13-10 Measurement Results

The results of measurement and analysis described in this section are categorized as the following five items.

1. Steam boiler and related facilities
2. Steam turbine generator
3. Steam trap system
4. Thermal insulation system
5. Electricity consumption

13-10-1 Steam Boiler and Related Facilities

The monitoring parameters in the boiler system were as follows:

Table 13-15 Monitoring Parameters

1. Air intake	Temperature & Flow rate
2. Flue gas	Temperature & Analysis
3. Fuel consumption	Flow rate
4. Boiler Feed Water	Flow rate, Temperature & Level of Dearator
5. Steam (Total)	Temperature, Flow rate & Pressure
6. Steam (To Steam Accumulator)	Flow rate
7. Steam (To Plate Evaporator)	Flow rate

(1) Air Intake

For audit purposes, air intake data were taken three times. The results are as follows:

Table 13-16 Air Intake Data

Velocity (m/s)	19.20	14.93	17.00
Flow rate (m^3/min)	812.97	632.17	719.81
Temperature 1 (°C)	39.38	38.23	40.23
Temperature 2 (°C)	92.0	-	-

Temperatures 1 & 2 represent the temperatures before and after pre-heater, respectively.

(2) **Flue Gas**

Fuel gas data were taken three times as shown in Table 13-17.

Table 13-17 Flue Gas Data

O_2 (%)	2.1	2.3	2.1
CO_2 (%)	14.3	14.0	14.2
CO (ppm)	45	5	9
Temperature 1 (°C)	374.7	362.4	368.6
Temperature 2 (°C)	231.9	-	-

Temperatures 1 & 2 represent the temperatures before and after pre-heater, respectively.

(3) **Fuel Consumption**

Fuel consumption was measured three times as shown in Table 13-18.

Table 13-18 Fuel Consumption Data

Flow rate (kg/hr)	2588.5	2785.8	2807.0

A sample of the fuel was taken to SIRIM Environmental & Energy Technology Center and the analysis results are as follows:

Table 13-19 Fuel Analysis Data

Parameters	Amount (wt %)
Carbon	83.79
Hydrogen	11.44
Oxygen	2.23
Sulfur	2.05
Nitrogen	0.403
Moisture	0.091

(4) Boiler Feed Water

Data (24/9/98~25/9/98) was obtained from CSR's daily log sheet, as presented below:

Table 13-20 Boiler Feed Water Data

Time	Temperature (°C)		Flow rate (MT/hr)		Dearator level (%)	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
08:00	109.9	109.6	32.50	36.64	69.0	71.2
09:00	110.0	109.8	49.04	47.00	69.5	69.0
10:00	107.8	109.8	44.59	45.58	70.6	70.4
11:00	109.8	109.6	41.07	46.38	70.3	69.3
12:00	109.9	109.8	47.26	46.60	71.1	68.9
13:00	109.7	109.8	41.01	48.90	69.1	70.6
14:00	109.8	109.7	50.72	48.40	69.3	70.7
15:00	109.6	109.7	34.14	28.70	71.0	70.7
16:00	109.8	109.8	52.71	60.28	71.1	70.8
17:00	109.7	109.8	46.04	37.59	69.3	69.1
18:00	109.8	109.6	37.02	44.50	69.3	70.9
19:00	109.5	109.7	51.13	58.05	70.3	68.9
20:00	109.8	109.8	36.25	41.02	70.8	70.1
21:00	109.7	109.8	47.01	41.31	69.0	70.6
22:00	109.0	109.8	42.41	47.73	69.9	69.7
23:00	109.7	109.7	42.01	35.07	69.1	69.5
00:00	109.8	109.8	56.81	54.62	69.0	71.0
01:00	109.7	109.6	63.18	56.05	69.4	69.8
02:00	109.8	109.7	44.99	45.82	69.5	70.8
03:00	109.6	109.6	37.44	43.55	69.4	69.0
04:00	109.7	109.6	51.11	38.48	70.9	71.1
05:00	109.7	109.8	42.04	49.85	70.5	69.1
06:00	109.7	109.8	40.24	44.67	71.3	69.4

(5) Steam Consumption Breakdown

Data was taken on the September 29, 1998 and presented as follows:

Table 13-21 Steam Consumption Data

Time	Total (ton/hr)	To Plate Evaporator (ton/hr)	To Steam Accumulator (ton/hr)	To Turbine (ton/hr)
14:00	32.5	0.0	4.0	28.5
15:00	41.6	0.0	7.7	33.9
16:00	42.3	0.0	7.9	34.4
17:00	48.1	1.0	12.9	34.2
18:00	48.1	1.7	16.9	29.5
19:00	45.5	1.5	11.9	32.1
20:00	43.6	1.7	11.9	30.0
21:00	42.3	1.7	9.4	31.2
22:00	43.2	1.7	8.9	32.6
23:00	45.7	1.3	11.2	33.2
00:00	44.5	1.7	10.9	31.9
01:00	45.1	1.7	10.7	32.7
02:00	46.9	1.7	13.7	31.5
03:00	47.5	0.4	16.9	30.5
AVG	44.06	1.15	11.06	31.87

As Table 13-21 shows, the steam consumption breakdown on average is as follows:

To Plate Evaporator = 1.15 tons/hr (2.6%)
To Steam Accumulator = 11.06 tons/hr (25.1%)
To Power Plant = 31.87 tons/hr (72.3%)

The actual steam consumption, which causes the variation of boiler operation, varies from one hour to another depending on the demand.

(6) Steam (Total)

Table 13-22 High Pressure Steam Data

Time	Temperature (°C)		Flow rate (ton/hr)		Pressure (psig)	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
08:00	281.5	282.0	30.60	34.38	295	300
09:00	281.8	281.7	46.74	44.34	302	300
10:00	281.9	281.9	42.33	43.51	298	300
11:00	281.9	282.3	38.66	43.77	295	300
12:00	281.7	282.3	44.43	44.20	295	300
13:00	281.9	282.0	38.39	45.40	295	300
14:00	281.3	282.0	48.14	45.50	312	300
15:00	282.4	281.5	31.15	27.05	298	298
16:00	282.6	282.4	48.85	57.26	300	298
17:00	282.9	281.8	41.71	35.61	298	298
18:00	282.3	281.9	33.94	41.92	292	300
19:00	281.8	282.9	49.30	55.42	295	310
20:00	283.0	283.1	32.51	38.91	295	300
21:00	282.4	282.9	43.10	39.42	295	300
22:00	282.4	282.8	40.27	45.45	298	300
23:00	282.0	283.1	38.94	33.16	295	300
00:00	281.7	282.3	53.84	51.24	310	300
01:00	281.6	282.3	39.70	52.90	310	300
02:00	282.1	282.4	60.28	43.37	308	300
03:00	282.0	282.2	37.56	40.93	310	306
04:00	282.0	282.0	48.67	36.74	310	305
05:00	282.2	282.9	39.46	47.49	300	310
06:00	281.2	282.9	37.90	41.44	300	300

(7) Air Ratio Calculation

For calculation purposes, there are 3 different formulae used including the above-mentioned formula:

Formula 1 λ = Actual Air / Theoretical Air

$\approx 21 / (21-(\text{Percentage of } O_2 \text{ content in flue gas}))$

$= 21 / (21-2.3) = 1.123$

Formula 2 λ = Actual Air Quantity / Theoretical Air Quantity

$= A / Ao = 1.136$

but, A $= v_{air}.A.(273/273+\theta) / Q_{fuel}$ (Nm^3/kg_{fuel})

$= 14.93*0.706*3600*(273/(273+39.38))/ 2785.8=11.89$

and, Ao $= 8.89C + 26.7(H-O/8) + 3.33S$ (Nm^3/kg_{fuel})

$= 8.89*0.8379+26.7(0.1144-0.0223/8)+3.33*0.0205 = 10.497$

where, v_{air} = air intake velocity (m/s)

A = air intake area (m^2)

θ = air intake temperature (°C)

Q_{fuel} = fuel intake flowrate (kg/hr)

C, H, O and S = elementary analysis of fuel in fraction

Formula 3

$$\lambda = 1 + \frac{(CO_2-0.5CO)}{\{1.867C+5.6(H-O/8)+0.7S\}x\{(CO_2 + (O)/(1.867C+0.7S)\}}$$

$=1+(0.143-0.5*0.000045)/(1.867*0.8379+5.6*(0.1144-0.0223/8)+0.7*0.0205)/((0.143+0.0223/(1.867*0.8379+0.7*0.0205))$

$= 1.416$

where, CO_2 = percentage of CO_2 gas in the flue gas (%)

CO = percentage of CO gas in the flue gas (%)

C, H, O and S = elementary analysis of fuel in fraction

For further calculation, the result value of formula 2 is applied.

(8) Heat Loss from Flue Gas

Heat loss from flue gas is calculated as follows.

$lg = (Lg/Hl) \times 100[\%] =(800/10632)*100=7.5\%$

$Lg = [G_0 +(m-1) \times A_0] \times Cg \times (Tg-To)$

$=(11.168+(1.136-1)*10.497)*0.33*(231.9-39.38)=800$

$Go = 0.79Ao + 1.867 \times C + 11.2 \times H + 0.7 \times S + 1.24 \times W + 0.8 \times N$

$= 0.79*10.497+1.867*0.8379+11.2*0.1144+0.7*0.0205+1.24*0.00091+0.8*0.00403$

$=11.168$

where, H1 = lower heating value of fuel

$=8100*0.8379+34000(0.1144-0.0223/8)+2500*0.0205$

$=10632$

m = air ratio

Cg = 0.33 [kcal/Nm3 x °C

Tg = flue gas temperature, °C

To = ambient temperature, °C

C, H, N, S, O and W = elementary analysis of fuel in fraction

13-10-2 Steam Turbine Generator

There is a total of 4 steam turbine generators in this factory, and No.4 generator is in operation now. Figure 13-7 illustrates the main flow diagram for the turbine generator and Table 13-23 shows the operational data for the turbine generator No.4, read on September 23 through 25, 1998. Since there is no steam flow meter around the generator, the inlet steam flow rate should be estimated through balancing the operational data around the steam boiler measured on September 29 and 301998.

13-10-3 Steam Trap System

64 steam traps in operation were investigated out of 90 traps installed in steam piping and steam-consuming facilities. The types of steam traps are categorized into two, DISC and FLOAT type. Table 13-24 presents the arrangement of steam traps in the whole plant site.

Table 13-24 Arrangement of Steam Traps by Type

Area / Type	Float	Disc	Total	Remarks
Boiler #4	5	4	9	
Boiler #3	2	3	5	Not operation; 5
Boiler #1 & #2	0	3	3	Not operation; 3
High Pressure Header	0	4	4	
Steam line (ex-HP header to Store)	0	4	4	
Steam line (old line)	0	3	3	Not operation; 3
Steam line (CO2 receiver)	0	3	3	
Steam line (accumulator)	0	3	3	
Steam line (B1B2 flash tank)	0	2	2	
Steam line (dearator)	1	1	2	
Turbine #4	1	3	4	
Turbine #3	0	4	4	Not operation; 4
Steam Separator (behind TG#1,2)	2	0	2	
Beside Steam Separator (TG#1,2)	1	2	3	Not operation; 3
Affination Station	1	1	2	
Clarification (carbonator line)	1	0	1	
Clarification (melter #2,3 line)	0	1	1	Not operation; 1
Crystallization Station	21	5	25	
Curing Station	8	1	9	
TOTAL	43	47	90	

(1) Investigation Procedure

Investigation procedure is as follows.

1) Observation of steam piping layout and steam traps

2) Identification of steam traps installed and specification

- Trap location diagram to show the location of traps and other pertinent equipment.

3) Formulation of coding system for the types of steam traps and area location

- Area numbers and trap numbers to ensure the efficiency of trap management

4) Justifying the steam traps and tagging

- Easier visual identification of traps in the factory

5) Measurement by the steam trap checker

6) Analyzing the Data

- Failure analysis by trap type, by area and by results
- Analysis by the amount of steam leakage and monetary loss

(2) Analysis of Malfunctioning Steam Traps

Table 13-25 shows the summarized failure analysis, including the estimated monetary loss resulting from steam leakage from malfunctioning traps

The measurement result shows that 30 traps are working well and 31 traps are malfunctioning, while 3 traps are not in service.

Table 13-25 Summarized Failure Analysis of Steam Traps

Malfunction Category	Good	Failed	No service	Total	Monetary Loss (US$/year)
Good	30	0	0	30	0
Leaking	0	9	0	9	2,757
Blowing	0	1	0	1	1,356
Low Temperature	0	14	0	14	0
Blocked	0	7	0	7	0
No Data	0	0	3	3	0
TOTAL	30	31	3	64	4,113

Table 13-26 shows the total steam trap analysis data. Figure 13-8 illustrates the analysis on malfunctioning traps by type and malfunction categories.

Here the functioning conditions of the steam traps are classified into seven, that is, 'Leak (Small)', 'Leak (Medium)', 'Leak (Large)', 'Blowing', 'Low temperature', 'Blocked' and 'Good'.

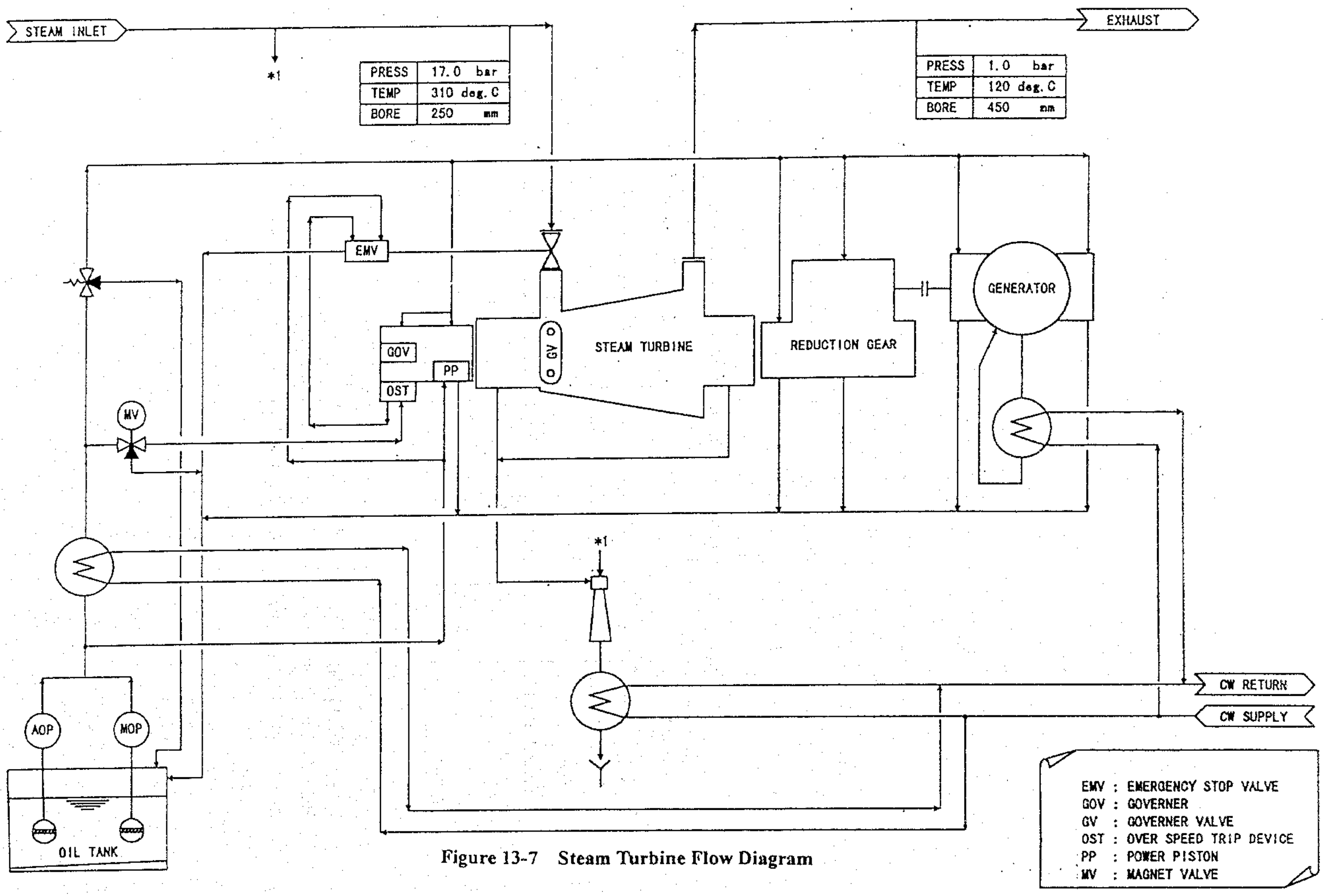


Figure 13-7 Steam Turbine Flow Diagram

Table 13-23 Operation Data for Steam Turbine Generator

Equipment No. Turbine Generator No.4

Date /Hours	Inlet Steam			Extracted Steam			Steam Released to Atm.			Condensed Steam			Turbine	Generator					
	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Flow Rate (kg/h)	Temp. °C	Pressure (bar)	Speed (rpm)	Speed (rpm)	Output (kW)	Volt	Ampere (A)	Power Factor	Cumulative Output (KWh)
Design Spec.	38,200	310.0	17		120	1							6,545	1,800	3,500	3,300	765		
23/9/98																			
10.00 am	NA	277.7	17.2	NA	112	0.55	0	NA	NA	102	69	Atm	6,600	1,815	2,810	3,340	615	NA	6,480,800
12.00 pm	NA	277.8	17.2	NA	112	0.50	0	NA	NA	NA	78	Atm	6,614	1,819	2,790	3,340	560	NA	NA
2.30 pm	NA	277.4	17.4	NA	113	0.58	0	NA	NA	NA	NA	Atm	6,621	1,821	2,680	3,240	550	-0.93	NA
4.30 pm	NA	277.7	17.6	NA	112	0.58	0	NA	NA	NA	NA	Atm	6,636	1,825	2,960	3,270	597	-0.93	6,499,100
Average		**277.65**	**17.3**		**112**	**0.55**	**0**			**102**	**74**	**Atm**	**6,618**	**1,820**	**2,810**	**3,298**	**581**	**-0.93**	**2,815**
24/9/98																			
10.00 am	NA	277.9	17.2	NA	113	0.6	0	NA	NA	NA	NA	Atm	6,600	1,815	2,700	3,340	558	-0.95	6,548,700
12.00 pm	NA	277.8	17.2	NA	113	0.5	0	NA	NA	NA	NA	Atm	6,600	1,815	3,080	3,320	498	-0.94	NA
2.30 pm	NA	278	17.2	NA	113	0.55	0	NA	NA	NA	NA	Atm	6,618	1,820	2,720	3,370	530	-0.89	NA
4.30 pm	NA	277.9	17.2	NA	113	0.59	0	NA	NA	NA	NA	Atm	6,632	1,824	2,800	3,340	570	-0.92	6,566,900
Average		**277.9**	**17.2**		**113**	**0.56**	**0**			**NA**	**NA**	**Atm**	**6,612**	**1,819**	**2,825**	**3,343**	**539**	**-0.93**	**2,800**
25/9/98																			
10.00 am	NA	277.4	16.7	NA	113	0.5	0	NA	NA	NA	NA	Atm	6,610	1,818	2,670	3,370	500	-0.97	6,615,900
12.00 pm	NA	278.1	17.2	NA	113	0.55	0	NA	NA	NA	NA	Atm	6,629	1,823	3,300	2,900	521	-0.95	NA
2.30 pm	NA	277.1	17.7	NA	113	0.55	0	NA	NA	NA	NA	Atm	6,614	1,819	2,860	3,410	525	-1.00	NA
4.30 pm	NA	277.5	17.2	NA	113	0.58	0	NA	NA	NA	NA	Atm	6,629	1,823	2,890	3,310	535	-0.94	6,633,900
Average		**277.53**	**17.2**		**113**	**0.55**	**0**			**NA**	**NA**	**Atm**	**6,620**	**1,821**	**2,930**	**3,248**	**520**	**-0.96**	**2,769**

Table 13-26 Total Steam Trap Analysis Data

Trap No.	Type	Model	Size (mm)	Failure Mode	Leak Level	Surface Temp.(°C)	Steam Loss(t/y)	Monetary Loss($/y)	Drain Recovery
A10-00001	DISC	TD42	20	Leak(S)	2	154	23	185	No
A10-00002	DISC	TD42	20	Good	0	135	0	0	No
A10-00003	FLOAT	FT20	20	Low temp	0	80	0	0	No
A10-00004	DISC	TD42	20	Leak(S)	4	165	33	263	No
A10-00005	DISC	TD42	20	Leak(M)	10	161	60	470	No
A10-00006	FLOAT	FT20	20	Leak(L)	11	94	83	655	No
A10-00007	DISC	TD42	20	Good	0	137	0	0	No
A10-00008	DISC	TD42	20	Good	0	141	0	0	No
A10-00009	FLOAT	FT20	20	Low temp	0	56	0	0	No
A40-00001	DISC	TD32F	25	Blocked	0	34	0	0	Yes
A40-00002	DISC	TD42	25	Leak(L)	14	142	84	661	Yes
A40-00003	DISC	TD32F	25	Low temp	0	76	0	0	No
A40-00004	DISC	TD42	25	Blowing	15	146	172	1,356	No
A50-00001	DISC	TD3-7	20	Blocked	0	34	0	0	No
A50-00002	DISC	1/2-TD42	20	Good	0	152	0	0	No
A50-00003	DISC	TD42	15	Good	0	142	0	0	No
A50-00004	DISC	TD42	25	Blocked	0	32	0	0	No
A71-00001	DISC	TD42	25	Blocked	0	38	0	0	No
A71-00002	DISC	TD42	25	Blocked	0	36	0	0	No
A71-00003	DISC	TD42	25	Leak(S)	1	79	11	87	No
A72-00001	DISC	TD42	25	Leak(S)	1	75	15	115	No
A72-00002	DISC	TD42	25	Leak(S)	2	150	29	226	No
A72-00003	DISC	TD42	20	No Service					No
A73-00001	DISC	TD42	15	Good	0	116	0	0	No
A73-00002	DISC	A46R		Good	0	75	0	0	No
A80-00001	DISC	TD32F	20	Low temp	0	64	0	0	No
A80-00002	FLOAT	FT10-4.5	20	Good	0	73	0	0	No
B10-00001	DISC	TD42	20	Blocked	0	32	0	0	No
B10-00002	DISC	TD32F	20	Leak(S)	1	72	12	95	No
B10-00003	FLOAT	UNA-26H	50	Good	0	160	0	0	No
B10-00004	DISC	TD42	20	Low temp	0	49	0	0	No
B30-00001	FLOAT	FT20	25	Low temp	0	85	0	0	No
B30-00002	FLOAT	FT20	25	Low temp	0	64	0	0	No
C10-00001	FLOAT	FT10-4.5	50	Low temp	0	52	0	0	No
C20-00001	FLOAT	FT10-4.5	50	Good	0	79	0	0	No
D10-00001	FLOAT	FT20	25	Good	0	83	0	0	No
E20-00001	FLOAT	GM8	100	Good	0	71	0	0	Yes
E20-00002	FLOAT	GM8	100	Good	0	81	0	0	Yes
E20-00003	FLOAT	GM8	100	Good	0	68	0	0	Yes
E20-00004	FLOAT	GM8	100	Good	0	75	0	0	Yes
E20-00005	FLOAT	GM8	100	Good	0	86	0	0	Yes
E20-00006	FLOAT	GM8	100	Good	0	74	0	0	Yes
E30-00001	FLOAT	FT10-015	100	Good	0	82	0	0	No
E30-00002	FLOAT	FT10-015	100	Good	0	80	0	0	No
E30-00003	FLOAT	FT10-10	25	Good	0	79	0	0	No
E30-00004	FLOAT	FT10-10	25	Good	0	74	0	0	No
E40-00001	FLOAT	FT10-14	25	Good	0	78	0	0	Yes
E40-00002	FLOAT	FT10-14	25	No Service	0		0	0	Yes
E50-00001	FLOAT	FT46	25	Good	0	75	0	0	Yes
E50-00002	FLOAT	FT46	25	Good	0	73	0	0	Yes
E50-00003	FLOAT	FT46	25	Good	0	79	0	0	Yes
E50-00004	FLOAT	GM8	100	Low temp	0	45	0	0	Yes
E50-00005	FLOAT	GM8	100	Good	0	66	0	0	Yes
E50-00006	FLOAT	FT46	25	Good	0	80	0	0	Yes
E60-00001	FLOAT	FT16	25	Good	0	91	0	0	No
E90-00001	DISC	FT10-1	25	Good	0	83	0	0	No
Ex0-00001	DISC	TD32F	25	Low temp	0	43	0	0	Yes
F10-00001	FLOAT	FT10-1	25	Low temp	0	70	0	0	No
F10-00002	FLOAT	FT10-1	25	No Service					No
F20-00001	FLOAT	FT11-14	25	Good	0	122	0	0	No
F30-00001	FLOAT	FT14-020	20	Low temp	0	75	0	0	Yes
F40-00001	FLOAT	GM2	50	Low temp	0	52	0	0	Yes
F40-00002	FLOAT	GM2	50	Blocked	0	38	0	0	Yes
F40-00003	DISC	TD3-2	20	Low temp	0	68	0	0	No

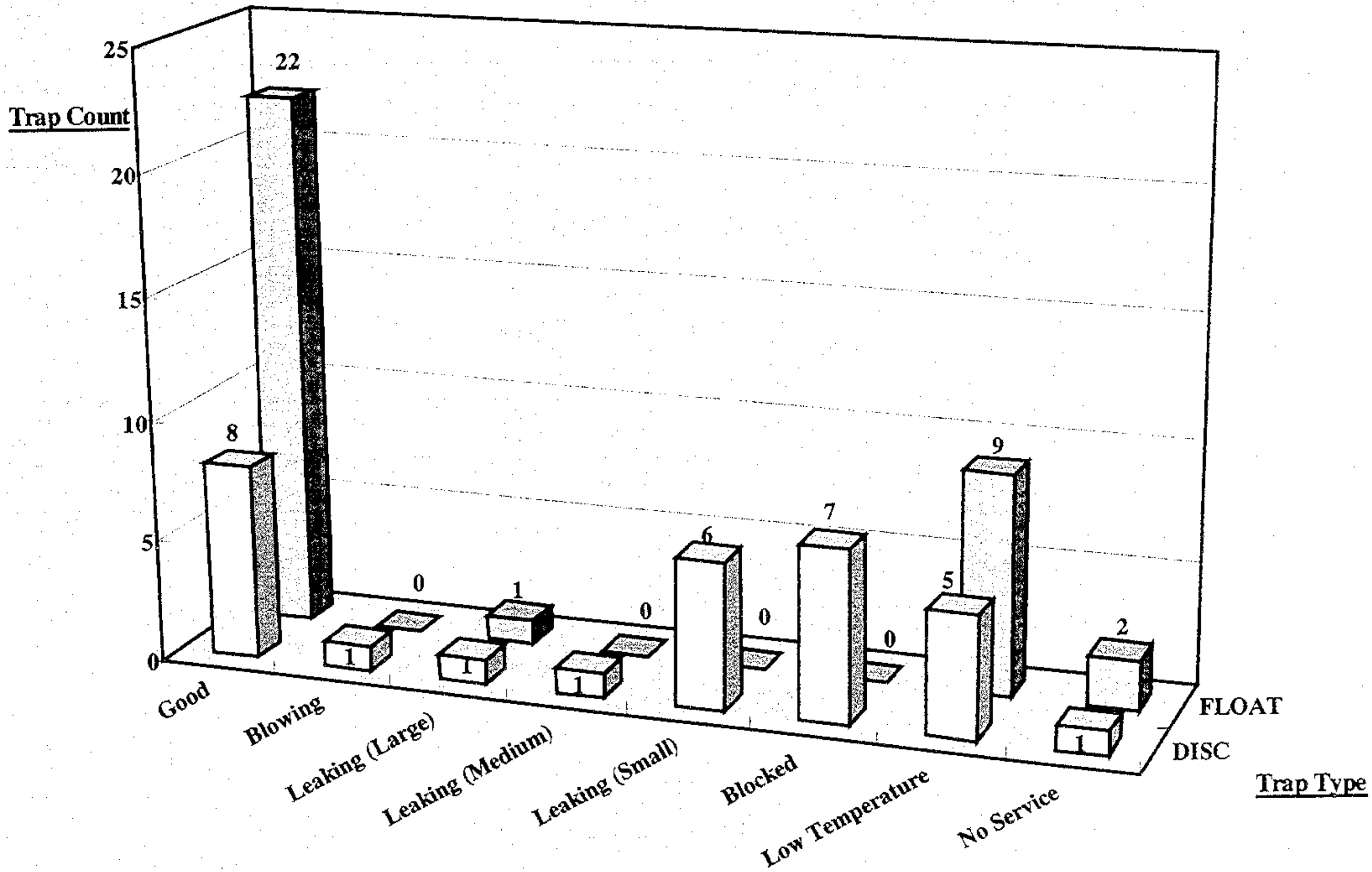


Figure 13-8 Steam Trap Failure Analysis

13-10-4 Thermal Insulation System

Thermal insulation conditions of steam piping were checked along the main steam lines. Heat losses from each steam line were estimated using the heat loss calculation equation mentioned in section 13-9-6. The results are summarized in Table 13-27.

Table 13-27 Heat Loss from Steam Main Line

Line	Rated Flow rate (t/hr)	Steam Pipe O.D (mm)	Steam Pipe Length (m)	Insulation Material	Insulation Thickness (cm)	Heat Loss, Q (kcal/hr)	Steam Loss (kg/hr)	Steam Loss (%)
Pressure: 17 bar Steam Temperature: 280 °C Atmospheric Temperature: 33 °C								
Boiler #4 to HP Header	50.0	250	50	rock wool	5.0	10,770	15.1	0.030
HP Header to T.G #4 a)	38.5	250	27	rock wool	5.0	5,816	8.1	0.021
Pressure: 11 bar Steam Temperature: 260 °C Atmospheric Temperature: 33 °C								
HP Header to Plate Evaporator	5.0	100	90	rock wool	3.8	10,133	14.3	0.286
HP Header to Accumulator b), c)	5.0	250	85	calcium silicate	5.0	18,041	25.5	0.510
Pressure: 0.5 bar Steam Temperature: 110 °C Atmospheric Temperature: 33 °C								
T.G #4 to LP Header d)	38.5	400	26	calcium silicate	5.0	2,516	3.9	0.010
LP Header to Vacuum Pan e)	30.0	600	70	calcium silicate	5.0	9,780	15.0	0.050
LP Header to Vertical Shelf Dryer e)	5.3	50	20	rock wool	2.5	474	0.7	0.014
LP Header to Melter #1 e)	Not known	250	35	rock wool	5.0	1,779	2.7	N.A
LP Header to Melter #2,3 e)	Not known	200	40	rock wool	5.0	1,691	2.6	N.A
LP Header to Steam Header for Evaporators e)	5.7	250	50	rock wool	5.0	2,542	3.9	0.069
LP Header to Molasses Plate Heater e)	1.5	100	25	rock wool	3.8	748	1.2	0.077
TOTAL						64,290		

Applied Heat Conductivity Value for Insulation Material

	110 °C	260 °C	280 °C
Calcium Silicate;	0.0485	0.0547	0.0557
Rock Wool ;	0.0376	0.0490	0.0507

Note:
a) = abnormal surface temperature (120 °C) was observed at this line
b) = No insulation at expansion joint
c) = No insulation at flow meter
d) = No insulation at a small section of straight pipe
e) = No insulation for valves around LP header

13-10-5 Electricity Consumption

(1) Measurement of Power Supply and Distribution System

This factory has one turbine generator to supply the entire power demanded at the sugar plant. Electric power consumption was measured at each point, as illustrated in Figure 13-6. Table 13-28 shows the main electrical equipment connected to each line.

(2) Major Motors

This factory has installed about 426 motors, which are classified by rated capacity as follows.

1) less than 10 kW	270
2) 10 – 30 kW	91
3) 30 – 50 kW	27
4) 50 – 100 kW	14
5) more than 100 kW	24

Electric power consumption for the biggest motor, the cooling water pump, is shown in Figure 13-9. Power factor for the motor was kept at 0.9 or more during the measurement.

(3) Generated Power Profile

Figure 13-10 shows the generated power consumption measured hourly on September 29, 1998. Output power fluctuates between 2,800 and 3,200 kW just to accommodate the plant power demand.

Power factor at the supply end was manually kept at 0.8 or higher.

(4) Power Profile for Air Compressor and Centrifuge

Figure 13-11 and Figure 13-12 give a detailed view of power consumption trends in the air compressor and TSK centrifuge, respectively.

There were some fluctuations due to the frequent load-unload operation.

Table 13-28 Electrical Equipment Service

ITEM	No. 1 Transformer(H1)	No. 2 Transformer(H2)	No. 3 Transformer(H3)	No. 4 Capacitor	No. 5 Transformer(H5)
Service	(1) Dryer Panel (2) Centrifugal x3 (3) 2-Warm Water Return Pumps	(1) Vacuum pump (#4-6) x3 (2) Curing (3) Evaporator (4) Dryer #B8 #C Panel x 2	(1) 50 Hp pump #1,#2	600 KVAR	(1) Boiler #1 & #2 (2) lighting
	No. 6 Transformer(H6)	No. 7 Transformer(H7)	No. 8 Transformer	No. 9 Capacitor	No. 12
	(1) Boiler #3 (2) Boiler #4	(1) Welding Set Panel (2) Warm Water Pump for Press Steel Tank (3) VOO Agitator (4) KONTI 88 Konti 10 (5) D & E Sugar Line (6) 4, 375KVA, 1500 KVA T/G Back up Power (7) L2 ASEA (8) L2 TSK x2 (9) TESTING (10) PTS	(1) MCCB (2) TSK #1 (3) TSK #2 (4) TSK #3 (5) TSK #4 (6) Dryer "A" Panel	300 KVAR No. 10 Capacitor 150 KVAR No. 11 Capacitor 150 KVAR	75 KW Vacuum pump No. 13 75 KW Vacuum pump
	No. 14 Transformer	No. 15 Transformer	No. 16 transformer	No. 17 Capacitor	
	(1) CO2 PLANT (2) TANAKA FUGAL (3) ASEA FUGAL (4) TSK FUGAL (5) Air compressor (6) Cooling Fan Motor (7) Clarification Juice Pumps	(1) Ice D/B (2) Workshop Eng. (3) Water Treatment Plant (4) New Store D/B (5) Battery Charger (6) Washing Machine Station	(1) Cryst. Seed Mixer (2) Cryst. 1 - 8 Mixer (3) Cryst. 9 - 11 Mixer (4) Lighting D/B (5) Aff. Mixer (6) 50 Kg Pacing Station (7) Auto Pelletizer (8) 1 Ton Packing (9) Prepack Machine (10) Dust Collector	600 KVAR	

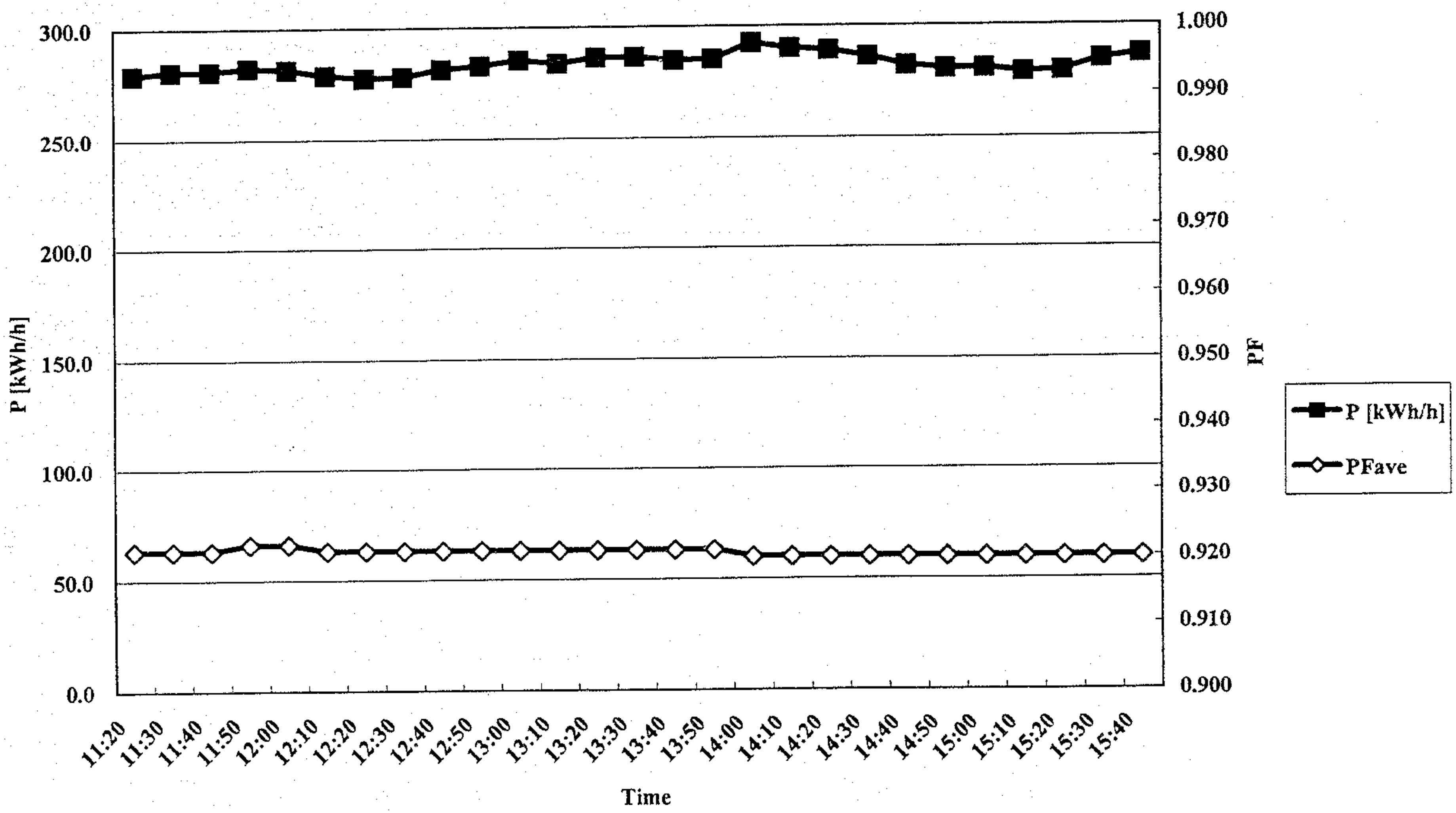


Figure 13-9 Power-Power Factor for Cooling Water Pump

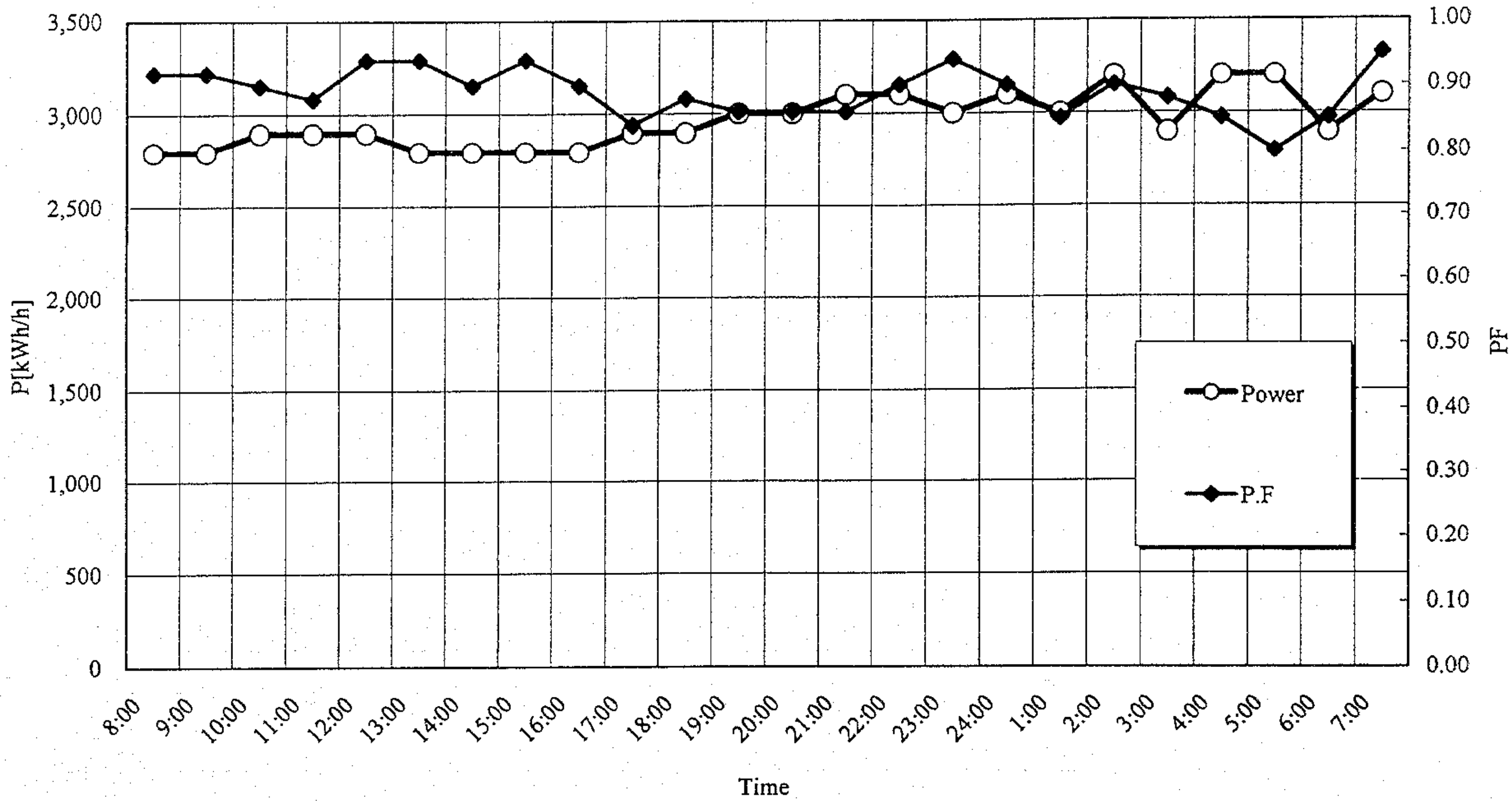


Figure 13-10 Electricity Consumption - Power and Power Factor at TG #4 Output (29 Sep. 1998)

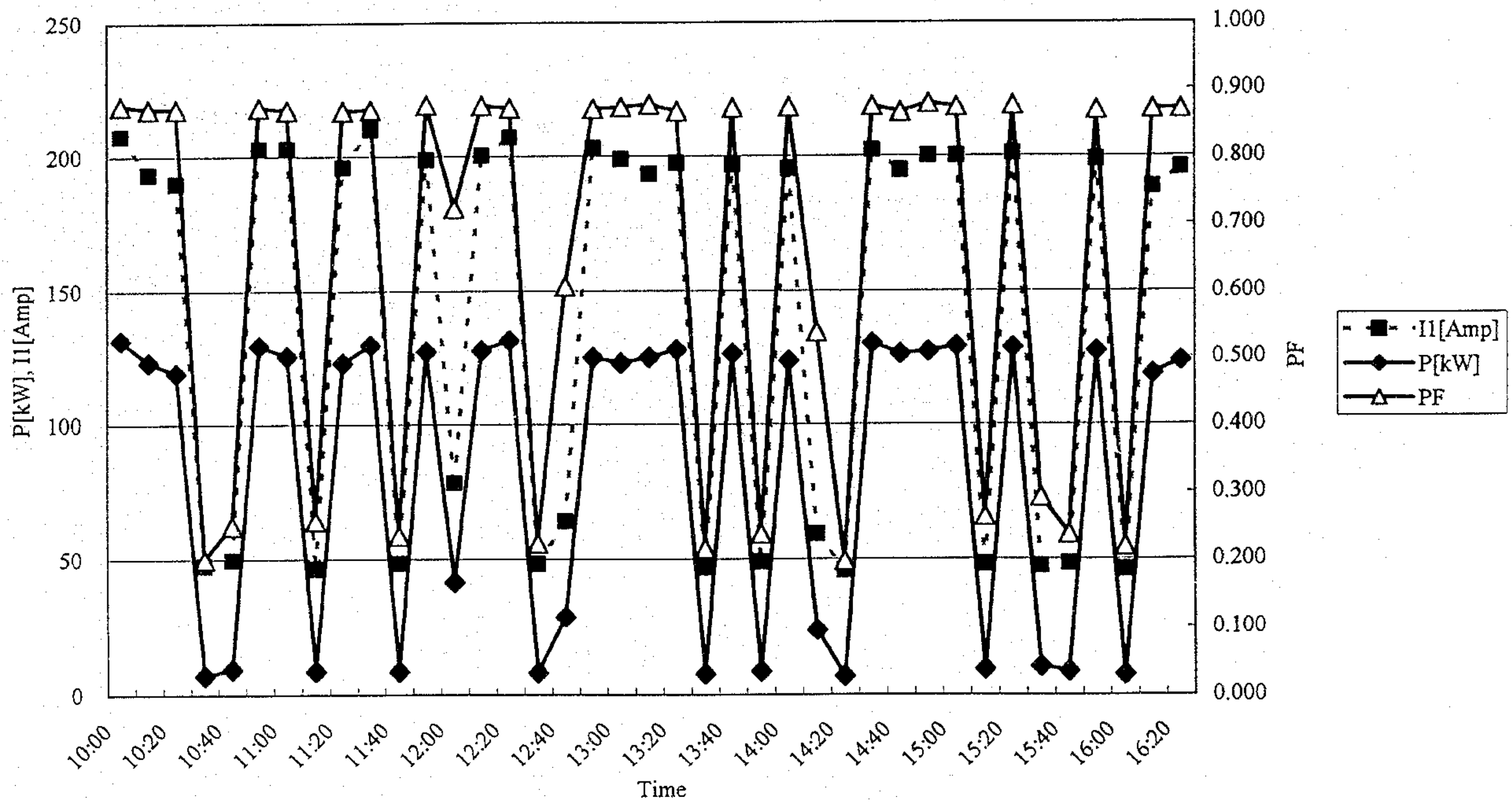


Figure 13-11 Electricity-Amp.-Power Factor for Air Compressor (Temporary Data)

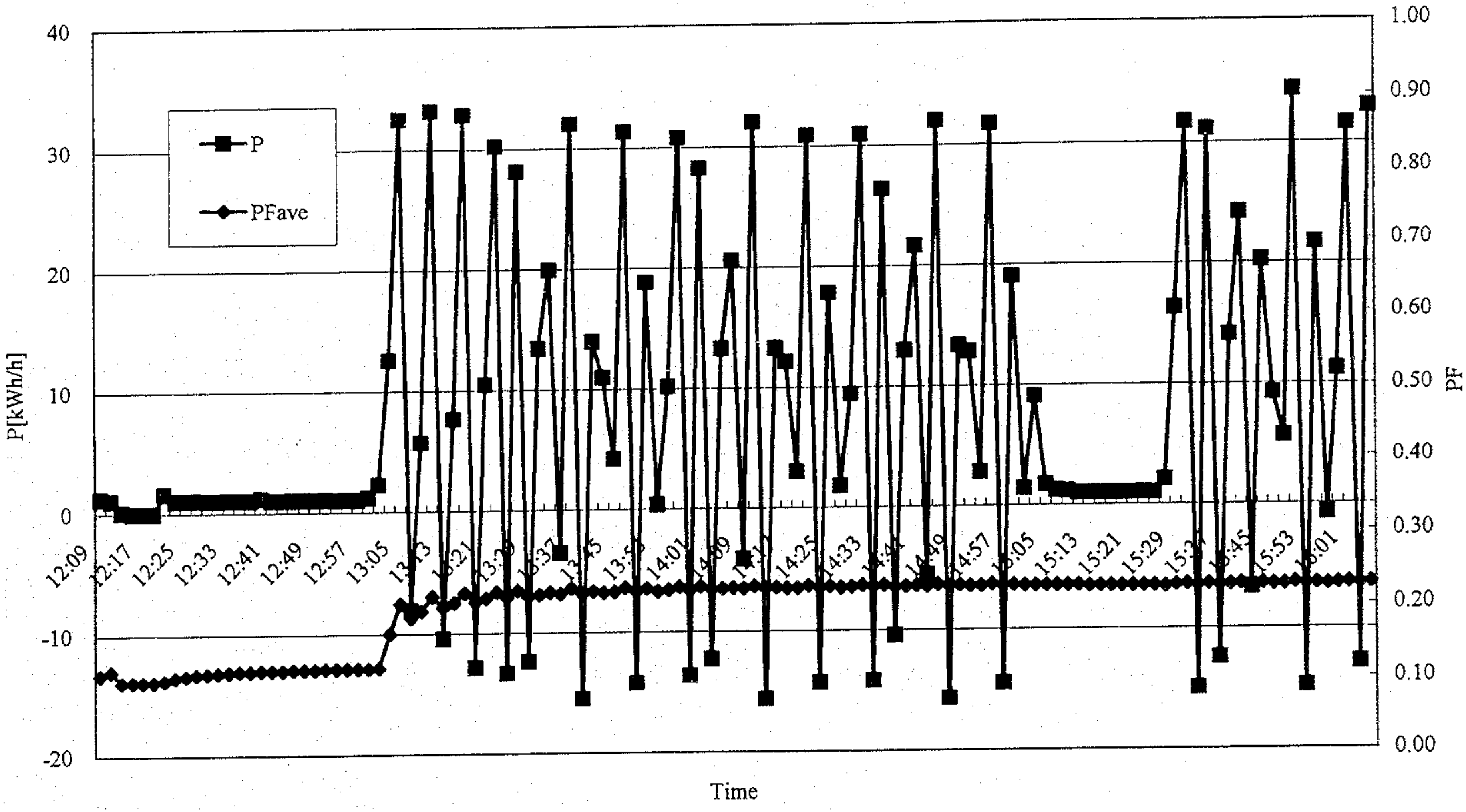


Figure 13-12 Electricity - Power Factor for TSK Centrifugal

13-11 Energy Flow Chart of Major Energy-Consuming Facilities

There are three main energy-related facilities in the factory. In addition to three energy flowcharts of each facility, on overall energy flow chart was studied.

1. Steam Boiler
2. Steam Transfer Line
3. Steam Turbine Generator
4. Steam Control Valve to Accumulator
5. Electricity Consuming Network
6. Overall Energy Flow

13-11-1 Energy Flowchart around the Steam Boiler

Based on the result of measurement and analysis, the energy balance around the steam boiler was calculated as follows.

Table 13-29 Energy Flow around Steam Boiler

	Quantity	Temperature (°C)	Pressure (bar)	Heat(Kcal/h)	Ratio(%)
Inlet					
1) Fuel Oil	2,785.8 kg/hr	30	Ambient	29,620,000	86.28
2) Air	33,294 Nm^3/hr	38	Ambient	310,000	0.90
3) Feed Water	27.3 ton/hr	29	Ambient	800,000	2.33
4) Recycled Condensate	15.5 ton/hr	113	0.5	1,700,000	4.95
5) Steam (Dearator)	2.9 ton/hr	113	0.5	1,900,000	5.54
Total				34,330,000	100.00
Outlet					
1) Steam	44,060kg/h	282	20.6	31,340,000	91.29
2) Blow Down	1.6 ton/hr	282	20.6	340,000	0.99
2) Exhaust gas	35,078Nm^3/hr	231.9	-	2,600,000	7.57
3) Heat Loss	-	-	-	50,000	0.15
Total				34,330,000	100.00

From these calculated results, it is judged that the boiler was operated under sound conditions with suitable heat efficiency (steam/fuel oil) of 91.29%.

Material and heat balance of the boiler system is shown in Figure 13-13.

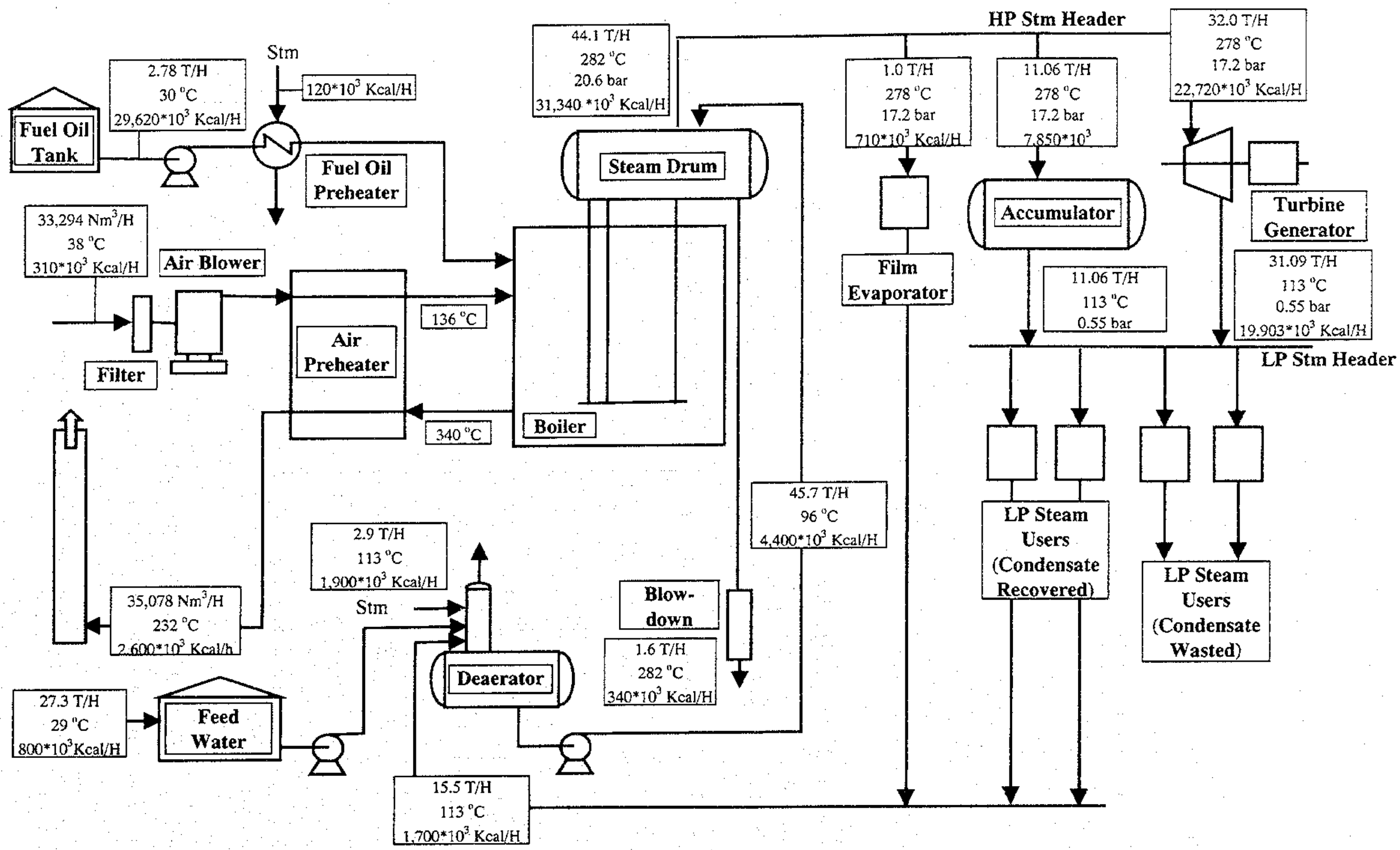


Figure 13-13 Material and Heat Balance of Boiler System

13-11-2 Energy Flowchart around Steam Transfer Line

The heat balance around the steam transfer line was also calculated as follows in Table 13-30.

Table 13-30 Energy Balance around Steam Transfer Line

	Quantity	Temperature (°C)	Pressure (bar)	Heat Energy (kcal/h)	Ratio (percent)
INPUT					
1) Generated Steam	44,060 kg/hr	282	20.6	31,340,000	100.00
Total	44,060 kg/hr			31,340,000	100.00
OUTPUT					
1) Steam to Film Evaporator	1,000 kg/hr	278	17.2	710,000	2.27
2) Steam to Accumulator	11,060 kg/hr	278	17.2	7,850,000	25.05
3) Steam to Turbine Generator	32,000 kg/hr	278	17.2	22,720,000	72.50
4) Heat Loss from Pipe Surface	-	-	-	60,000	0.18
Total	44,060 kg/hr			31,340,000	100.00

13-11-3 Energy Flowchart around Steam Turbine Generator

The heat balance around the steam turbine generator was also calculated as follows in Table 13-31.

Table 13-31 Energy Balance around Steam Turbine Generator

	Quantity	Temperature (°C)	Pressure (bar)	Heat Energy (kcal/h)	Ratio (percent)
INPUT					
1) Steam Inlet	32,000 kg/hr	278	17.2	22,720,000	100.00
			Total	22,720,000	100.00
OUTPUT					
1) Extracted Steam	31,098 kg/hr	113	0.55	19,902,720	87.60
2) Steam Released to Atmosphere	0 kg/hr	-	-	0	0.00
3) Condensed Steam	102 kg/hr	74	Atm.	7,550	0.03
4) Generated Power	2,900 kWh	-	-	2,494,000	10.98
5) Loss	Balance			315,730	1.39
			Total	22,720,000	100.00

13-11-4 Energy Flowchart around Pressure Control Valve to Steam Accumulator

The energy balance around the steam pressure reducing valve to the Steam Accumulator was also calculated as follows in Table 13-32.

Table 13-32 Energy Balance around Steam Control Valve to Accumulator

	Quantity	Temperature (°C)	Pressure (bar)	Heat Energy (kcal/h)	Ratio (percent)
INPUT					
1) Steam for Steam Accumulator	11,060 kg/hr	278	17.2	7,850,000	100.00
Total	11,060 kg/hr			7,850,000	100.00
OUTPUT					
1) Steam to Steam Accumulator	11,060 kg/hr	113	0.55	7,131,500	90.85
2) Kinetic Energy Loss by Control Valve	-	-	-	718,500	9.15
Total	11,060 kg/hr			7,850,000	100.00

13-11-5 Electricity Consumption Network

Electrical power consumption balance is shown in Table 13-33.

Table 13-33 Electrical Power Balance

Service	Quantity (kWh)	Ratio (%)	Remarks
Inlet			
1) Generated Power	2,900	94.16	Turbine Generator No.4
2) Receiving from TNB	180	5.84	
TOTAL	(3,080)	(100.00)	
Outlet			
1) Office Use (TNB)	120	3.90	
2) No. 1 Line (P1ACB2)	85	2.76	LINT IT4(35), Others(50)
3) No. 2 Line (P2ACB2)	510	16.56	NIRO Evaporator(60), Film Eva.(50), Others(400)
4) No. 3 Line (TNB)	60	1.95	Vacuum Pump(60)
5) No. 5 Line (P5A1,2)	160	5.19	Boiler(80), Lighting(80)
6) No. 6 Line (P6)	320	10.39	Boiler(320)
7) No. 7 Line (P7A1)	500	16.23	Pan Agitator & Others (500)
8) No. 7 Line (P7A2)	65	2.11	TSK, ASEA, Others (65)
9) No. 8 Line (P8A1)	200	6.49	TSK, MCCB, Others (200)
10) No.12,13 Line	100	3.25	Vacuum Pump #1, 2
11) No.14 Line (P14M)	450	14.61	Air Compressor(100), TANAKA(250), Others(100)
12) No.15 Line (P15C)	300	9.74	Cooling Water Pump(280), Others(20)
13) No.16 Line (MCCSP)	40	1.30	Mixer, Others (40)
14) Balance	170	5.51	
TOTAL	(3,080)	(100.00)	

13-11-6 Overall Energy Flow

An overall energy flowchart of the sugar plant is shown in Figure 13-14.

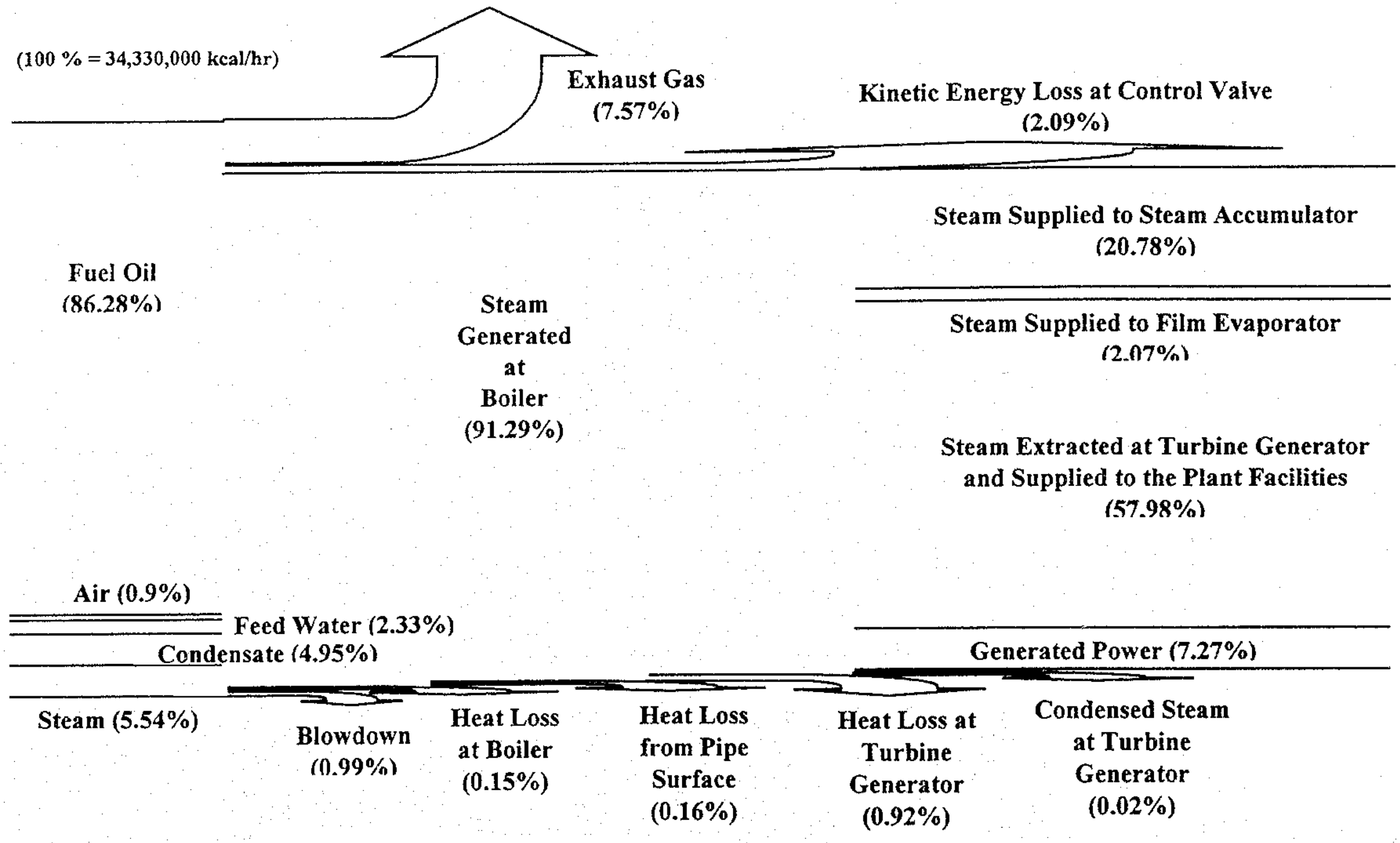


Figure 13-14 Overall Energy Flowchart (Central Sugars Refinery)

13-12 Measures for Energy Efficiency Promotion

The results of measurement and analysis for the factory were analyzed and processed in a previous section of this report. In accordance with the results of the factory energy audit, recommendated measures for energy efficiency promotion are described and discussed in this section. The major items are as follows.

1. Improvement of heat energy efficiency in the steam and steam condensate recovery system
2. Improvement of steam trap system
3. Decreasing heat loss in the thermal insulation system
4. Recovery of electric power from energy loss in steam control valve

13-12-1 Improvement of Heat Energy Efficiency in Steam and Condensate System

(1) Steam System

Figure 13-13 in the previous section shows the present material and heat balance of the steam and condensate system. Judging from these data, there are several items for improving the energy utilization efficiency, as follows.

1. Utilization of heat energy in flue gas

   The temperature of flue gas was recorded at 232°C, which is rather high, compared to similar Japanese facilities.

Table 13-34 Standard and Target Temperature of Boiler Flue Gas

Standard (Target)

Boiler Capacity	Flue Gas Temperature (°C)			
	Solid Fuel		Liquid Fuel	Gas Fuel
	Fixed Bed	Fluid Bed		
Over 30 ton/hr	200(180)	200(170)	200(160)	170(150)
10 to 30 ton/hr	250(180)	200(170)	200(160)	170(150)
5 to 10 ton/hr	—	-(300)	220(200)	200(180)
Under 5 ton/hr	—	-(320)	250(220)	220(200)

As this table shows, flue gas temperature should be around 160 °C to 200 °C. In other words, the economic feasibility of heat recovery in this temperature range can be expected in the factory.

1) Method of heat recovery

There are three kinds of heat recovery, shown below.

- Direct heat exchange between feed air and flue gas
  (expansion of existing pre-heater)
- Economizer installation for steam heating
- Utilization of low temperature fluid as heat recipient

2) Expansion of pre-heater

Installing the same kind of pre-heater as the present one seems rather difficult in terms of space allowance and heat efficiency.

One recommended and common technology is the "Ungstrom Type Pre-heater" to transfer sensible heat from the flue gas to the combustion air through a rotating heat exchanger. It is quite compact and efficient, with rather small investment.

3) Economizer

An economizer, which makes saturated steam unsaturated and high energy, is also commonly used as a heat recovery device. However, it is rather difficult to install the heat exchanger inside the furnace after design and operation because of the structure strength and space.

4) Heat recovery from sources other than the boiler

There are several candidates for the system, such as water heating, chilled water making (absorption type chiller) and utilization in process.

But the heat recovery in steam system is the most effective and is self-standing, without any operational influence to the process system.

Taking into account the recovery of steam condensate, preheating of boiler feed water was selected in this study.

(2) Condensate System

The recovery ratio of steam in this factory is around 30 to 40 percent of boiler feed water. It is estimated that there are three reasons for the low recovery ratio, as described below.

- Direct steam injection to the process system
- Contamination by process fluid in the system
- Low static pressure of condensate for recycling

In the sugar manufacturing process, the amount of direct steam injection and contamination by process fluid is not so great. The main reason could be the low static pressure of condensate.

However the huge investment cost of condensate recovery could be minimized through the utilization of rather cheap carbon steal materials in piping, tanks and pumps. It is recommended that a recovery system be installed.

In this factory, a water treatment system is not in operation. It is better to study the operation or feasibility of installing a new water treatment facility. But if not feasible, recovering condensates becomes more important because condensate itself is one of the cleanest sources of water, leading to decreased blow-down ratio and increased boiler efficiency.

(3) Overall fluctuation of steam system

As the down-stream steam consuming facilities change their load quite frequently, the operation of the steam system and turbine system also fluctuate accordingly.

If fluctuation is not so rapid, it is not so serious from the point of energy efficiency. But this factory's operational fluctuation appears so rapid and great that it has a detrimental effect on energy saving and life on the plant.

To recheck the control performance of present system is important in order to stabilize the fluctuation. This can solve the problem to some extent.

For such a purpose, keeping the generated electricity constant is an effective method for energy efficiency promotion. And changing the receiving amount of electricity from outside could absorb fluctuation of electricity consumption.

A schematic plan for the recommendation is illustrated in Figure 13-15 'Material and Heat Balance of Boiler System (recommendation)' and Figure 13-16 'Improvement for Condensate Recovery'.

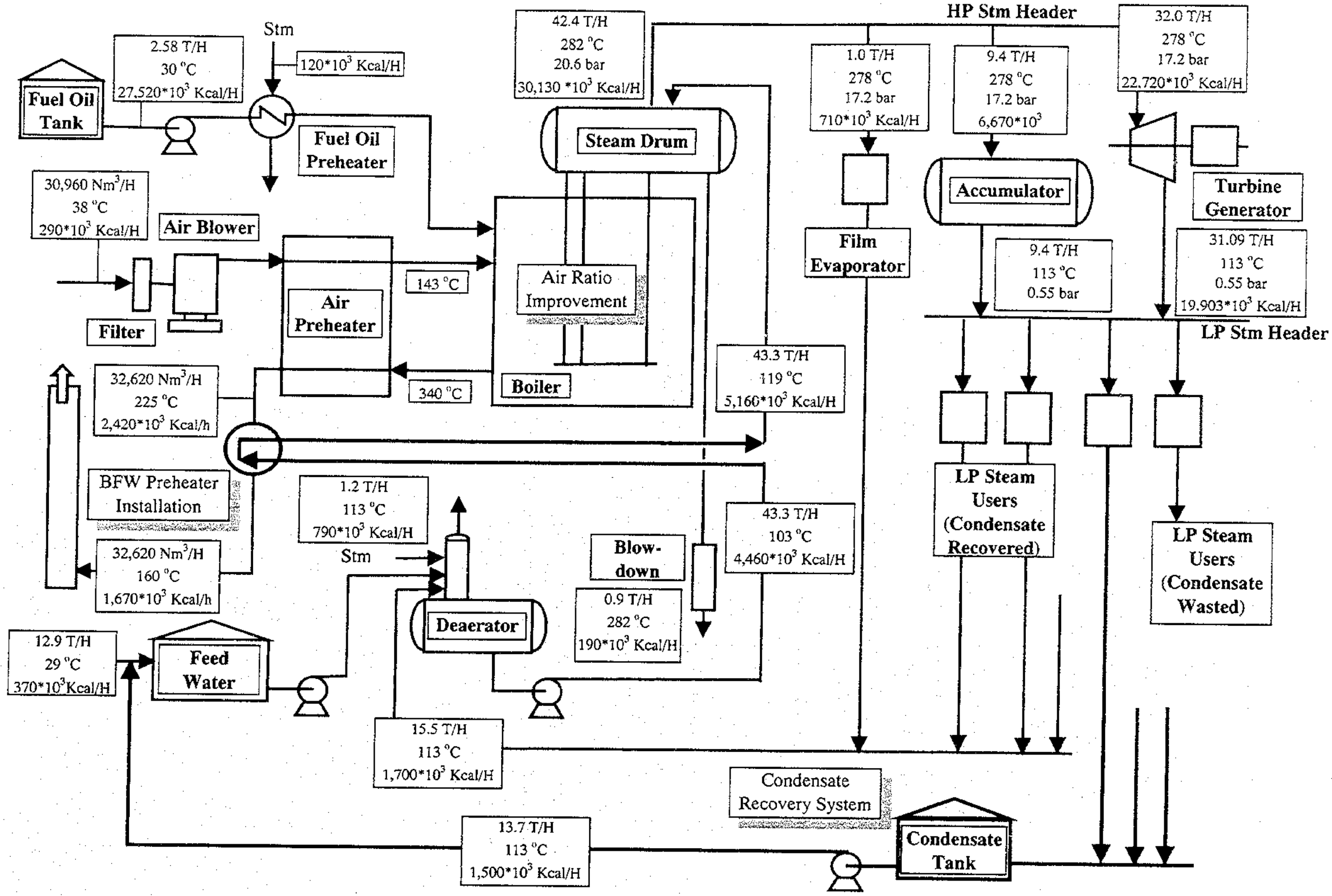


Figure 13-15 Material and Heat Balance of Boiler System (recommendation)

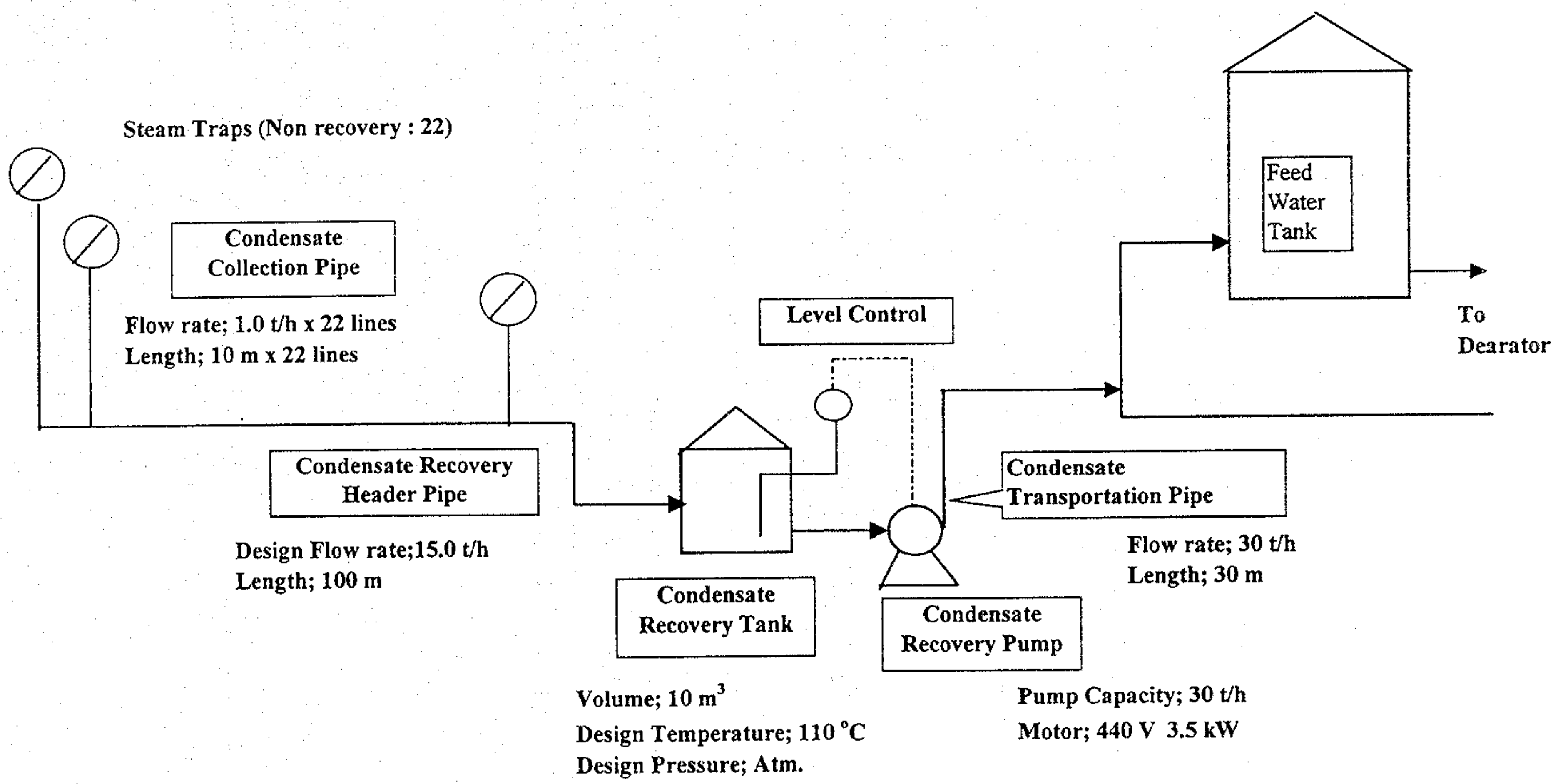


Figure 13-16 Improvement for Condensate Recovery

13-12-2 Improvement of Steam Trap System

As mentioned in the previous section, there are about 64 steam traps installed in steam-utilizing facilities. Their working condition and maintenance are generally satisfactory. However, some steam traps are blowing or leaking, and some are blocked. The service life of steam traps is usually 3-5 years.

The following are recommended: 1) to replace the leaking or blowing traps, 2) to conduct a scheduled maintenance for the blocked or low-temperature traps as shown in Table 13-35.

13-12-3 Decreasing Heat Loss in the Thermal Insulation System

Heat loss from major steam lines is not so great, as Table 13-27 shows. Some portions of the straight lines or some of the valves and flanges were left uninsulated to facilitate maintenance and inspection work, but insulation should be applied to these portions. Standard drawings of thermal insulation for valves and flanges are shown in Figure 13-17.

13-12-4 Recovery of Electric Power from Energy Loss in Steam Control Valve

Out of 50 ton/h boiler, only 30 ton/h is used effectively for the turbine. The remaining 20 ton/h is depressurized to 0.5 bar for heating purpose only. It seems quite unusual to waste high-energy steam. A rough estimation from the energy balance shows that the kinetic energy lost in the pressure-reducing control valve would have the capability to generate about 750 kW of electrical power.

(718,500 kcal/hr / 860 kcal/kW x 0.90 = 750 kW)

The additional installation of a supplementary turbine is recommended.

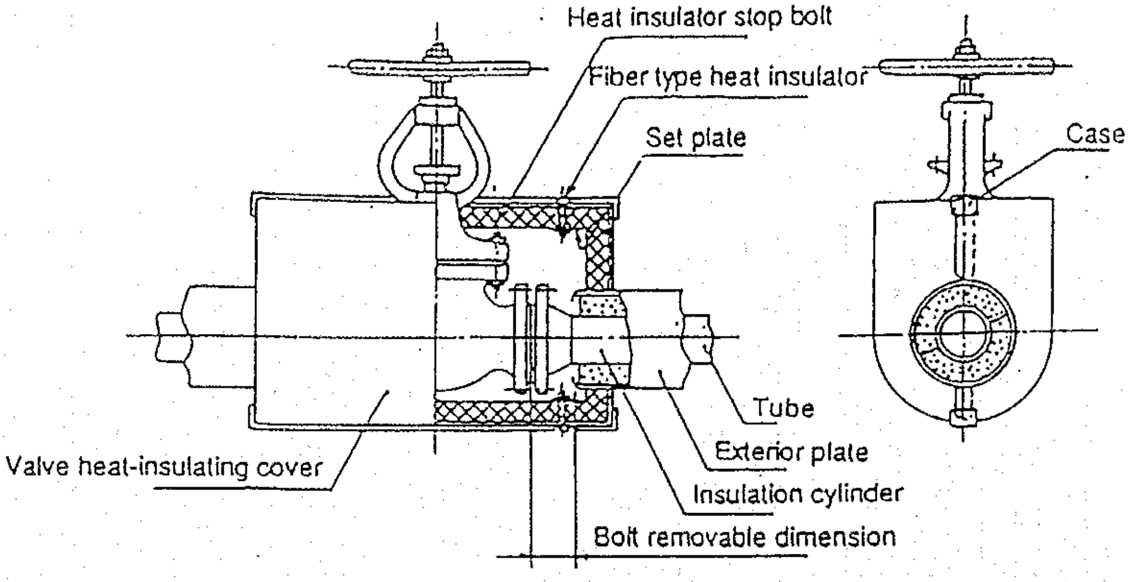
Since steam and electric power are roughly balanced now, the generated power should be supplied to outside users through TNB. This means that tariff system reconstruction is essential.

This turbine should also have some operational flexibility to absorb the change of supply steam pressure and quantity with governor control.

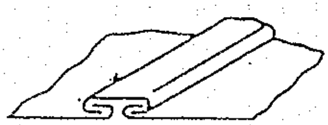
Table 13-35 Failed Trap List

Trap No.	Type	Model	Size (mm)	Failure Mode	Steam Loss(t/y)	Monetary Loss($/y)	Recommended Measures	Recommended Steam Trap Type (Model)	Spec.(kg/h)	Price (10^3 yen)
A10-00001	DISC	TD42	20	Leak(S)	23	185	Replace	FLOAT (SSIN-21)	140	31.5
A10-00003	FLOAT	FT20	20	Low temp	0	0	Overhaul	FLOAT (JH3X-22)	560	118.5
A10-00004	DISC	TD42	20	Leak(S)	33	263	Replace	FLOAT (SSIN-21)	140	31.5
A10-00005	DISC	TD42	20	Leak(M)	60	470	Replace	FLOAT (SSIN-21)	140	31.5
A10-00006	FLOAT	FT20	20	Leak(L)	83	655	Replace	FLOAT (JF3X-5)	640	32.5
A10-00009	FLOAT	FT20	20	Low temp	0	0	Overhaul	FLOAT (JF3X-5)	640	32.5
A40-00001	DISC	TD32F	25	Blocked	0	0	Overhaul	FLOAT (SSIN-21)	140	42.5
A40-00002	DISC	TD42	25	Leak(L)	84	661	Replace	FLOAT (SSIN-16)	140	32.0
A40-00003	DISC	TD32F	25	Low temp	0	0	Overhaul	FLOAT (SSIN-21)	140	42.5
A40-00004	DISC	TD42	25	Blowing	172	1,356	Replace	FLOAT (SSIN-16)	140	32.0
A50-00001	DISC	TD3-7	20	Blocked	0	0	Overhaul	FLOAT (SSIN-21)	140	31.5
A50-00004	DISC	TD42	25	Blocked	0	0	Overhaul	FLOAT (SSIN-16)	140	32.0
A71-00001	DISC	TD42	25	Blocked	0	0	Overhaul	FLOAT (SSIN-16)	140	32.0
A71-00002	DISC	TD42	25	Blocked	0	0	Overhaul	FLOAT (SSIN-16)	140	32.0
A71-00003	DISC	TD42	25	Leak(S)	11	87	Replace	FLOAT (SSIN-10)	65	32.0
A72-00001	DISC	TD42	25	Leak(S)	15	115	Replace	FLOAT (SSIN-10)	65	32.0
A72-00002	DISC	TD42	25	Leak(S)	29	226	Replace	FLOAT (SSIN-16)	140	32.0
A80-00001	DISC	TD32F	20	Low temp	0	0	Overhaul	FLOAT (SSIN-21)	65	39.0
B10-00001	DISC	TD42	20	Blocked	0	0	Overhaul	FLOAT (SSIN-21)	140	31.5
B10-00002	DISC	TD32F	20	Leak(S)	12	95	Replace	FLOAT (SSIN-10)	65	39.0
B10-00004	DISC	TD42	20	Low temp	0	0	Overhaul	FLOAT (SSIN-21)	140	31.5
B30-00001	FLOAT	FT20	25	Low temp	0	0	Overhaul	FLOAT (JF5X-16)	700	60.0
B30-00002	FLOAT	FT20	25	Low temp	0	0	Overhaul	FLOAT (JF5X-16)	700	60.0
C10-00001	FLOAT	FT10-4.5	50	Low temp	0	0	Overhaul	FLOAT (J75X-1)	16,000	347.0
E50-00004	FLOAT	GM8	100	Low temp	0	0	Overhaul	FLOAT (J8X-1)	22,000	550.0
Ex0-00001	DISC	TD32F	25	Low temp	0	0	Overhaul	FLOAT (SSIN-10)	65	42.5
F10-00001	FLOAT	FT10-1	25	Low temp	0	0	Overhaul	FLOAT (J7X-16)	2,100	102.0
F30-00001	FLOAT	FT14-020	20	Low temp	0	0	Overhaul	FLOAT (JF3X-10)	600	32.5
F40-00001	FLOAT	GM2	50	Low temp	0	0	Overhaul	FLOAT (J7LX-1)	4,800	150.0
F40-00002	FLOAT	GM2	50	Blocked	0	0	Overhaul	FLOAT (J7LX-1)	4,800	150.0
F40-00003	DISC	TD3-2	20	Low temp	0	0	Overhaul	FLOAT (JF5X-10)	870	58.5

Heat Insulation of Valve



Details of case



Heat Insulation of Flange

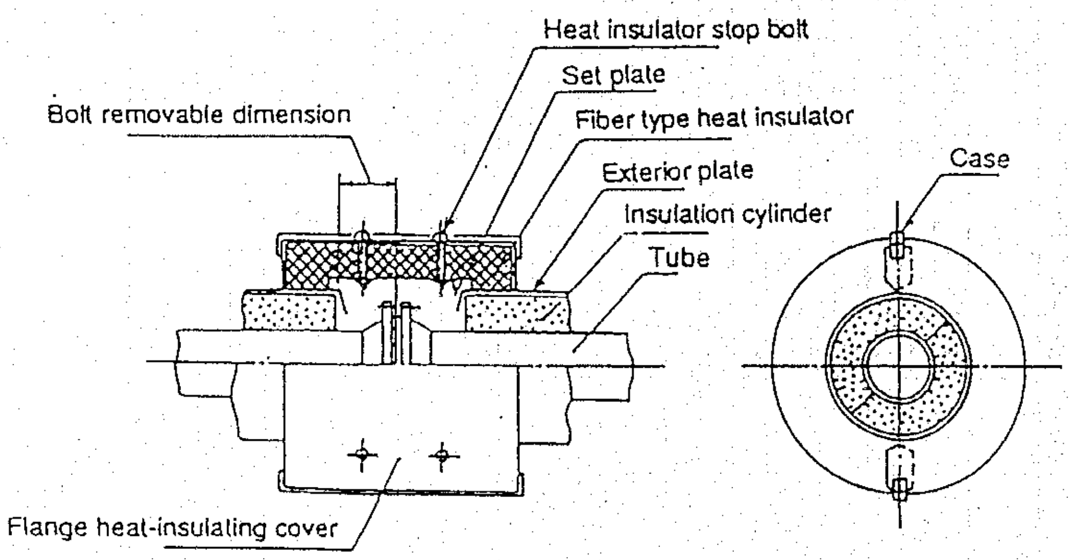


Figure 13-17 Standard Drawing of Thermal Insulation for Valves and Flanges

13-13 Cost of Measures for Energy Efficiency Promotion

Budget type costs were estimated for the two measures, "Improvement of heat energy efficiency in the steam and steam condensate recovery system" and "Improvement of steam trap system". As for "Decreasing heat loss in the thermal insulation system", costs required to repair insulation that was pointed out could be covered by ordinary maintenance costs. For the measure of "Recovery of electrical power from energy loss in steam control valve", modification of the tarriff system and building the new power transmission system from the factory to TNB's grid should be the first step. Upon due consideration of these activities, cost estimation should be made on the appropriate estimation basis.

(1) Improvement of heat energy efficiency in steam and steam condensate recovery system

- Utilization of heat energy in boiler exhaust gas
- Improvement of steam condensate recovery (13.7 t/h)

	10^3 Yen
1. Economizer (heat transfer area: 271 m^2)	7,000
2. Economizer Installation work (air-duct, BFW piping, insulation, painting)	4,500
3. Condensate line piping (840 inch-m, carbon steel)	4,500
4. Condensate tank (carbon steel, 10 m^3)	1,200
5. Tank insulation	2,000
6. Condensate recovery pump / motor (capacity: 30 t/h)	500
7. Civil, electrical, election, insulation, others	3,800
TOTAL	23,500

Item 1: Utilization of heat energy in boiler exhaust gas

Installation of BFW Heater after the existing Air Heater to recover the heat loss in the boiler exhaust gas

BFW Heater Basic Conditions:

	Temp.(°C)		Press.(bar)		Flow rate
	Inlet	Outlet	Inlet	Outlet	
BFW	103	119	21	21	43.3 t/h
Exhaust Gas	225	160	Atm	Atm	32,620 Nm^3/h

Item 2: Improvement of steam condensate recovery

Installation of steam condensate recovery facilities to recover condensate from 22 out of 43 non-recovering steam traps

Note: Total traps ((64)) recovering traps (21), target traps (22)

1) Condensate collection pipes

   Condensate flow rate= 1.0 t/h from each trap x 22 lines

   Pipe length = 10 m each line x 22 lines

2) Condensate recovery header pipe

   Design flow rate = 15.0 t/h

   Pipe length = 50 m x 2 header pipes

3) Recovery tank

   Volume = 10 m^3

   Design Temperature = 110 °C

   Design Pressure = Atm.

4) Recovery pump/motor

   Pump capacity = 30 t/h

   Motor = 440 V 3.5 kW

5) Condensate transportation pipe

   Design flow rate = 30 t/h

   Pipe length = 30 m

(2) Replacement of failed steam traps

- Substitution of 10 failed (blowing, leaking) steam traps

	10^3 Yen
1. Installation of steam trap	326
TOTAL	326

13-14 Potential of Energy Efficiency Promotion

Effects of energy efficiency promotion are summarized below for the two measure of which budget type costs were estimated in the previous section.

(1) Improvement of Heat Energy Efficiency in Steam and Condensate Recovery System

- Utilization of heat energy in boiler exhaust gas - Improvement of steam condensate recovery	Fuel oil reduction 2.78 – 2.58 = 0.2 ton/hr (1,600 ton/year)

(2) Replacement of failed steam traps

- Replacement of leaking and blowing traps	Prevention of steam leaks: 4,113 US$/year

13-15 Benefit of Measures for Energy Efficiency Promotion

In this section, benefits are estimated of the measures for energy efficiency promotion based on an assumed price of energy for Central Sugars Refinery (CSR). This estimation is made for two measures, "Improvement of Heat Energy-saving in Steam and Steam Condensate Recovery System" and "Replacement of Failed Steam Traps" for which energy-saving potentials have been obtained in the previous section.

13-15-1 Energy Prices for CSR

The energy prices of CSR could not be obtained from CSR, as these are corporate secrets. Accordingly, the study team assumed the prices for study purposes, as Table 13-36 shows.

Table 13-36 Assumed Energy Price

	Unit Price
Medium Fuel Oil	323.5 RM/ton
Generated Steam	30 RM/ton

13-15-2 Benefits of Measures

(1) Improvement of Heat Energy Efficiency in Steam and Steam Condensate Recovery System

The benefit derived from this measure is estimated at 517,600 RM/year by the calculations shown in Table 13-37 below.

Table 13-37 Estimation of Benefit from "Improvement of Heat Energy Efficiency in Steam and Steam Condensate Recovery System"

No.	Item	Estimated Value	Remarks
Energy Saving			
①	Reduction in Fuel Oil Consumption	1,600 ton/year	Refer to section 13-14
Saving in Fuel Oil Bill			
②	Saving in Fuel Oil Bill	517,600RM/year	① x 323.5 RM/ton

(2) Replacement of Failed Steam Traps

A 4,113 US$/year benefit is estimated for this measure, as section 13-14 shows. This benefit is equivalent to 15,629 RM/year under the current exchange rate.

13-16 Financial Evaluation of Measures

In this section, financial evaluations are made for the following measures requiring investment and obtaining benefits in the previous section, in order to ascertain the financial feasibility of the measures.

- Improvement of Heat Energy Efficiency in Steam and Steam Condensate Recovery System
- Replacement of Failed Steam Traps

13-16-1 Method of Financial Evaluation

(1) Applied Method

Two different methods, both widely used and accepted for financial evaluation of the investment projects, are applied in the study. The first method is the payback period method to calculate the payback period defined as the period required to recover the investment outlay through the accumulated net cash flows earned by the project. The second method is the internal rate of return (IRR) method on a discounted cash flow basis. The Financial Internal Rate of Return on Investment (FIRROI) is defined the discount rate for which the present value of net receipts from the project is equal to the present value of the investment.

(2) Payback Period

Net cash flow is defined as follows:

1) Increased Sales Revenue
2) Less: Fixed Investment
3) Less: Pre-production Expenditure
4) Less: Increase in Net Working Capital
5) Less: Increased Operating Costs

6) Less: Increased Marketing Costs
7) Less: Increase in Corporate Tax Paid

In the case of the investment for improved energy efficiency, the change in sales revenue and marketing cost should be zero. The changes in net working capital and pre-production expenditure are negligible for the case of a project for improved energy efficiency. Fixed investment was estimated in the previous section. Changes in operating costs, which consist mainly of changes in utility bills such as electricity and fuel, were also estimated. Corporate tax change is calculated based on the change in taxable profit due to changes in operating costs in consideration of the country's tax rate, and depreciation system.

When calculating the payback period, a cash flow table starting from the construction period to the operating period is created. Accumulated net cash flow is negative during construction due to fixed investment and pre-production expenditure, however it will increase by the recovery of capital and become zero in a certain year. The payback period is defined as the period from the start of operation until the year when the cumulative net cash flow is zero.

(3) Internal Rate of Return (IRR)

The calculation procedure begins with the preparation of a cash flow table in the same way as the payback period method. Then, the discount rate when the cumulative net cash flow of the project becomes zero is obtained by trial-and-error. The discounted rate thus obtained is the Financial Internal Rate of Return on Investment (FIRROI).

13-16-2 Premises for Financial Evaluation

Financial evaluations are made on the following premises.

1) Exchange rate: US$ 1 = RM 3.8 ; US$ 1 = JY 118

2) Project life: 15 years from the start of operation (5 years from the start of operation for the replacement of failed steam traps)

3) Corporate tax rate: 30 percent

4) Depreciation: The straight-line method is applied. The depreciation period is 15 years for the plant and machinery.

5) Fixed investment: Table 13-38 summarizes the fixed investment cost for the measures, which were obtained by converting the Japanese Yen values in the section 13-13.

Table 13-38 Fixed Investment Cost for Measures

Measures	Fixed Investment Cost (RM)
Improvement of Heat Energy Efficiency in Steam and Steam Condensate Recovery System	757,000
Replacement of Failed Steam Traps	10,498

13-16-3 Results of Financial Evaluation

Table 13-39 shows FIRROI before tax, FIRROI after tax and the payback period for the measures. Estimated cash flow tables for these measures are presented in Tables 13-40 and 13-41.

Table 13-39 Results of Financial Evaluation

Measures	FIRROI before tax	FIRROI after tax	Payback Period
Improvement of Heat Energy Efficiency in Steam and Steam Condensate Recovery System	68.4%	49.8%	2.0 years
Replacement of Failed Steam Traps	147.3%	103.1%	0.9 years

13-16-4 Conclusion of Financial Evaluation

According to the information obtained during the field survey, the lending rate in Malaysia has been ranging from 12 to 14% per annum recently. This rate could be regarded as an indication of the opportunity cost of capital in Malaysia.

Both measures are considered financially feasible from favorable FIRROIs much higher than the opportunity cost of capital, as well as sufficiently short payback periods under the conditions set for the study. These favorable results come from the relatively large benefit for the first measure and the small investment for the second measure.

Table 13-40 Cash Flow Table (Measure: Improvement of Heat Energy Efficiency in Steam and Steam Condensate Recovery System)

Unit: Thousand RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	757	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
Less: Corporate tax increased	0	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Incremental Cash Flow (before Tax)	-757	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
Incremental Cash Flow (After Tax)	-757	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377
Cumulative net cash flow	-757	-379	-2	375	753	1,130	1,508	1,885	2,263	2,640	3,017	3,395	3,772	4,150	4,527	4,905
Depreciation	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Table 13-41 Cash Flow Table (Measure: Replacement of Failed Steam Trap)

Unit: RM

Year	0	1	2	3	4	5	0	0	0	0	0	0	0	0	0	0
Less: Fixed investment	10,498	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	15,629	15,629	15,629	15,629	15,629	0	0	0	0	0	0	0	0	0	0
Less: Corporate tax increased	0	4,479	4,479	4,479	4,479	4,479	0	0	0	0	0	0	0	0	0	0
Incremental Cash Flow (before Tax)	-10,498	15,629	15,629	15,629	15,629	15,629	0	0	0	0	0	0	0	0	0	0
Incremental Cash Flow (After Tax)	-10,498	11,151	11,151	11,151	11,151	11,151	0	0	0	0	0	0	0	0	0	0
Cumulative net cash flow	-10,498	652	11,803	22,953	34,104	45,254	0	0	0	0	0	0	0	0	0	0
Depreciation	0	700	700	700	700	700	0	0	0	0	0	0	0	0	0	0

13-17 Recommendations for Energy Efficiency Promotion

Based on the energy audit and subsequent study for CSR including the financial evaluation, the following measures are recommended for improving its energy efficiency.

(1) Improvement of Heat Energy Efficiency in Steam and Steam Condensate System

The energy audit revealed a rather high temperature of boiler flue gas and a low recovery rate of steam condensate in the steam and steam condensate system of CSR. It is recommended that the heat of boiler flue gas be recovered to increase the boiler feed water (BFW) temperature. For this purpose, it is necessary to install a BFW preheater for heating BFW coming from the existing deaerated BFW pump by flue gas coming from the existing air preheater. As for a measure to increase the recovery rate of steam condensate, the installation is recommended of a steam condensate recovery system, consisting of a condensate tank, a condensate recovery pump, and related piping. This measure is considered financially feasible under the conditions set for the study.

(2) Improvement of Steam Trap System

It was observed that 31 steam traps among the 64 installed in the steam-utilizing facilities were malfunctional due to by blowing, leaking or blocking. It is recommended that blowing or leaking steam traps be replaced with new steam traps. As for the blocked or low-temperature traps, scheduled maintenance is recommended. This measure is considered financially feasible based on the financial evaluation.

(3) Decreasing Heat Loss by Thermal Insulation

During the energy audit, it was observed that some portions of straight lines, valves and flanges were not insulated. It is recommended that these parts be insulated to prevent heat loss.

(4) Power Generation to Recover Energy Loss from Steam Control Valve

Of the 50 ton/hour of steam generated by boilers, 20 ton/hour was depressurized by the steam control valve to low-pressure steam at 0.5 bar for heating purposes. According to a rough estimation by the study team, 750 kW of power could be generated by recovering the energy loss due to this depressurization. It is recommended that a supplementary turbine be installed to recover this energy loss, provided that the present tariff system is amended to allow CSR to supply excess electricity to outside users through TNB.

Chapter 14 Steel Mill

14-1 Characteristics of Minimill Subsector

The Minimill is a steel production process. The main products made by this process are rebar and section, which are types of bar steel.

Consumption of steel materials totalled 8.1 million tons in 1995 in Malaysia, and the demand growth rate of steel materials was more than that of economy growth, which was 10 percent. Production of steel materials in the country totalled 3.21 million tons, and 60 percent of steel materials was imported. Production of crude steel was 2.3 million tons, all of which was produced as billet and became raw material for rebar, section and wire rod.

The Minimill consists of production plants including a steelmaking plant (electric arc furnace, ladle furnace and continuous casting machine) a rolling mill plant (bar rolling mill and/or rod rolling mill) with auxiliary facilities such as an oxygen plant, compressed air plant, water treatment station, main receiving sub-station, shredder plant, analysis and inspection laboratory, maintenance shop, etc.

Total energy consumption of the Minimill is generally 70 percent in the steelmaking plant (SMP); and 80 percent of electricity is consumed in the SMP.

Energy saving in the electric arc furnace has been achieved, together with efforts to increase productivity. Energy saving in an electric arc furnace includes (1) utilizing oxygen gas by means of oxy-lancing and oxy-fuel burners, (2) adoption of a large-scale furnace and a large-capacity transformer, (3) introduction of new technologies, EBT (eccentric bottom tapping system), ladle furnace operation, scrap preheating, DC (direct current) arc furnace system, and twin furnaces to most efficiently use the exhaust gas heat, for example, and (4) improvement of operational techniques such as long arc operation and foamy slag operation. Nowadays the DC twin furnace operation is considered the most advanced furnace. In the rolling mill plant, energy use is reduced in the reheating furnace by adoption of hot charge operation together with improvement of the refractory, heat exchangers, combustion burners and combustion control. The slit rolling practice has also contributed to increased productivity.

14-2 Outline of Factory, Facilities and Flowsheet of Major Products

14-2-1 General

Amsteel Mills Sdn. Bhd. (ASM) of the Lion Group has been selected as a model steel mill in this study. Lion Group was established to join trading businesses and began producing confectionery in Hong Kong and sugar products in Vietnam. The group consists of 8 divisions and ASM is the steel division.

ASM is located in the Bukit Raja Industrial Estate, 30 km west of Kuala Lumpur. ASM's first rolling mill was constructed and commissioned in 1978. ASM is one of the largest and most technically sophisticated steel mills in the nation, and has one steel-making plant producing steel bars and wire rods. The capacity of the steel-making and rolling plant for steel bars and wire rods are 0.75 million and 0.9 million tons per year. Currently, ASM supplies approximately one third of the nation's requirement of steel bars and wire rods. The company's paid capital was 671 million RM in 1997.

14-2-2 Organization

Executive Director Mr. Lam Kok Kee, is the general manager of the steel division of the company. The factory manager is Mr. Simon Quah. The total number of employees is 820 at present. There are 21 operation engineers in total (metallurgy : 6 , mechanical : 15) and 4 utility engineers (electrical : 4). The organization chart of ASM is shown in Figure 14-1.

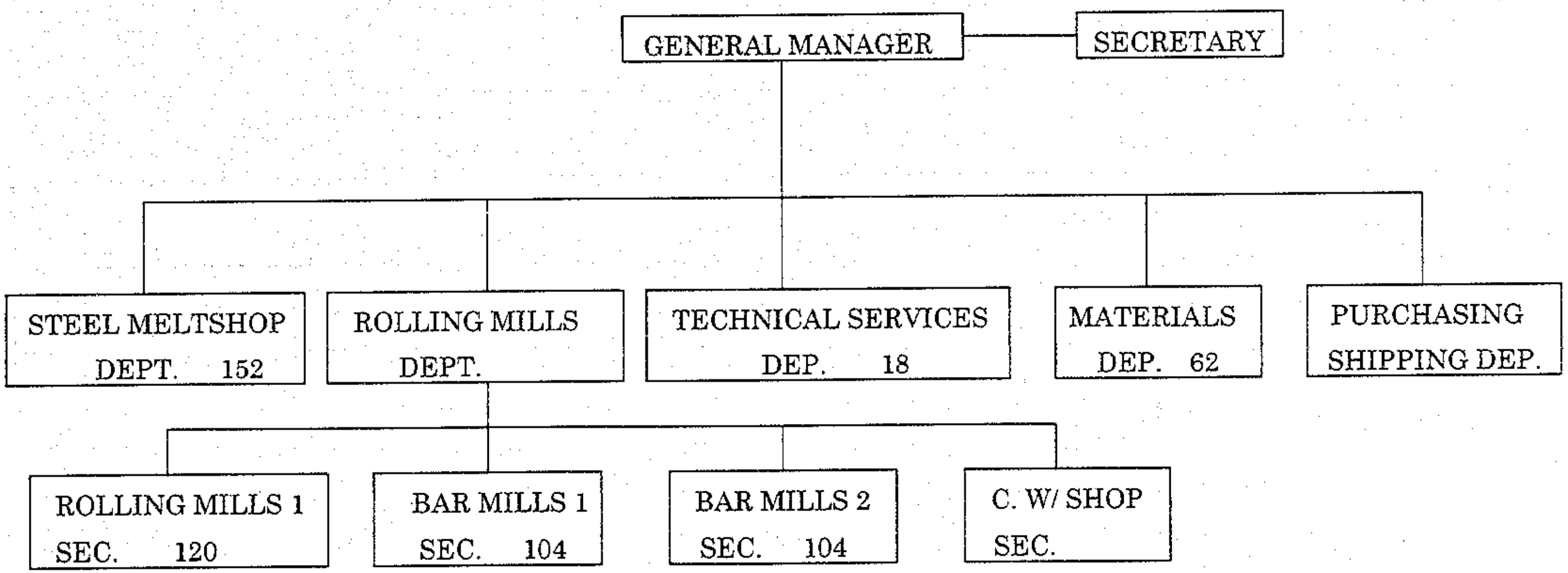
14-2-3 Employment and Training

(1) Employment

School education in Malaysia is basically a 6-5-2-4 system. Elementary (6 years) and secondary (5 years) schools are compulsory. Engineers are from universities, and other workers are from high or secondary schools.

(2) Education and Training

For the employees, educational and operating training is given outside ASM, at S.I.T. CORPORATE LEARNING CENTRE Sdn. Bhd. Training is classified into three skill levels. Each level consists of 11-15 training courses. Normally, employees selected for training can attend a training course every 4 or 6 months. Training cost is 500,000 RM/Year. Training courses and schedules are shown in Table 14-1.



※ Figures present number of employees.

Figure 14-1 Organization Chart of ASM

Table 14-1 Training Modules Schedule Summary Jan. - Jun. 1998

	No.	Training Modules	Jan	Feb	Mar	Apr	May	Jun
SKILL LEVEL 1	1	Workplace Communication			10-11	27-28	11-12	
	2	Business Writing Skills	13-14		5-6	20-21	25-26	
	3	Work / Personal Effectiveness	6		16	17		12
	4	One-To-One Training		26-27	17-18		18-19	17-18
	5	Problem Solving for Improved Performance			2-3	29-30	14-15	22-23
	6	Effective Customer Service	7-8		19-20		4-5	
	7	Working Effectively in a Team		3-4		8-9	20-21	10-11
	8	Quality Concepts	15-16		12-13		6-7	24-25
	9	Application of Safe Work Practices		5-6	26-27	22-23		
	10	Managing Basic Business Computing	22-23		23-24	15-16	21-22	
	11	Business Computing Skills- Word Processing		9-10	17-18	22-23		15-16
	12	Records Handling, Processing & Maintenance		10-11		13-14	5-6	25-26
SKILL LEVEL 2	1	How to Lead Informal Meetings			10-11			
	2	Essential Interpersonal Skills for Team Communication		16-17		6-7		
	3	Managing Operations - Productivity			19-20	2-3	13-14	
	4	Managing & Organizing Work for Goal Achievement	19-20		23-24		7-8	
	5	Workplace Assessor Training		11-13		20-22		16-18
	6	Managing Team Problem Solving		3-4		29-30		2-3
	7	Managing Operations - Customer Service	7-8	23-24		18-19		
	8	Managing & Developing Teams			15-16	21-22	8-9	
	9	Quality Improvement in the Workplace		18-19		1-2		15-16
	10	Supervising Occupational Safety & Health			5-6	13-14	25-26	
	11	Managing Information			12-13	23-24		10-11 15-16
SKILL LEVEL 3	1	Effective Meeting Skills				7-8	11-12	
	2	Presentation Skills			16-18		27-29	
	3	Managing Projects			23-25			22-24
	4	Manage Finance - Setting & Achieving Budget			4-5			18-19
	5	Managing Operations & Logistics		19-20			7-8	
	6	Managing Strategically			26-27		19-20	
	7	Performance Management I	21-22			16-17		
	8	Performance Management II					4	8
	9	Problem Solving & Decision Making		10-13	31-	3		
	10	Entreprenuering & Innovating			9-10			4-5
	11	Leading Team Strategically			30-31		13-14	
	12	Managing for Quality			25-26	27-28		
	13	Quality Management System			2-3		28-29	
	14	Managing & Planning for Occup. Safety & Health			19-20			
	15	Managing Information System Analysis				20-21		2-3
GENERIC	1	Business Computing Skills - Spreadsheet	5-6		24-25		7-8	22-23
	2	Business Computing Skills - Graphics Presentation	19-20				19-20	
	3	Business Computing Skills - Database			3-4	7-8	11-12	9-10

14-2-4 Outline of the Steel Works

(1) Area

The area of ASM is 243,000 square meters. One third is building area.

(2) Grade of Steel

Grades of steel are as follows:

1) 5 % of production is low carbon grade,
2) 35% of production is medium carbon grade, and
3) 60% of production is re-bar grade for construction steel.

(3) Main Products

The products are as follows:

1) 120 to 130 square millimeter billets at 5.5 to 11.5 meters long,
2) 10 to 40 millimeter plain and deformed bars, and
3) 5.5 to 30.0 millimeter wire rods.

Production volumes of the past 5 years are shown in Table 14-2. Production is increasing year by year. Production from rolling mills exceeds billet production and the shortage of billets is compensated by imports from Poland.

Table 14-2 Production and Productivity for the Past Five Years

(Unit: tons per year)

No.	Product	1993		1994		1995		1996		1997	
		t/y	t/h	t/y	t/h	t/y	t/h	t/y	t/h	t/y	t/h
1	Billet	389,374	61	588,897	77	642,681	85	660,077	87	660,286	-
2	Rolling Mills										
	Rod Mill One	282,890	38	303,105	53	261,771	44	321,698	53	369,464	-
	Bar Mill One	164,994	26	181,716	28	174,542	26	183,944	27	212,633	-
	Bar Mill Two	209,640	38	257,640	41	272,168	41	284,698	45	312,972	54

(4) Raw Materials

The raw materials charged to the electric arc furnace (EAF) are all scraps.

(5) Layout of the Steel Works

Layout of the steel works is shown in Figure 14-2.

(6) Steel-making Plant (SMP)

The SMP has the following facilities.

1) Electric Arc Furnace (EAF)
   1 unit×85 tons/heat (Hereafter the word " heat " is used to mean molten steel.) with eccentric bottom tapping (EBT), an 80 MVA transformer, 1 oxygen lance manipulator, 3 jet burners
2) Ladle Furnace (LF)
   1 unit×85 tons/heat with 33MVA transformer
3) Continuous Casting Machine (CCM)
   1 unit×6 strands for billets of 100 to 140 mm square and 4 to 11.5 meters long
4) Production of billet in 1997 : 660,300 tons

(7) Rolling Mill Plant (RMP)

The RMP consists of three rolling mills as shown below.

1) Rod mill 1
   Reheating furnace capacity is 65 metallic tons / hour with walking beams, oil fired burners
   1 unit×continuous rolling with 7 roughing stands, 8 intermediate stands, 12 finishing stands, shears, laying head, finishing facilities
   Production of wire rod in 1997 : 369,500 tons
2) Bar mill 1
   Reheating furnace capacity is 35 metallic tons / hour
   1 unit×continuous rolling with 15 stands, shears, slit rolling, cooling bed
   Production of bar in 1997 : 212,600 tons
3) Bar mill 2
   Reheating furnace capacity is 60 metallic tons / hour
   1 unit×continuous rolling with 17 stands, shears, , cooling bed
   Production of bar in 1997 : 313,000 tons

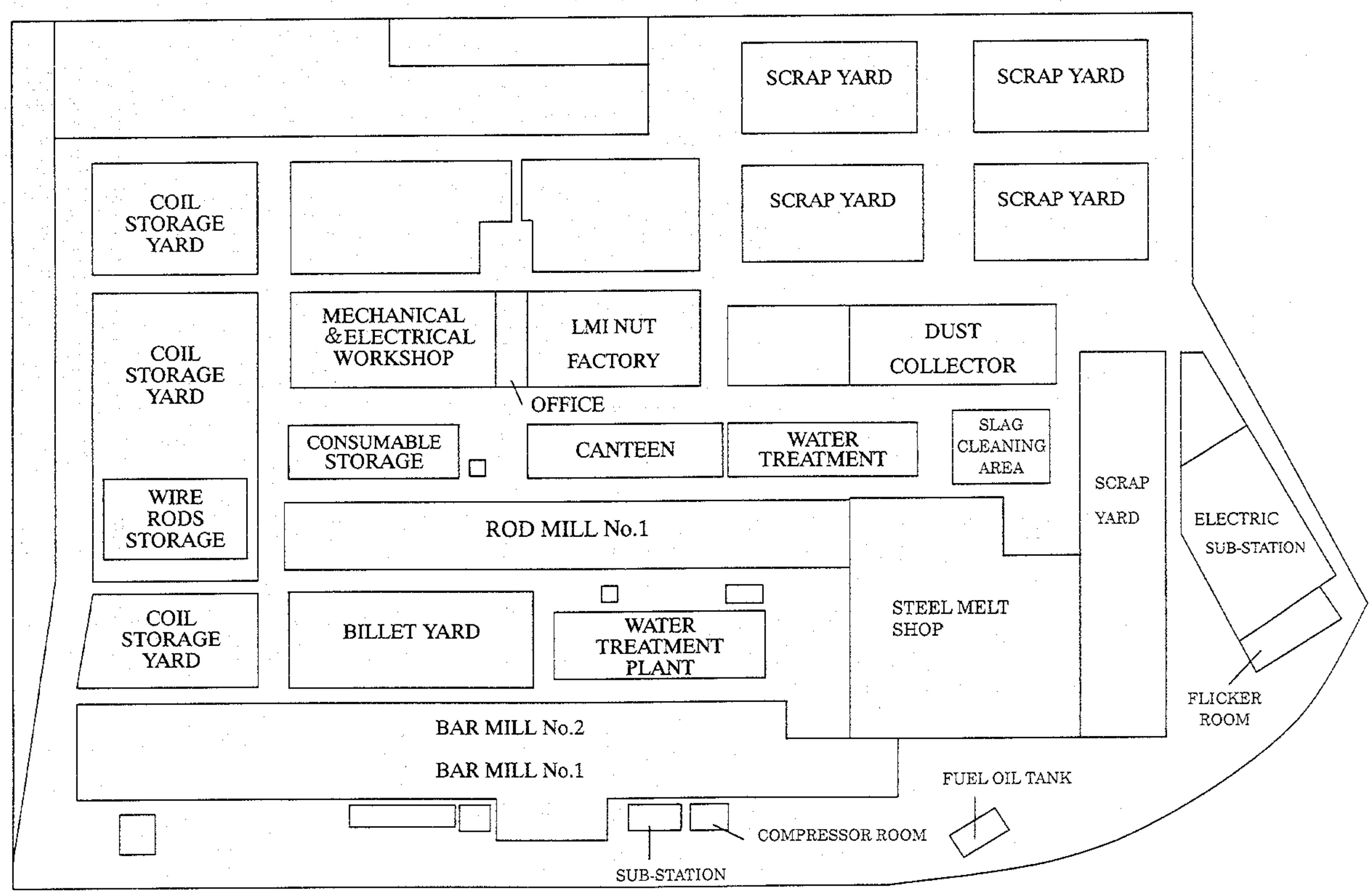


Figure 14-2 Layout of Steel Works

(8) Auxiliary Facilities

In addition to the above major facilities, the steel works have the following auxiliary facilities

1) Open scrap yard
2) Shredder plant
3) Dust collector
4) Water treatment plant,
5) Compressor room
6) Electrical sub station,
7) Lubricant storage yard,
8) Mechanical and electrical work shop
9) Coil storage yard

(9) Flow Sheet of Products

Process flow diagram is shown in Figure 14-3.

(10) Type of Operation

The Steel-making and rod mills are in continuous operation for 24 hours by 3 shifts. Bar mill 1and 2 are under 10-hour batch operation from 22 o'clock to 8 o'clock.

(11) Generator

ASM has 5 generators for emergency facilities such as lighting, pumps and instruments. Their total capacity is 2,375 kVA at 50 Hertz.

(12) Electric Power Receiving

1)	Receiving voltage	:	132 kV
2)	Maximum demand	:	65 MW
3)	Power factor	:	98 %

(13) Unit Price of Energy

1)	Fuel oil (MFO)	:	0.35 RM/l
2)	Diesel oil	:	0.65 RM/l
3)	Unit price of electricity	:	Demand charge 16.20 RM/kW·month Power rates... peak 0.178 RM/kWh off peak 0.098 RM/kWh

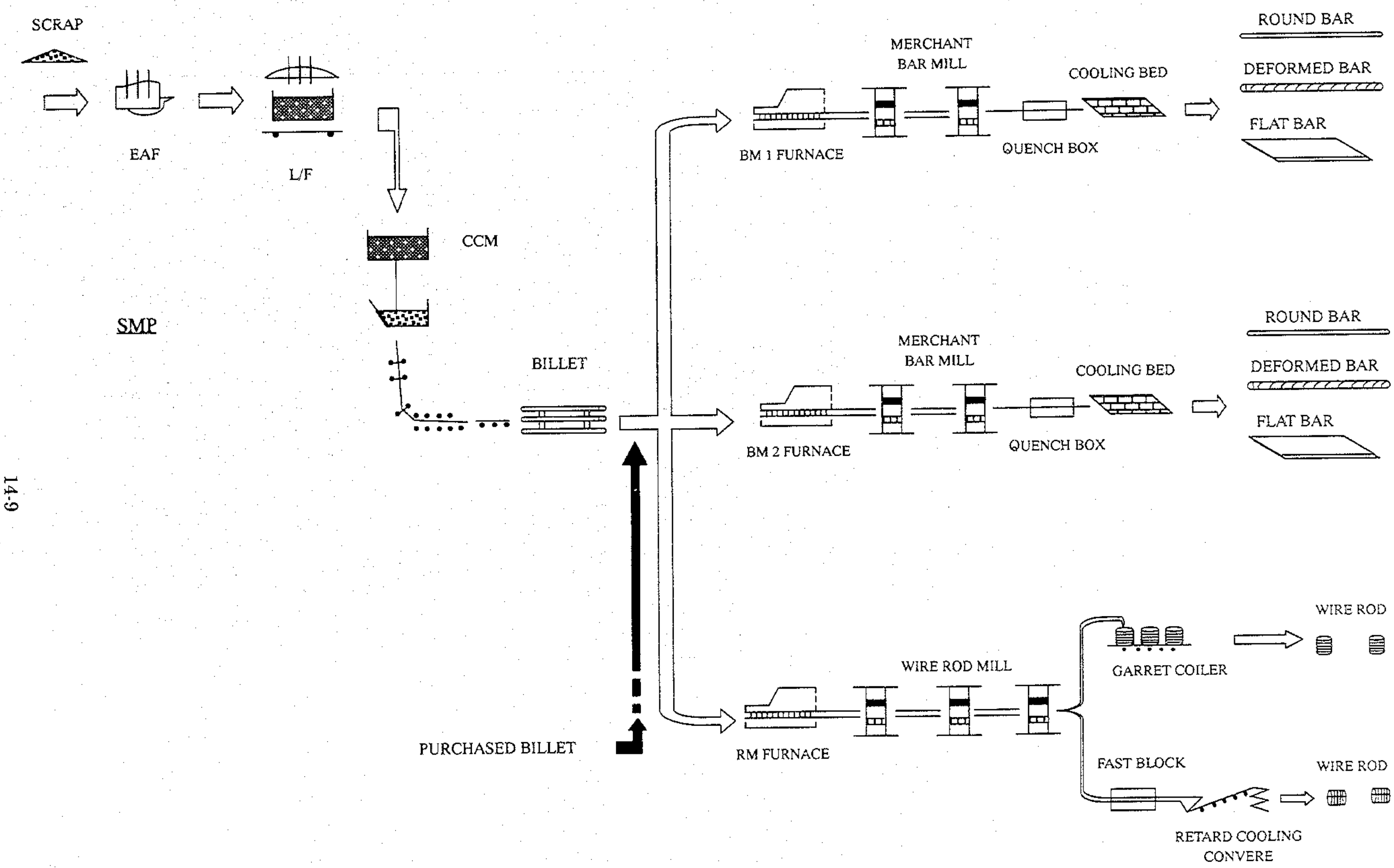


Figure 14-3 Process Flow Diagram

14-3 Steel-making Plant (SMP)

14-3-1 Outline of SMP

The EAF with a capacity of 70 tons/heat EAF and CCM unit started operation in August, 1981. The SMP has been expanded to produce 750,000 tons per year of billets consisting of EAF and LF capacities of 85 tons/heat, and 6 strands of CCM. As Table 14-2 shows, the production of billets in 1997 reached 660,000 tons.

Billets produced in the SMP are mainly of rebar quality, which contains 0.25 to 0.33 percent carbon. Other qualities are low carbon steel of between 0.06 and 0.12 percent carbon, thread of between 0.18 and 0.24 percent carbon and high carbon steel of between 0.42 and 0.62 percent carbon. The SMP chronology of events is shown in Table 14-3.

Table 14-3 Steel Meltshop Chronology of Events

Year	Month	Events
1981	August	1st Commissioning - 70 Tons EAF / CCM.
1985	April	Upgraded EAF Transformer 33 MVA to 55 MVA. Electrode Diameter 500 mm to 550 mm. Installed Ladle Furnace. Upgrade Dust Collector to 360,000 m^3 / hr.
1989	March	Upgrade EAF to Eccentric Bottom Tapping (EBT). Retrofit Dust Collector Bag House Cleaning System.
1993	August	Upgrade EAF Electrode Mast / Superstructure. Install Complete New Dust Collector, Capacity 21,000 m^3 / min. Upgrade EAF Transformer 55 MVA to 80 MVA, Secondary Voltage 650 V - 950 V. Upgrade 132 kV Substation / Flicker Compensation. Install Auto Transformer Step Up 15 kV to 33 kV. Install 12 MVA Series Reactor. Install Complete New CCM with 6 Strands Curve Mould, Solid Dummy, EMS and Automation Level 2.
1995	April	Upgrade EAF Furnace Shell from 70 m^3 to 85 m^3. Upgrade Ladle Furnace to Small PCD 650 mm. Hydraulic / Digital Control Electrode Regulation.

14-3-2 Outline of the Facilities

(1) Layout and Operation Flow

The layout of the plant is shown in Figure 14-4. In the scrap yard, scraps are loaded by overhead crane into the scrap bucket that is placed on the bucket car, and then they are transported to the EAF yard.

The EAF is normally charged with two buckets of scraps by a charging crane. In the EAF, scraps are melted by electric power using three twin burners and oxygen lancing. After melting at a certain target temperature and adjusting the molten steel to the desired composition, the heat is tapped through the EBT (eccentric bottom tapping system) into the ladle. After tapping is completed, the heat is transferred to the LF station adjacent to the EAF by the tapping crane.

The burnt lime and de-oxidants are fed into the ladle during tapping. At the LF station, molten steel is finally subjected to metallurgical treatment for adjustment of composition, and temperature is also adjusted by electric power, alloy addition and inert gas bubbling. Then the heat is transferred by crane to the turret of the CCM and cast into billets. Those billets are placed in the billet yard, through some transfer tables and cranes.

(2) Main Equipment

The capacity of the electric arc furnace (EAF) was originally 70 tons/heat and the capacity of the transformer was 33 MVA. The shell diameter of the EAF was expanded to 5.8 meters, to a capacity of 85 tons/heat and a transformer capacity to 80 MVA. The original capacity of the continuous casting machine (CCM) was 70 tons/hour and it was upgraded to a completely new machine with 6 strands and a capacity of 120 tons/hour. The dust collector was upgraded twice. The first upgrade was to 360,000 m^3/hour and the second was to 1,260,000 m^3/hour. Specifications of the equipment are shown in Table 14-4.

(3) Production

Billet production for the past five years is shown in Table 14-2.

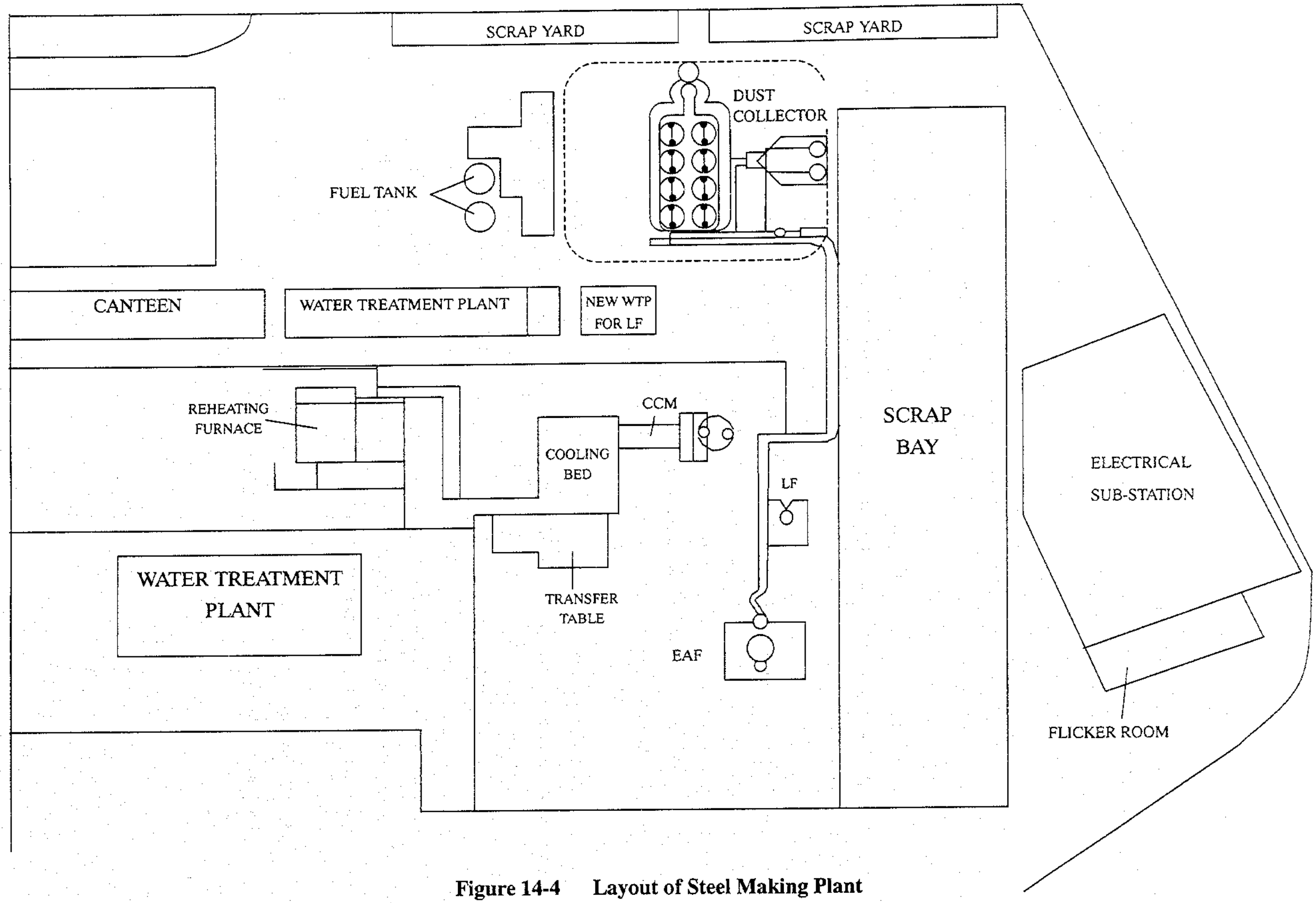


Figure 14-4 Layout of Steel Making Plant

Table 14-4 Equipment List - Steel-making Plant (SMP) (1/2)

No.	Equipment	Qty	Main Specification	Remarks
1-	EAF	1	Type : AC Furnace with eccentric bottom tapping (EBT) Furnace Capacity : 85 tons/heat Furnace Diameter : 5.8 meter Transformer : 80 MVA / 55 kA : 12 MVA Series Reactor Secondary Voltage : 650 / 850 / 950 V Electrode Diameter: 550 mm (PCD : 1250mm) Others : 1 Oxygen lance manipulator, 3 Twin burners, 53 min. tap to tap	
2-	LF	1	Furnace capacity : 85 tons/heat Transformer : 33 MVA Electrode Diameter: 350 mm (PCD : 650 mm) Secondary Voltage : 160 - 448 V (19 Steps)	
3-	CCM	1	No. of strands : 6 Casting Radius : 8 meter Casting Speed : Average 3.5 m/min Casting Capacity : 120 ton/hour at average speed Special Features : Curve mould with EMS Auto mould level control Liftable type ladle turrets Solid dummy bars Diagonal hydraulic shears Automation level 2	

Table 14-4 Equipment List - Steel-making Plant (SMP) (2/2)

No.	Equipment	Qty	Main Specification	Remarks
4-	Dust Collector	1	Suction Capacity : Total 1,260,000 m^3/hour Installed Power : 1×6,130 m^3/min at 250 ℃ @ 1,200kW(Booster Fan) : 2×10,000 m^3/min at 70 ℃ @ 2×950kW (Main Fans) Filter Bag House : Total 1,696 Number of filter bags 16 compartments / 21,182 m^2, Filtration area	
5-	Crane	4	Scrap yard crane : 50 ton	
		2	Scrap charging crane : 1×80 ton 1×60 ton	
		1	Tapping crane : 150 ton	
		1	Billet service crane : 40 ton	
		2	Billet handling crane : 15 ton	
		1	EAF service crane : 20 ton	

(4) Unit Consumption

Monthly operation parameters including unit consumption are shown in Table 14-5 (1 to 3). These tables indicate sound operation results of a tap-to-tap interval from 53 to 64 minutes, electric power consumption of 400 to 440 kWh/ton (Billet), an oxygen consumption of 34 to 40 Nm^3/ton in EAF, and electrode consumption of 2.0 to 2.6 kg/ton (Billet).

(5) Material Balance Sheet

The material balance sheet for 1996 is shown in Figure 14-5.

Table 14-5 Monthly Operating Parameters for EAF – Steel-Making Plant (1/3)

This table cannot be made public because of ASM's confidentiality.

Table 14-5 Monthly Operating Parameters for EAF – Steel-Making Plant (2/3)

This table cannot be made public because of ASM's confidentiality.

Table 14-5 Monthly Operating Parameters for EAF – Steel-Making Plant (3/3)

This table cannot be made public because of ASM's confidentiality.

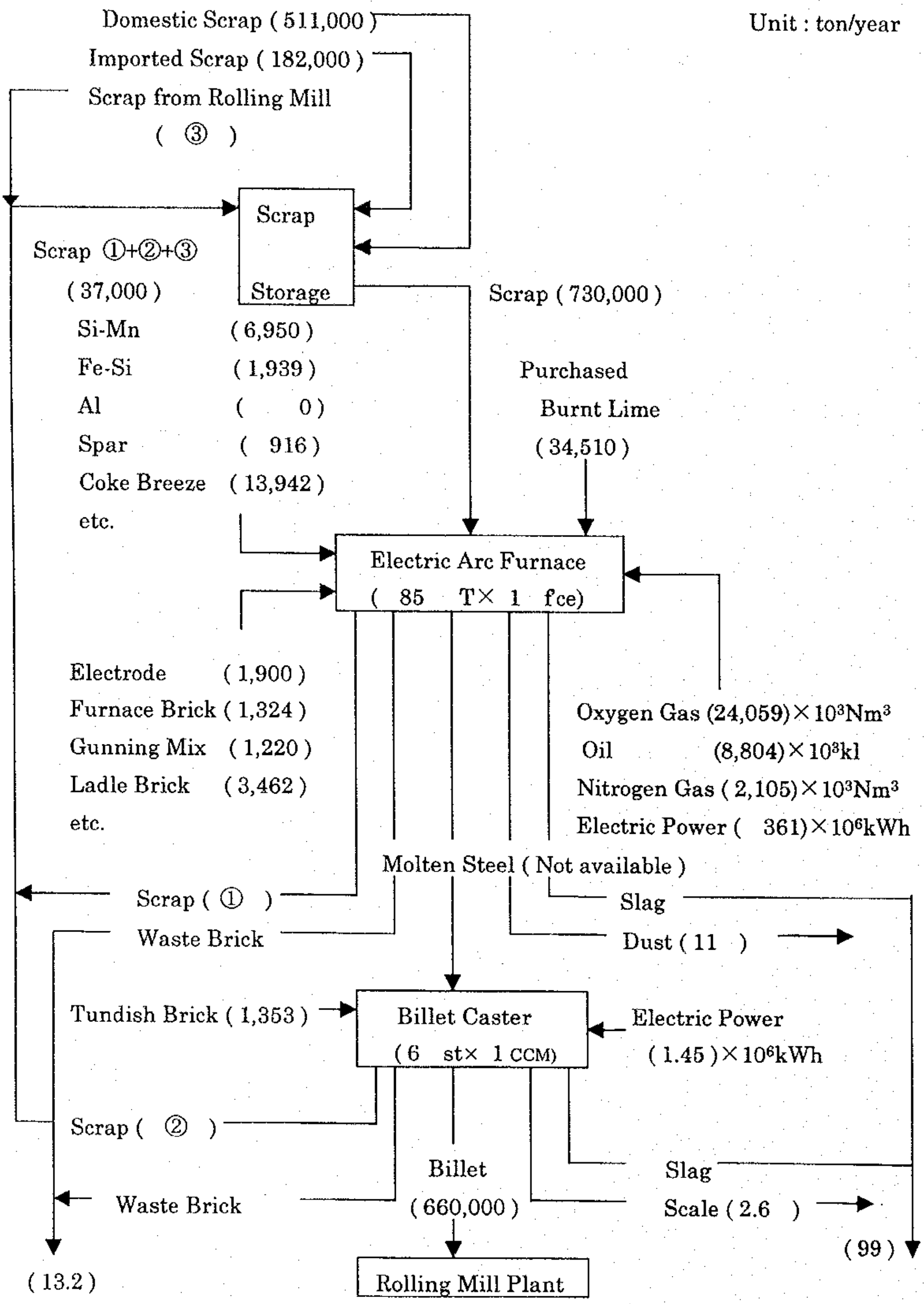


Figure 14-5 Material Balance in 1996

14-4 Rolling Mill Plant (RMP)

14-4-1 Outline of RMP

The RMP was originally designed to produce 150,000 tons/year rebar with 35 tons/hour reheating furnace and 15 rolling stands, and 300,000 tons/year wire rod with 65 tons/hour reheating furnace and 25 rolling stands. After that Bar mill 2 was established in 1992, boasting a 300,000 tons /year production capacity with a 60 tons/hour reheating furnace and 17 rolling stands. The production capacity has been expanded to 880,000 tons/year. As Table 14-2 shows, the production of final products reached 895,000 tons in 1997.

14-4-2 Outline of the Facilities

(1) Layout and Operation Flow

The layout of the plant is shown in Figure 14-6. At the Rod Mill, billets transferred from the transfer tables are charged into a walking-type reheating furnace equipped with oil burners. Billets are rolled into 5.5 to 30.0 millimeter wire rods in seven stands of the roughing mill, eight stands of the intermediate mill and twelve stands of the finishing mill.

At Bar Mill 1, slit rolling is applied to the manufacture of 10 to 13 millimeter bars to increase productivity in 1991.

(2) Main Equipment

The specifications of the equipment are shown in Table 14-6.

(3) Production

Production for the past five years is shown in Table 14-2.

(4) Unit Consumption

Productivity of Rod Mill 1 is shown in Table 14-7. Monthly operation parameters including unit consumption of Rod Mill 1 are shown in Tables 14-8(1) through 14-8(5). The table shows high productivity of 44 to 60 tons/hour, high yield more than 98 percent, and low oil consumption of 28 to 33 liters per ton.

Tables 14-9(1) through 14-9(3) show monthly operation parameters of Bar Mill 2 with unit consumption. It shows high yield.

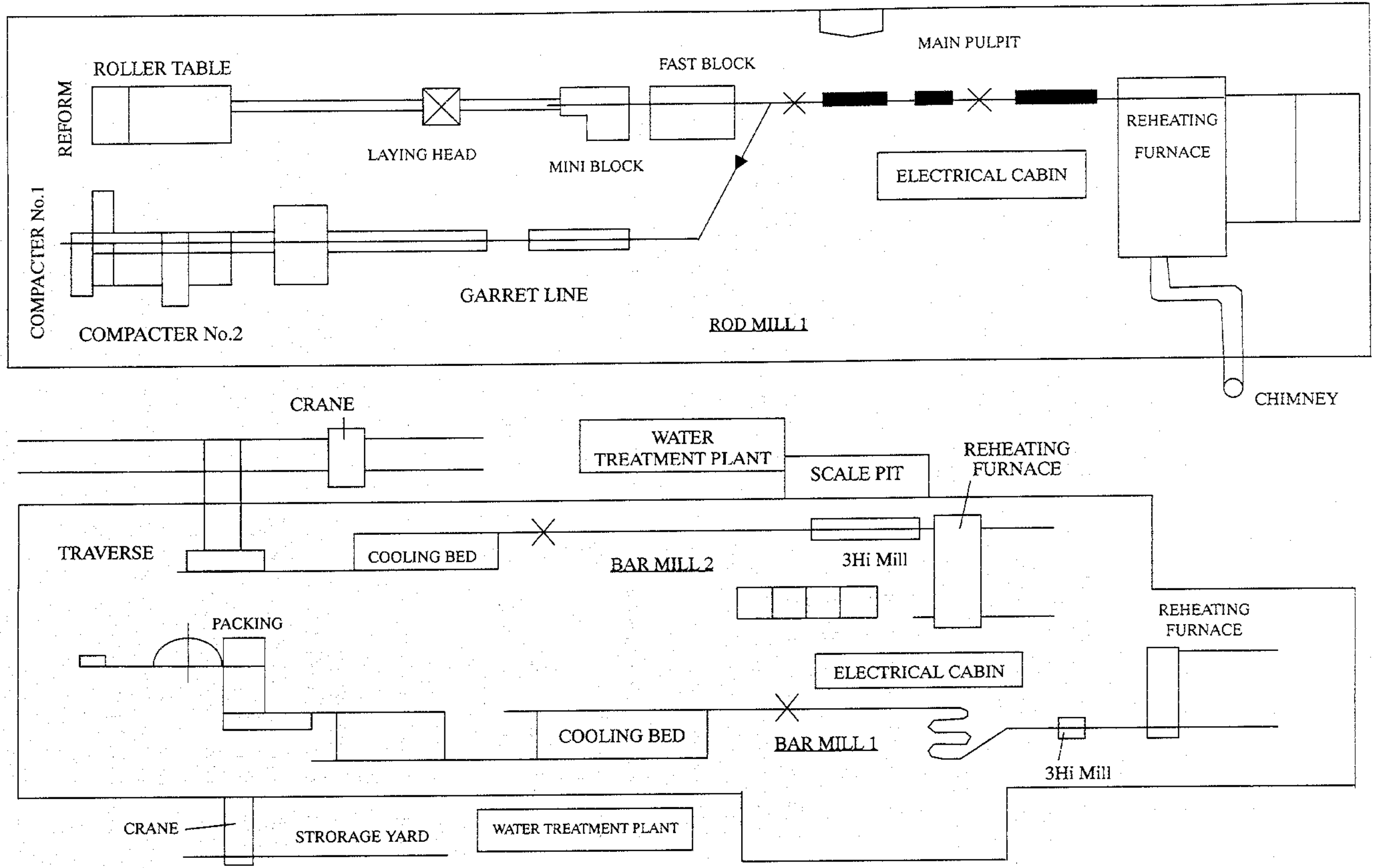


Figure 14-6 Layout of Rolling Mill Plant

Table 14-6 Equipment List-Rolling Mill Plant (RMP) (1/2)

No.	Equipment	Qty	Main Specification	Remarks
1-	Bar Mill 1	1	Mill Capacity : 200,000 ton/year Billet Size : Block 120×120 Billet Weight : 607 kg Mill Speed (ϕ 10 mm) : 10.5 meter/second No. of Passes : 15 Passes Make of Stands: DANIELI Furnace Capacity : 35 ton/hour Mill Control System : SIEMENS Product Range : ϕ 10 - ϕ 13 Slit ϕ 14 - ϕ 32	
2-	Bar Mill 2	1	Mill Capacity : 300,000 ton/year Billet Size : Block 130×130 Billet Weight : 756 kg Mill Speed (ϕ 16 mm) : 10.5 meter/second No. of Passes : 17 Passes Make of Stands: TAIWAN, DANIELI BASCOTECNIA Furnace Capacity : 60 ton/hour Mill Control System : INGELECTRIC-TEAM Product Range : ϕ 16 - ϕ 40	

Table 14-6 Equipment List - Rolling Mill Plant (RMP)(2/2)

No.	Equipment	Qty	Main Specification	Remarks
3-	Rod Mill 1	1	Mill Capacity : 380,000 ton/year Billet Size : 130 mm×130 mm×11.5 m Billet Weight : 1,526 kg Coil Dimension: OD = 1,090 mm, ID = 850 mm Coil Weight : 1,440 kg Mill Speed (Φ 5.5 mm) : 10.5 m/s (Miniblock) No. of Stands : 27 Stands Make of Stands: DANIELI & MORGAN Fast Block : MOELLER & NEUMANN Mini Fast Block : MORGAN Constraction Furnace Capacity : 65 ton/hour Mill Control System : ABB Product Range : Φ 5.5 mm - Φ 20.5 mm (Block) Φ 17.0 mm - Φ 30.0 mm (Garret)	

Table 14-7 Productivity for the Past 5 Years – Rod Mill 1-

This table cannot be made public because of ASM's confidentiality.

Table 14-8(1) Yield and By-products for Recent 12-month Period – Rod Mill 1-

This table cannot be made public because of ASM's confidentiality.

Table 14-8(2) Yield by Size for Recent 12-month Period – Rod Mill 1-

This table cannot be made public because of ASM's confidentiality.

Table 14-8(3) Unit Consumption of Utilities for Recent 12-month Period – Rod Mill 1-

This table cannot be made public because of ASM's confidentiality.

Table 14-8(4) Working Hours for Recent 12-month Period – Rod Mill 1-

This table cannot be made public because of ASM's confidentiality.

Table 14-8(5) Repair Schedule for Recent 12-month Period – Rod Mill 1-

This table cannot be made public because of ASM's confidentiality.

Table 14-9(1) Yield and By-products for Recent 12-month Period – Bar Mill 2-

This table cannot be made public because of ASM's confidentiality.

Table 14-9(2) Unit Consumption of Utilities for Recent 12-month Period – Bar Mill 2-

This table cannot be made public because of ASM's confidentiality.

Table 14-9(3) Repair Schedule for Recent 12-month Period – Bar Mill 2-

This table cannot be made public because of ASM's confidentiality.

14-5 Current Condition and Problems with Energy

14-5-1 Energy Management and Efficiency

Consumption of electric power, oxygen gas and fuel oil, all representing different types of energy, are measured by instruments installed in the control pulpit, and daily, weekly, monthly and annual reports are prepared for management review together with other operation parameters by computer processing. Daily operation results are reported and discussed in the morning meeting every day.

14-5-2 Results for Rationalization of Energy Use

The following measures for energy saving are taken.

1. Use of large capacity transformer for EAF
2. Application of high power and long arc operation to the EAF, resulting in reduced melting time, or short tap-to-tap time.
3. Use of oxy-fuel burners in the EAF makes it possible to reduce melting time and ensures uniform temperature distribution, or elimination of cold spots.
4. Foamy slag operation is applied to the EAF to use the arc heat more efficiently and to prevent the damage of the furnace wall by enveloping the arcs.
5. The eccentric bottom tapping (EBT) system (slag-free tapping) of the EAF results in shorter tapping time and heat loss.
6. The ladle furnace (LF) contributes to increased production of steel by relieving the EAF of the refining load. The EAF is operated for the sole purpose of melting scrap and the LF for refining the heat.
7. Adoption of a low impedance electrode supporting arm increases electric power efficiency.
8. Ca-Si injection for high quality steel contributes to maintaining stable operation.
9. Slit rolling contributes to increased production and energy-saving.
10. Adoption of recuperators in the rolling mill utilizes the waste heat of the reheating furnace for preheating combustion air and fuel oil

As Table 14-3 shows, ASM has been improving productivity by expanding the capacities of the relevant equipment pieces and by adopting state-of-the-art technologies. Tap-to-tap time has been improved to between 54 and 66 minutes.

Consequently, electric power consumption has also been reduced to 420 kWh per ton.

14-6 Current Condition and Problems with Facilities

14-6-1 Major Energy-Consuming Facilities

Major energy-consuming facilities are as follows:

1. Electric arc furnace: 660,000 tons per year of billet
   Electric power consumption: 420 kWh per ton, 277,000 MWh per year
   Oxygen consumption: 36 Nm^3 per ton, 23,887,000 Nm^3 per year
   Fuel oil consumption: 12 kilograms per ton, 7,923,000 kilograms per year
2. Ladle furnace: 660,000 tons per year of billet
   Electric power consumption: 53 kWh per ton, 35,100 MWh per year
3. Auxiliary facilities(include CCM): 660,000 tons per year of billet
   Electric power consumption: 73 kWh per ton, 48,300 MWh per year
   Diesel oil consumption: 0.25 kg per ton, 165,000 kg per year
4. Rolling mills: 790,000 tons per year of rebar and wire rod
   Electric power consumption: 105 kWh per ton, 82,700 MWh per year
5. Reheating furnaces: 790,000 tons per year of rebar and wire rod
   Fuel oil consumption: 32 kilograms per ton, 25,440,000 kilograms per year

14-6-2 Identification of Current Problems

(1) Problem with Major Energy-Consuming Facilities

As Section 14-5-2 describes, ASM has also been improving productivity and energy saving by expanding capacities and introducing of state-of-the art technologies. ASM has achieved superb operation results, but some further improvements are expected on the following items.

1. Electric power consumption of the electric arc furnace
   There is some room to further reduce electric power consumption by improving operating methods.
2. Introduction of a regenerative burner to the reheating furnace
   Reduction of fuel oil consumption by improving the heat recovery efficiency.
3. Hot charge
   Reduction of fuel oil consumption by application of hot charge.
4. Veneering of the furnace wall with ceramic fiber blanket
   Saving of fuel consumption by reduction of radiation heat from the furnace wall.

5. Reduction of dispersion for extracting temperature
   Saving of fuel consumption by improving the operating method.
6. Improving the air fuel ratio
   Reduction of the air fuel ratio by restoration of the oxygen content meter.

(2) Problems in Energy Consumption Already Recognized, and Items Requested for Auditing

1. ASM has envisaged reduction of electric power consumption for the electric arc furnace from 420 kWh/ton to 350 kWh/ton.
2. ASM has also envisaged reduction of electricity consumption for the ladle furnace and shredding plant.
3. ASM has requested the following items for energy audit.
   a. Voltage fluctuation in the EAF and LF.
   b. The cause of high power factor in the EAF and LF.
   c. High loss from substation to EAF and LF.

(3) Major Items and Points of Factory Audit

The JICA study team has concluded for the following reasons that the major items and points are heat balance of the reheating furnace and the electricity measurement.

1. As sub section 14-5-2 mentions, many measures have already been introduced to the electric arc furnace for saving energy consumption.
2. The scrap preheater is effective for energy saving, but recently, this is not recomended because of the hazardous dioxin generation problem. Therefore, it is difficult to save energy in the EAF by a substantial improvement of equipment.
3. The product mixture of ASM is not simple.
4. There is scope in the reheating furnace for energy saving.
5. The problems proposed by ASM are almost all electricity-related.

14-7 Method of Energy Audit

Energy consumption auditing work is based on analysis of monthly operation records and actual plant measurement or observation, which involves confirming operation data and collecting necessary data. The monthly operation record was collected through interviews, and actual plant measurements were performed according to the description in section 14-7.

14-7-1 General Description of Energy Audit

In order to select an energy auditing facility, monthly operation data was collected through March/'98 and June/'98 interviews.

Through the preliminary interview study, selection of a plant auditing facility was agreed upon, and the preheating furnace in the rod rolling mill was selected for the energy audit facility.

The main reasons for rejecting the electric arc furnace for the energy audit are, as follows;

(1) ASM steel making shop has already introduced the most modern equipment, for example,

1. A large transformer for the electric arc furnace;
2. High power, long arc operation for the electric arc furnace; reduction of melting time, i.e., tap-tap time
3. Oxy-fuel burner for the electric arc furnace; reduction of melting time, uniform melting, i.e., removal of cold spots
4. Foaming slag operation in the electric arc furnace; high-efficiency arc heating, furnace wall protection by covering arc through foamed slag
5. Eccentric bottom tapping; reduction of tap-tap time and reduction of heat loss
6. Adoption of ladle furnace; reduction of tap-tap time by separation of electric arc furnace functions, refining function to the ladle furnace and the remaining melting function to the electric arc furnace.
7. Adoption of a low impedance electrode supporting arm, increasing electric power input efficiency.

Thus, the remaining improvement points are very small or are considered operational technologies, and when evaluating the application rate of those improvement technologies, quantitative evaluation is very difficult.

(Of course, at this facility target point, ASM steel making plant does not have a scrap preheater. Recently, the scrap preheater is not recommended because of the hazardous dioxin generation problem.)

(2) One of the measuring targets for the electric arc furnace is high temperature (over 1000℃) corrosive exhaust gas, and frequent thermo-couple change is essential. Also, the measuring period of the electric arc furnace is not less than 3 continuous heats, and data collecting man-power is not less than 6 experts of metallurgical measuring experience. Nevertheless, combustion heat generated in the furnace is still a matter of discussion (whether heat generation is in the bath, in the furnace or combustion chamber).

At the same time, the preheating furnace of the rod mill is located side by side with the continuous caster delivery table, allowing adoption of hot billet charging. Application of hot billet charging enables maximum energy saving of over 30%.

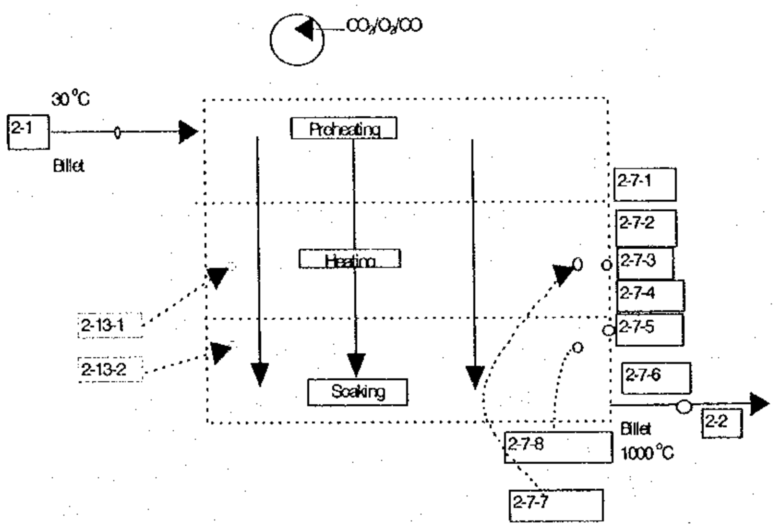
As a conclusion, measurement of the rod mill preheating furnace is analyzed for energy audit, and observation of electric arc furnace operation and monthly operating data are summarized for discussion.

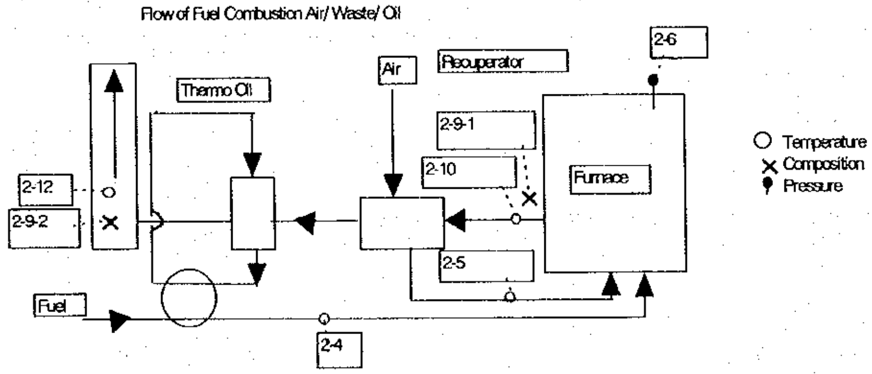
14-7-2 Outline of Measuring Items, Points and Measuring Instruments

The preheating furnace of the rod rolling mill, which is planned for energy audit, and electric power supply, which was requested by ASM members, were measured in respect to the following items.
In general, where there is mill data, data is collected through mill instruments, and other data is measured by JICA members.

(1) Reheating Furnace: Measuring Items, Points and Measuring Instruments
The measuring period consists of 1st , 4th and 5th shifts after weekly shutdown.
Measuring items and points of reheating furnace are illustrated in Figure 14-7.

REHEATING FURNACE: TEMPERATURE MEASURING POINTS





Measurements

Temperature	2-1	Billet Charging Temp
	2-2	Billet Extracting Temp
	2-4	Fuel Supply Temp
	2-5	Combustion Air Temp
	2-7-	1 - 6 Furnace Wall Temp
	2-7-7	Furnace Soaking Zone Roof Temp
	2-7-8	Furnace Preheating Zone Roof Temp
	2-10	Exhaust Gas Temp
	2-12	Outlet of Recuperator Temp
$O_2/CO_2/CO$	2-9-1	Exhaust Gas
	2-9-2	Outlet of Recuperator
Outside condition	2-16	Temp/Humidity/Pressure

Record		
Product	2-3	Billet Heating Quantity (T/hrs)
Temperature	2-4	Fuel Supply Temp
	2-5	Combustion Air Temp
	2-10	Exhaust Gas Temp
	2-12	Outlet of Recuperator Temp
	2-13-1	Fce Heatig Zone Atomosphere
	2-13-2	Fce Soaking Zone Atomosphere
Pressure	2-6	Furnace Pressure

Figure 14-7 Measuring Items and Points

1) **Heated material**

1. The production rate is from the shift average record, supplied by ASM.
2. Charged temperature is measured at the charging transfer table, using a radiation pyrometer (low temperature type).
3. Extracted temperature is measured at the extracting roller table, using a radiation pyrometer (high temperature type).
4. Scale loss is from monthly operation data, supplied by ASM.

2) **Fuel consumption**

1. Consumption rate is from shift average record, supplied by ASM.
2. Fuel composition is analyzed by SIRIM.
3. Density is from catalogue data.
4. High heating value is from catalogue data.
5. Specific heat is from text book data.
6. Feeding temperature is from mill data, the average of the temperature of 4 branches.

3) **Exhaust gas**

1. Furnace tale (=recuperater inlet) temperature is from the mill record, supplied by ASM.
2. Dry exhaust gas composition is measured by a Hotaka gas analyzer, applying A type (liquid fuel) scale.

4) **Combustion air**

1. Furnace inlet temperature is from the mill record, the average of the temperature of 4 branches, supplied by ASM.

5) **Ambient temperature**

1. Ambient temperature is read from an auto-recorder, set at the office front door.

6) **Furnace outside wall and roof temperature**

1. Furnace wall and roof temperature is recorded and read using thermo-couples. Setting was done by metal adhesive tape.

7) **Furnace inside wall temperature**

1. Furnace inside wall temperature is from the mill record, supplied by ASM.

(2) Electricity-Measuring Items, Points and Measuring Instruments

1) Measuring Items

1. Electricity.
2. Voltage.
3. Electrical current.
4. Power factor.

2) Measuring Points

Measuring points are shown in Figure 14-8.

1. Incoming No.1.
2. Incoming No.2.
3. New shredder plant.
4. Electric arc furnace.
5. Rod mill 1.
6. Ladle furnace.

3) Measuring Instrument

All items were measured by clamp-on power testers (HIOKI 3166). They were supplied by JICA.

Details of measuring items, points and measuring equipment are shown in Table 14-10.

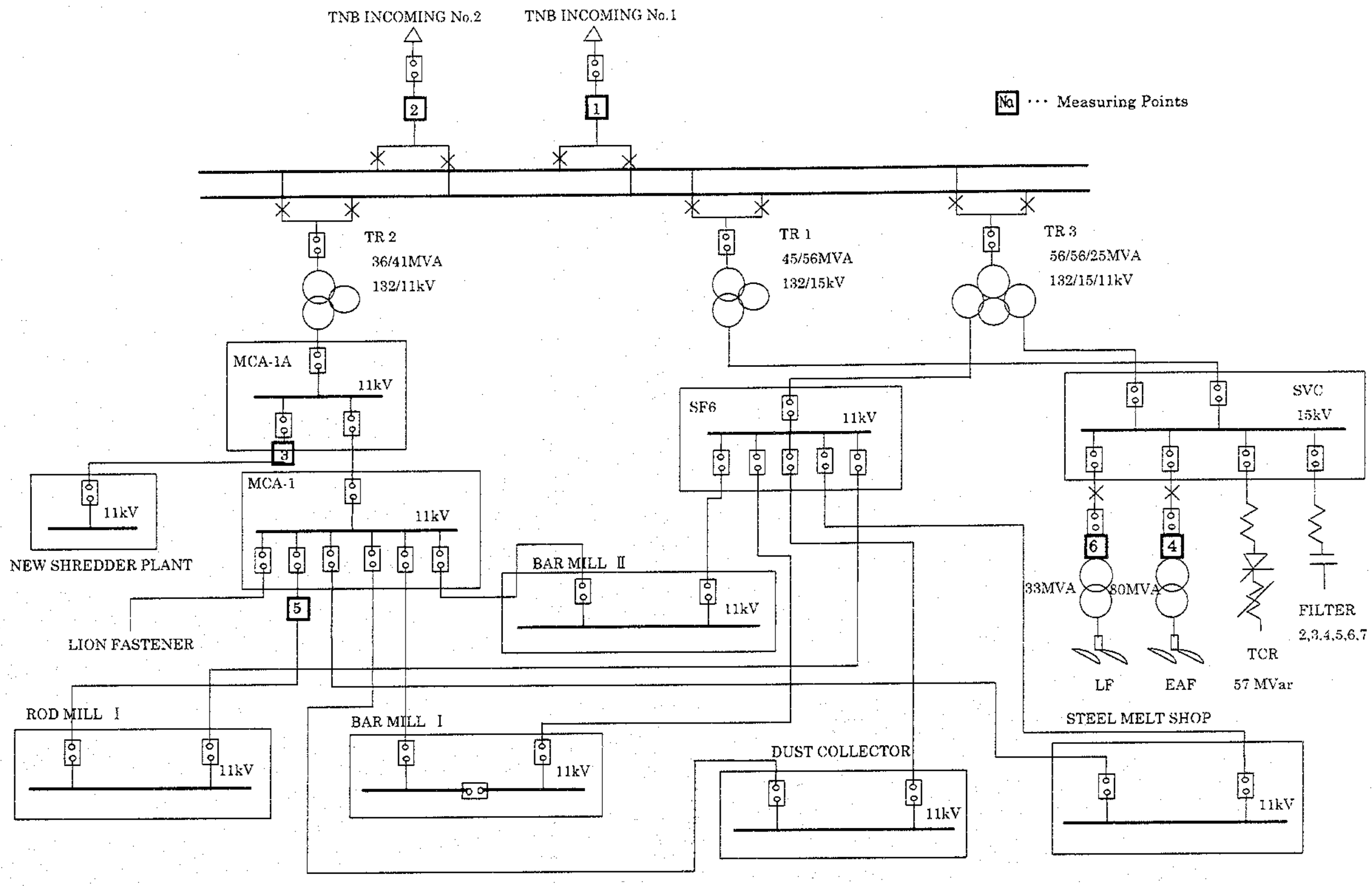


Figure 14 -8 Single Line Diagram

Table 14-10 (1) Outline of Measurements for Energy Audit (ASM)

Major Items of Energy Audit & Subject Items and Points	Measurement or Estimate	Available Equipment for Measurement			
		Required Equipment	ASM	JICA	Local Labo.
1.Electrical Power Receiving & Distribution					
1) Voltage	M	Clamp on power hitester		x	
2) Electrical Current	M	ditto		x	
3) Electricity	M	ditto		x	
4) Power Factor	M	ditto		x	
2. Measurement around the Reheating Furnace					
(1) Billet					
1) Charging Amount	M	Ope. Record	x		
2) Charging Temperature	M	Radiant Pyrometer(Low)		x	
3) Extracting Temperature	M	Radiant Pyrometer(High)		x	
4) Extracting Amount	M	Weigher or Ope. Record	x		
5) Heating Time	M	Clock	x		
6) Scale Loss	M	Weigher or Ope. Record	x		
(2) Fuel Oil					
1) Flow Rate	M	Operation record & Data	x		
2) Composition (C, H, N, O, S, Moisture)	M	C, H, N Analyzer etc.			x
3) Heating Value	Review	Supplier's data sheet	x		
4) Supply Temperature	M	Operation record & Data	x		
5) Flow Rate of Each Zone	M	ditto	x		
(3) Combustion Air					
1) Temperature	M	Operation record & Data	x		
2) Flow Rate of Each Zone	M	ditto	x		
3) Air-fuel Ratio of Each Zone	M	ditto	x		
(4) Reheating Furnace					
1) Temperature of Each Zone	M	Operation record & Data	x		
2) Furnace Pressure	M	ditto	x		
3) Wall Temperature	M	Thermocouple pyrometer:K		x	

Table 14-10 (2) Outline of Measurements for Energy Audit (ASM)

Major Items of Energy Audit & Subject Items and Points	Measurement or Estimate	Available Equipment for Measurement			
		Required Equipment	ASM	JICA	Local Labo.
(5) Combustion Exhaust Gas					
1) Temperature	M	Operation record & Data	X		
2) Composition of Exhaust Gas	M	CO, CO_2 Content meter		X	
(CO, CO_2, O_2)		Oxygen Content meter		X	
3) Inlet Temp. of Recuperator	M	Operation record & Data	X		
4) Outlet Temp. of Recuperator	M	ditto	X		
(6) Ambient Temperature	M	Temperature Humidity Pressure Recorder		X	
(7) Humidity	M			X	