a higher evaluation when the necessity for upgrading a power reception contract, for expansion of incoming and transformation equipment, for additional fuel tanks, and/or for strengthening of environment protection equipment is eliminated by energy conservation investments. Reversely, when the turbine exhaust is used as process steam, this steam can not be evaluated highly. In this way, the energy evaluation must be considered case by case, and simple use of costs, etc. can cause errors.

With the present technological progress and the rapidly changing economic situation, long investment recovery periods include large risks. For equipment planning, measures must be taken to lower the equipment costs as far as possible.

5. Techniques for Rational Use of Energy

5.1 Three Steps for rational use of energy

The rationalization of energy use includes the following steps, and stabilization of the operation is most important from the point of view of energy conservation.

(1) Stable operation

Maintaining the present equipment and operation in good condition (examples: Inspection and repair of defective portions, cleaning, strict observance of work standards, etc.) When a line is stopped because of trouble, the products in the process lose heat, and depending on the case, they may become rejects or may require retreatment. A furnace will cool down and require heating at the time of restart, and the optimum specific productivity can not be obtained until stabilization has occurred after start-up. In this way, operation stop because of trouble is a large factor in energy loss, and together with sufficient maintenance for the equipment, operation standards must be provided and the personnel must be trained to prevent erroneous operation.

(2) Improvement of equipment and operation conditions

Improvement of equipment structure and operation conditions (examples: Intensification of heat exchange, addition of energy conservation equipment, change of heating temperatures, recovery of waste heat, etc.)
In many cases, the existing equipment and the operation philosophy no longer can be called the best because of changes in the energy situation, and a new look must be taken after returning to the fundamentals. Many different viewpoints are possible for improvement, and checking is required with reference to the judgement standard published on the basis of laws.

Cases as shown in Table 4 can be considered for use of recovered waste energy.
In this case, the following items should be considered before thinking about use of waste energy, and sufficient investigations should be executed to prevent equipment waste.

(a) Can the amount of generated waste energy be reduced any further?
(b) Can the waste energy be used within the system?
(c) Can the waste energy be taken out in a more easily usable form?
(d) How can the recovered energy be used? What is the most profitable use method?

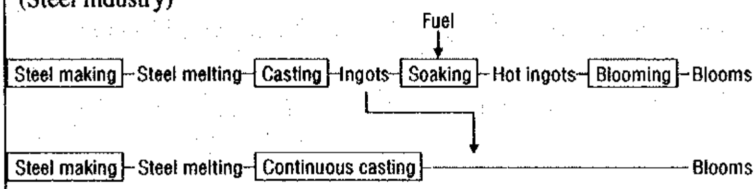
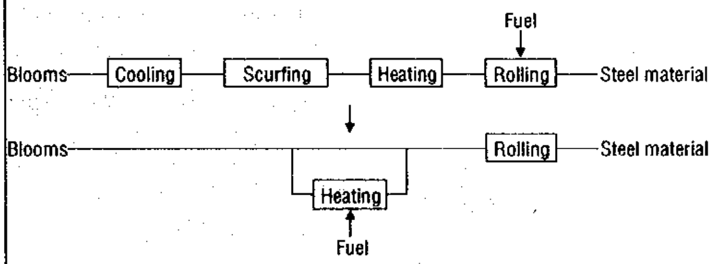
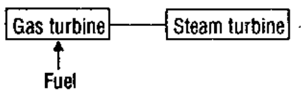
Table 4 Use of Recovered Waste Energy

Classification	Examples
Improved use ratio for by-product gas	Blast furnace gas, converter gas, gas from petroleum decomposition
Use of recovered exhaust pressure	Use of the blast furnace top pressure for generation of electricity, use of petrochemical waste gas turbines to drive compressors
Use of the recovered sensible heat of solids	Dry coke quenching method (use as steam or electricity) Slab cooling boiler (use as steam)
Use of recovered steam drain	(Use as boiler feed water)
Use of cooling water waste heat	Power generation systems using medium- and low-temperatures waste heat, pisciculture, horticulture
Use of exhaust gas waste heat	Waste heat boiler (use as steam) Power generation systems using medium- and low-temperatures waste heat Absorption refrigerating machines
Use of the temperature of LNG	Air separation Power generation

(3) Process and system improvement

Improvement of processes and systems is intended essentially to reduce the parts consuming energy, and a large effect can be expected. Examples are shown in Table 5.

Table 5 Process and system improvement

Item	Example
Elimination of processes	(Steel industry)  
Change to continuous operation	(Chemical plants) Batch distillation → Continuous distillation
Scale increase	
Transport rationalization	Elimination of cross transportation and double transportation Shortening of transport routes Increased lot size
Cascading use	Combined power generation 
Recycling	Blast furnace water-pulverized slag → Blast furnace cement
Use of catalysts and microorganisms	Catalytic deodorization method
Change of the production method	(Steel industry) Open hearth steel making → Converter steel making (Cement industry) Addition of SP or NSP

5.2 Energy conservation by improvement of the overall efficiency of the equipment

The overall efficiency of the equipment is the product of time availability, performance availability, and good product rate, and it is a measure showing how much the present equipment contributes to the time spent for producing added value.

- Time availability $= \dfrac{\text{(Duty time)} - \text{(Down time)}}{\text{(Duty time)}}$

- Performance availability $= \dfrac{\text{(Output)} - \text{(Actual cycle time)}}{\text{(Duty time)} - \text{(Down time)}} \times \dfrac{\text{Theoretical cycle time}}{\text{Actual cycle time}}$

  $= \text{(Net availability)} \times \text{(Speed availability)}$

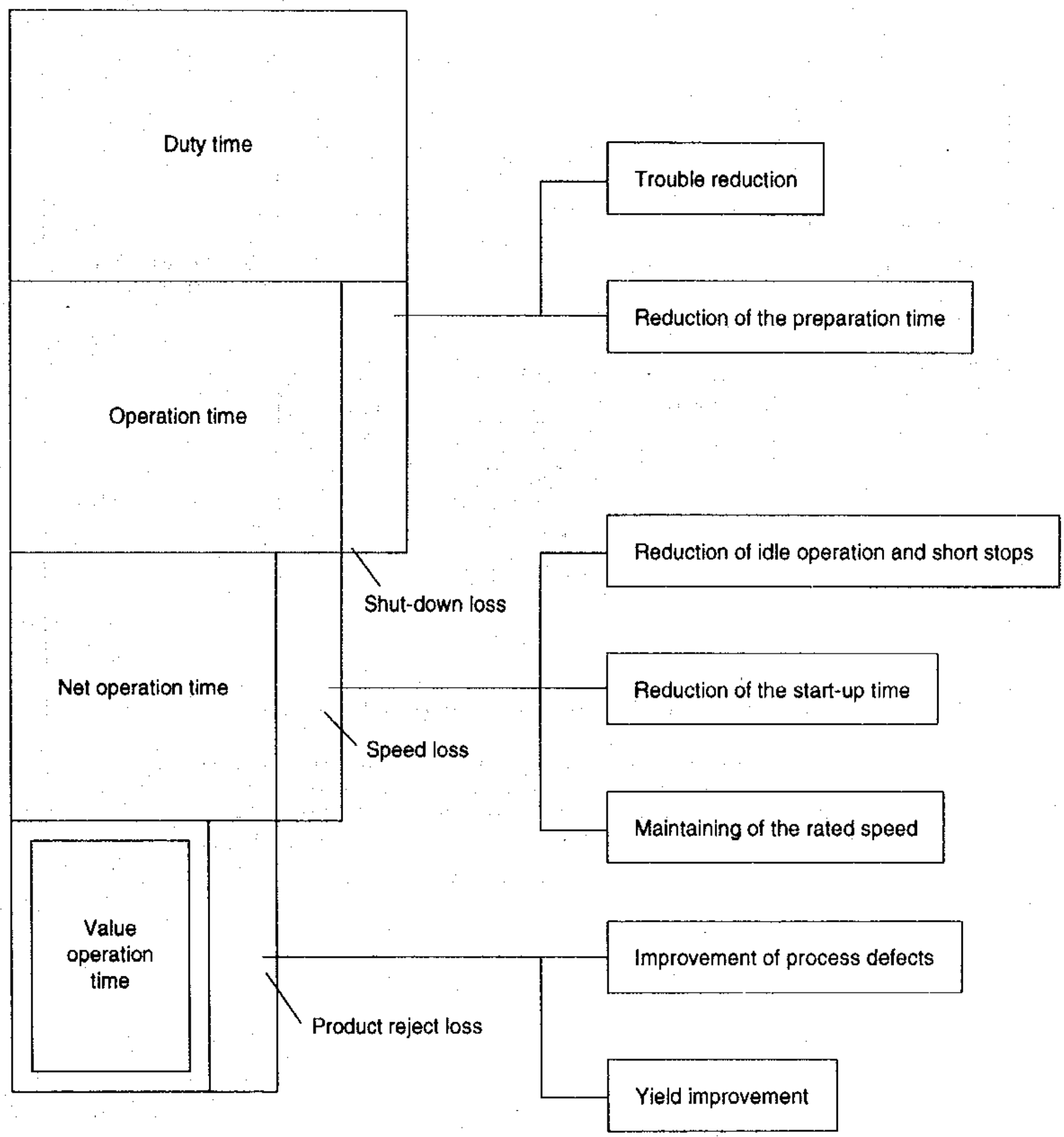
- Good product rate $= \dfrac{\text{Good product quantity}}{\text{Input quantity}}$

Good product quantity = Input quantity – (Start-up reject quantity + repair quantity)

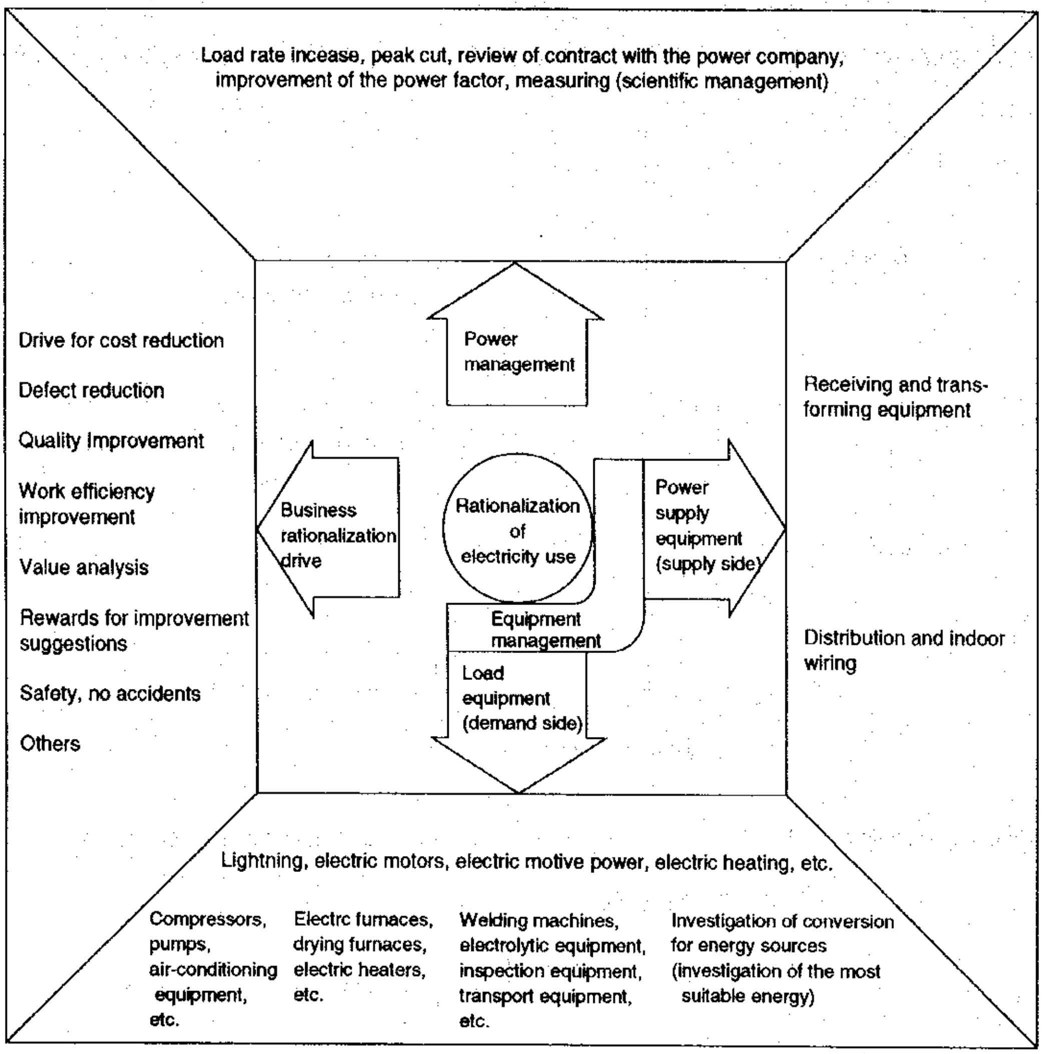
Overall equipment efficiency = Time availability × Performance availability × Good product rate

Energy conservation improvement by improvement of the overall equipment efficiency (promotion of TPM activities)

Overall equipment efficiency = Time availability x Performance availability x Good product rate

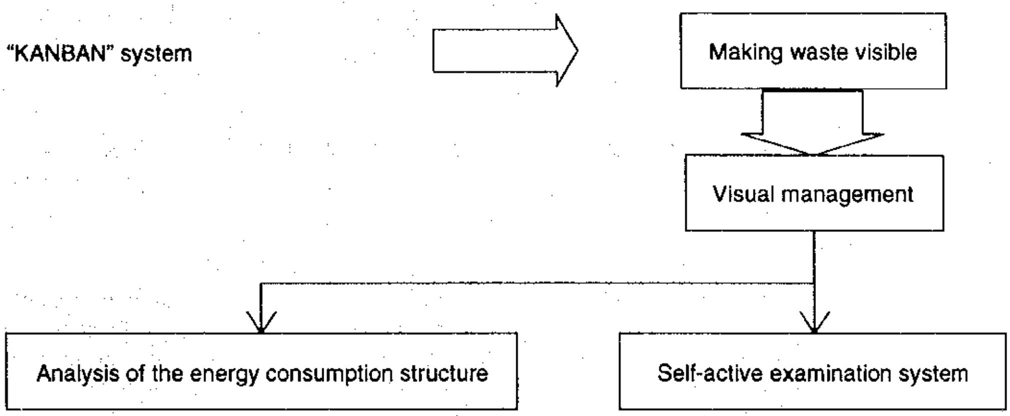


Approaches to rationalization of electricity use



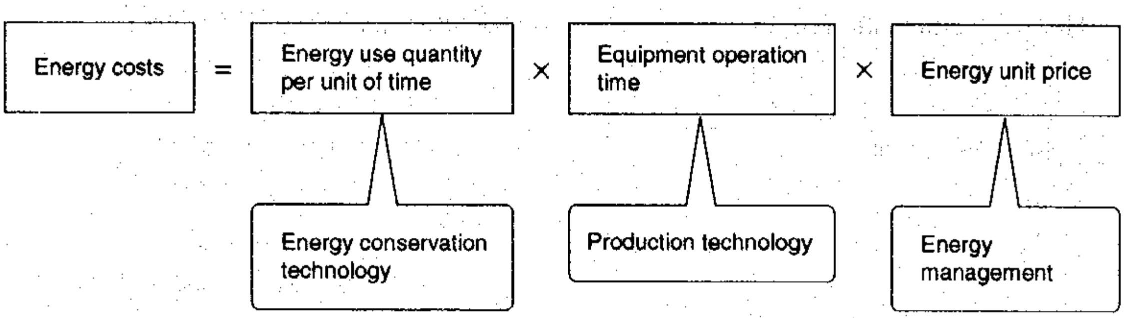
Thorough energy management (execution of the self-active examination system)

1. Thorough elimination of loss as represented by the "Kanban system" of Toyota

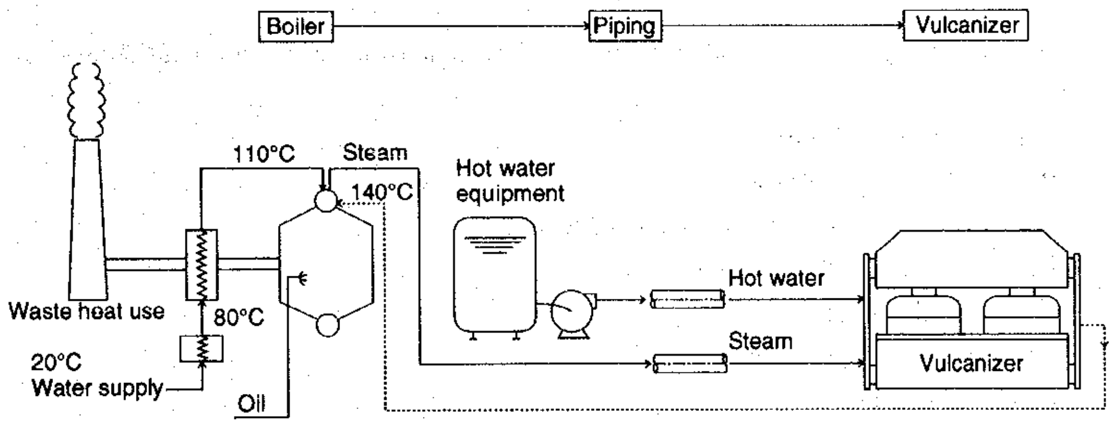


2. Aims
   (1) Prevention of short stops
   (2) Extraction of idle time
   (3) Grasping of fluctuating factors
   (4) Improvement of the equipment operation ratio
   (5) Prevention of careless mistakes
   (6) Energy prediction management
   (7) Reformation of the energy conservation consciousness
   (8) Development of improvement themes

Rationalization of energy use



Most suitable control Variability Prevention of idle running Load reduction Efficiency increase	Automation Synchronization Mobilization Improvement of the equipment operation ratio Speed increase	Improvement of combustion efficiency Demand control Improvement of the load ratio Load averaging



Efficient Production	Efficient transport	Efficient use
Reduction of radiated heat (better thermal insulation)	Reduction of radiated heat (better thermal insulation, most suitable selction of piping size and length)	Reduction of radiated heat (better thermal insulation)
Increased efficiency by use of waste heat (use of exhaust gas, waste hot water)		Development and improvement of the vulcanization method (gas curing, abolishing of cooling water,indirect heating, etc.)

6. 10 Steps for Promotion of Energy Conservation

The most representative method is the standard management method consisting of the following 10 steps.

Step 1: Decide the target.
Step 2: Plan the procedure.
Step 3: Identify the conditions of energy use.
Step 4: Evaluate in terms of money.
Step 5: Collect ideas.
Step 6: Make improvement plans.
Step 7: Evaluate.
Step 8: Carry out.
Step 9: Check.
Step 10: Standardize.

Step 1: Decide the target.

Set the strategic target for energy conservation.

Examples:

(1) Abstract target: Aiming for the best .... equipment in the world
(2) Concrete target: Introduction of heat pumps for waste heat recovery
(3) Absolute value target: Achieving a specific power consumption of __ kWh/t or less
(4) Relative target: Reduction of the specific energy consumption by 10% (in comparison to the preceding year)

Step 2: Plan the procedure.

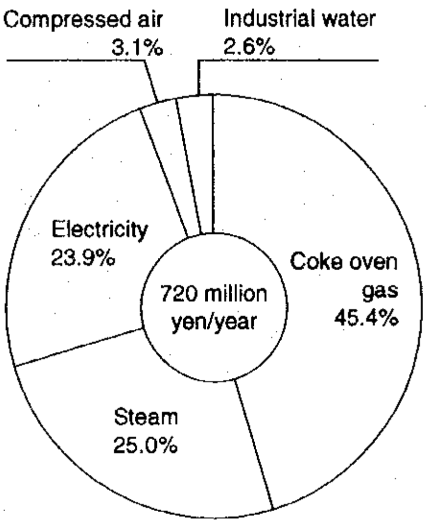
(1) Establish a plan using the 5Ws and 1H.
5Ws: When, Who, Where, What, Why
1H: How
(2) Create a promotion schedule.

Step 3: Identify the energy use condition.

Use various graphs to analyze the energy use condition.

Examples:

(1) Graphs expressing the various energy consumption quantities and energy cost ratios or total amounts (circle graph, bar graph, Pareto's chart)

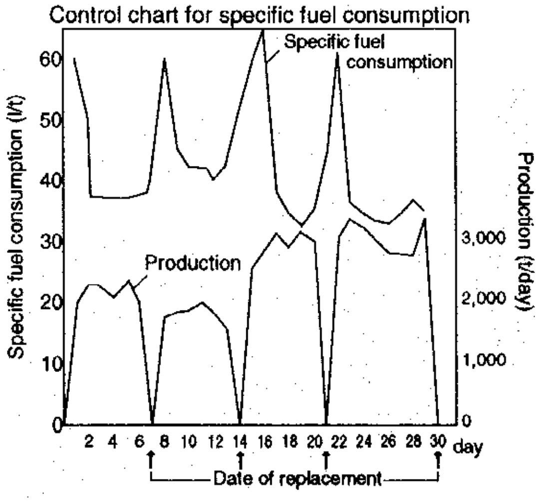


(2) Preparation of control charts showing the change of specific energy consumption

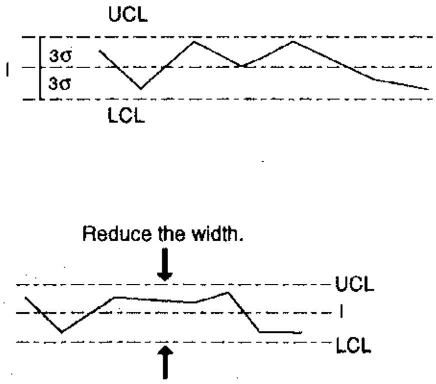
Key points:

- Getting to know scatter (in units of month, week, day, and shift)
- Visualization of the energy conservation results
- Clarify problems.
- Make $\bar{x}$ and σ–(sigma) smaller.

Control chart for specific fuel consumption

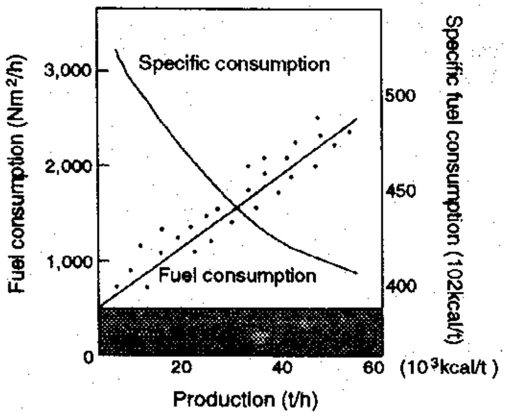


Control chart for specific energy consumption

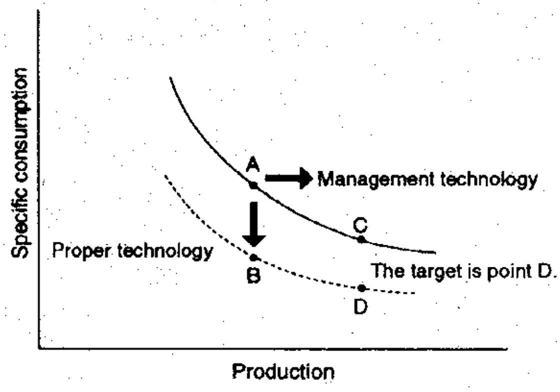


(3) Get to know the variable factors in specific energy consumption.
Draw up a correlation diagram.

Diagram for the correlation between production quality and specific energy consumption

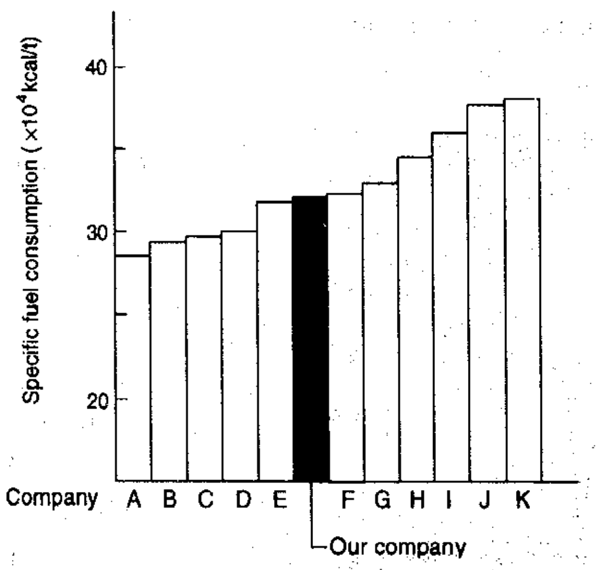


Approach to energy conservation from the correlation diagram



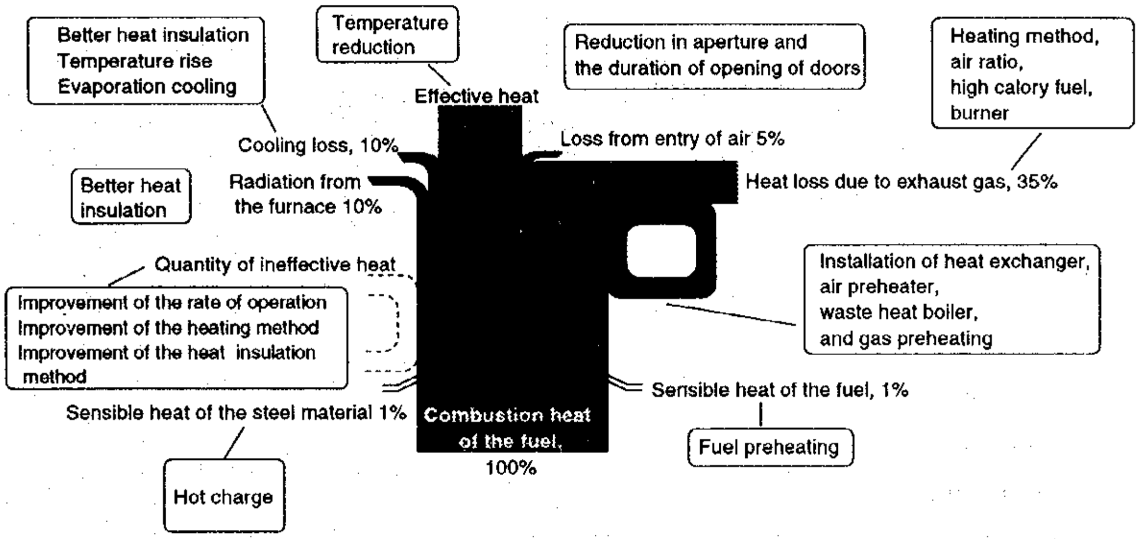
(4) Obtain the specific energy consumption by equipment, products, and product types, and draw up a reverse Pareto chart for comparison with the specific consumption of the competitors.

Reverse Pareto chart



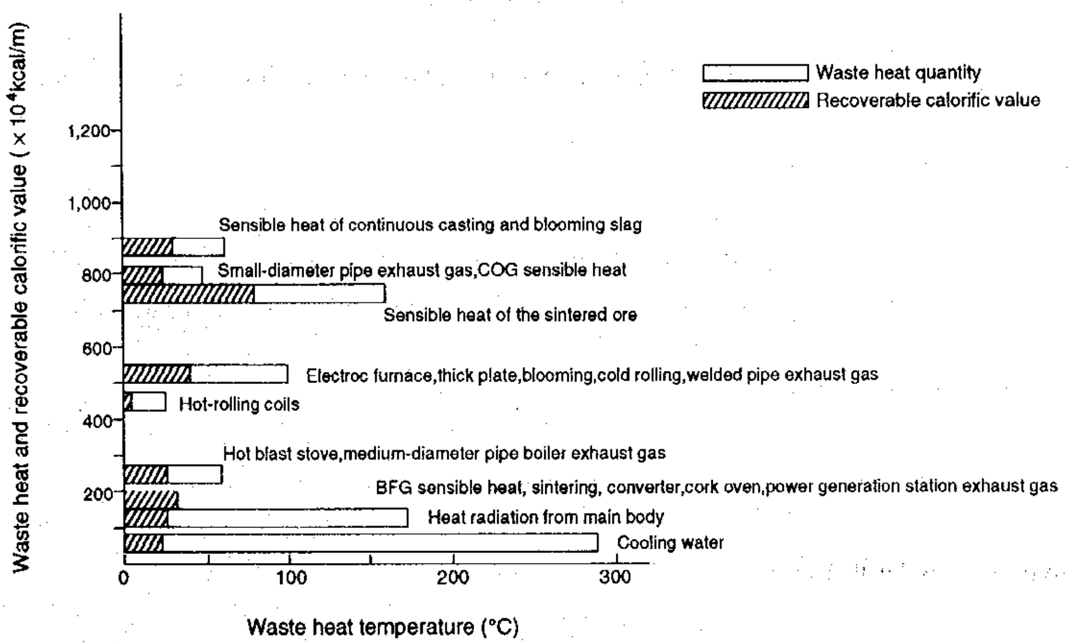
(5) Draw up a heat flow chart (heat balance chart) to get to know the states of heat input (input) and heat output (output).

Energy conservation on the basis of the heat balance

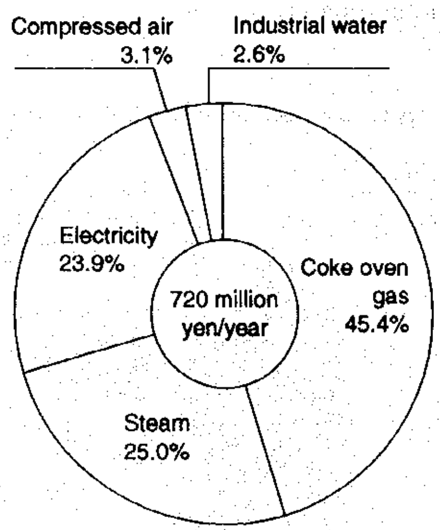


(6) Draw up a graph showing the relation between waste heat and temperature in order to get to know the actual condition of the waste heat (loss).

Actual condition of the waste heat



Step 4: Evaluate the predicted energy conservation effect in terms of money.



Step 5: Collect ideas.

Examples:

(1) Intuition

(2) Brain-storming and cause-and-effect diagrams

(3) KJ method

(4) Conception in terms of VE and VA

(5) IE approach

(6) Use check lists to find themes.

(7) Use the energy conservation MAP method.

Step 6: Classify the improvement plans by theme and draw up an implementation plan.

Step 7: Implement the plan.

Key points:

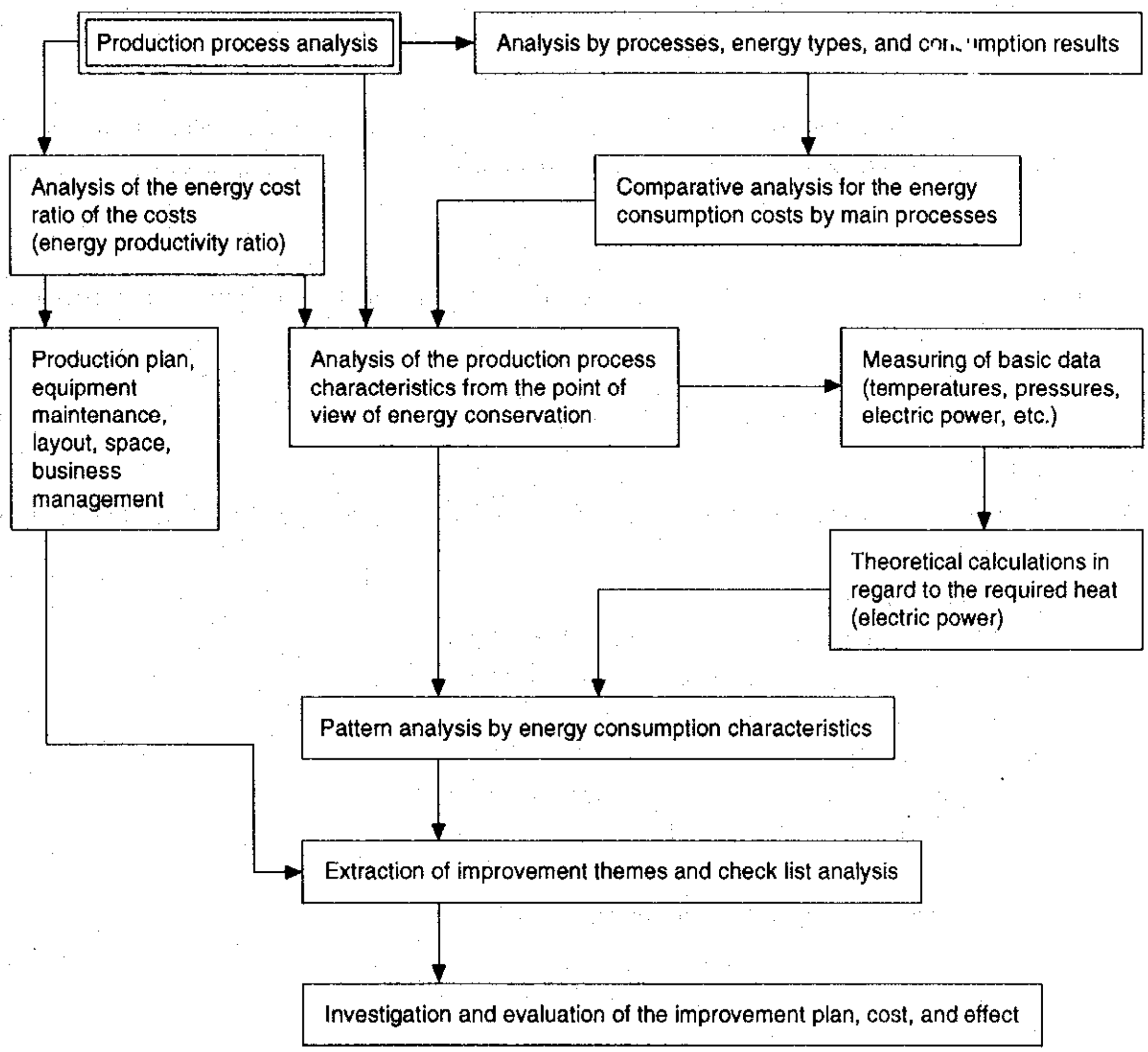
- Actually trying everything is the best way to improve energy conservation.
- Strengthen the management system for checking the execution plan and for follow-up.

Step 8: Identify the results.

Step 9: Evaluation of the improvement activities

Step 10: Standardization

Flow diagram for energy conservation diagnosis, analysis, and countermeasures



7. Example for Standardization of the Energy Conservation Design

Energy Conservation Design Check List

1. Purpose

The purpose of this standardization is aiming for permanent energy conservation at the time of equipment design, as well as design VA and cost reduction by effective energy use.

2. Scope of Application

This standardization applies for new installation, increase, modification, movement, and renovation of all production equipment.

3. Check Items for Energy Conservation Design

3.1 Equipment

3.1.1 Is the energy consumption calculated and entered into the drawings at the time of equipment design?

(1) Steam consumption:	kg/h, t/h
(2) Electricity consumption:	kWh, MWh, kWh/t
(3) Compressed air consumption:	Nm^3/h, Nm^3/t
(4) Industrial water consumption:	m^3/h, m^3/t
(5) Fuel consumption:	kl/h, kl/t, m^3/h
(6) Waste heat loss:	kcal/h, Nm^3/h (at °C)

Note: The peak load also should be entered.

3.1.2 Is the equipment being used with high efficiency?

(1) Introduction of highly efficient equipment
(2) Weight reduction for moving parts (especially rotating parts, etc.)
(3) Simplification and elimination of movement
(4) Use of inertia (springs, etc.)
(5) Minimizing of transport distances
(6) Use of equipment oriented towards energy conservation

3.1.3 Has effective use of natural energies been taken into consideration?

(1) Use of the product weight
(2) Use of the product shape
(3) Use of water head
(4) Use of the weight of moving parts
(5) Natural radiation of the cooling water return flow
(6) Effective temperature use in summer and winter

3.1.4 Has the measuring been optimized?

(1) Is the required instrumentation installed at the required locations?
(2) Are outlets, spare nozzles, etc. installed so that later installation is possible?
(3) Is meaningless measuring being executed?

3.2 Steam

3.2.1 Is the capacity correct?

(1) Heat capacity of the equipment
(2) Economical piping design
(3) Use conditions (temperature, time, etc.) and heat insulation thickness
(4) Has the heat balance been investigated?

3.2.2 Has the use been optimized?

(1) Heating temperature and steam pressure
(2) Heating time
(3) Reduction of the quantity of valves, flanges, steam traps, etc.
(4) Is the piping connected by welding?

3.2.3 Has the thermal insulation been optimized?

(1) Insulation thickness and material
(2) Insulation range
(3) Reduction of the piping length
(4) Independent use of piping exclusively for winter use

3.2.4 Is leakage being prevented?

(1) Appropriate use of steam traps
(2) Reduction of the piping length
(3) Reduction of bypass piping and valves

3.3 Electricity

3.3.1 Is the capacity appropriate?

(1) Reduction of capacity and quantity of transformers, motors, and wiring
(2) Is the capacity of pumps and fans excessively large?
(3) Improvement of the power factor for motors, etc. (installation of power condenser)

3.3.2 Has the use method been optimized?

(1) Automatic start and stop of conveyors, etc.
(2) Is the operation of related equipment and trains interlocked?
(3) Interlocking of main and auxiliary machines
(4) Is the power factor adjusted automatically?

(5) Use of timers
(6) Automatic ON/OFF control for fans, etc. according to the temperature
(7) Improving revolutions and rotation speed
(8) Countermeasures against idle running
(9) Countermeasures against no-load loss

3.3.3 Has the lighting been optimized?

(1) Use of light sources and fixtures with high efficiency
(2) Is the standard luminance being observed?
(3) Effective use of local lighting
(4) Use of natural light
(5) Use of branch switches and individual pull switches
(6) Lower installation height for light sources
(7) Use of automatic ON/OFF switches

3.4 Air

3.4.1 Is the capacity appropriate?

(1) Capacity of compressor and piping
(2) Reduction in the capacity and the quantity of fans and air blowers
(3) Use of small compressors exclusively for the equipment

3.4.2 Has the use been optimized?

(1) Air pressure
(2) Reduction of the number of cylinders
(3) Cylinder diameter and stroke
(4) Use of sponge rollers for water removal

3.4.3 Is leakage being prevented?

(1) Reduction of the number of valves and flanges
(2) Use of non-bleeding solenoid valves and instruments
(3) Shorter piping length
(4) Design change from high pressure to low pressure

3.5 Industrial Water

3.5.1 Is the capacity appropriate?

(1) Is the pump capacity excessively large?
(2) Has the piping size been designed economically?
(3) Is the system closed?
(4) Is water being used wastefully?

3.5.2 Has the use been optimized?

(1) Water pressure
(2) Cylinder diameter and stroke
(3) Have throttle valves for cooling water regulation been installed?
(4) Cascading use

3.5.3 Is leakage being prevented?

(1) Reduction of the number of valves and flanges
(2) Shorter piping length
(3) Main valve installation

3.6 Re-use of Energy

3.6.1 Is waste heat being recovered?

(1) Recovery of steam drain
(2) Flash tank installation
(3) Use of hot well tanks
(4) Use of waste heat gas
(5) Material preheating with waste heat
(6) Use of heat exchangers

3.6.2 Has the energy type been selected?

(1) Use purpose, heating system, and economy
(2) Use of hot water for space heating
(3) Use of the heat discharged by compressors
(4) Use of exhaust pressure
(5) Use of waste oil (as fuel or raw material)

3.7 Use of New Technology and Equipment for Energy Conservation

(1) Heat pumps
(2) Heat pipes