14-8 Schedule of Measurement

The schedule of energy audit for the steel plant was from October 1 to 13, 1998. It includes preparation of measuring and preliminary discussion of measurement result of audit.

(1) Preparatory Stage

1 Oct. (Thurs.):	Explanation, discussion, and confirmation of the audit plan.
2 Oct. (Fri.):	Transportation of measuring equipment.

(2) Energy Audit

6 Oct. (Tue.):	Explanation of measuring items and confirmation of measuring points. Compilation of a list of measuring procedures and work allocation. Measurement of electricity consumption for electric arc furnace (EAF) and ladle furnace (LF).
7 Oct. (Wed.):	Installation and adjustment of measuring equipment for reheating furnace. Measurement of electricity consumption for EAF, LF and new shredder plant.
8 Oct. (Thurs.):	Measurement of temperature, pressure and exhaust gas compsition for reheating furnace. Measurement of electricity consumption for incoming No.1, No.2 and rod mill 1.
9 Oct. (Fri.):	Measurement of temperature, pressure and exhaust gas component for reheating furnace. Measurement of electricity consumption for incoming No.1, No.2, rod mill 1 and new shredder plant.
10 Oct. (Sat.):	Meeting for EAF operation. Analysis of measuring results. Measurement of electricity consumption for incoming No.1, No.2, EAF, and new shredder plant.
11 Oct. (Sun.):	Analysis of measuring results. Measurement of electricity consumption for incoming No.1, No.2, EAF, and new shredder plant.

(3) Discussion of Improvements for EAF and Transportation of Measuring Equipment

12 Oct. (Mon.):	Presentation on energy efficiency improvements for EAF. Repackaging of measuring equipment.

Measurement of electricity consumption for incoming No.1, No.2 and EAF.

13 Oct. (Tue.): Transportation of measuring equipment to JBE&G.

Table 14-11 shows a detailed schedule for measurement.

Measuring was done under co-operation of JICA members and Malaysian members. Measuring members are as follows.

JICA:	S. Kinoshita, Y. Ishibashi, H. Omori, S. Iizuka.
ASM:	Hui Ah Chong, V. Ramamutthie, Chiam Jit Sing.
SIRIM:	Chew Thean Yean, Syed Anuar Shah, Hassan Ismail, Zulkarnain Abdullah, Rahim B. Tambi.

Table 14-11 (1) Detailed Schedule of Measurement (ASM)

Measuring Items	Working Day							
	1	2	3	4	5	6	7	8
0. Preparation & Discussion of the plan	x	x	x					
1. Electricity Consumption								
1) Incomer No.1 and No.2				x	x	x	x	x
2) Electric Arc Furnace		x	x		x	x	x	x
3) Ladle Furnace		x	x					
4) Rod Mill 1				x	x			
5) New Shredder Plant			x		x	x	x	
2. Measurement around the Reheating Furnace								
(1) Billet				x	x			
1) Charging Amount				x	x			
2) Charging Temperature				x	x			
3) Extracting Temperature				x	x			
4) Extracting Amount				x	x			
5) Heating Time				x	x			
6) Scale Loss				x	x			
(2) Fuel Oil								
1) Flow Rate				x	x			
2) Component				x				
3) Heating Value				x				
4) Supply Temperature				x	x			
5) Flow Rate of Each Zone				x	x			
(3) Combustion Air								
1) Temperature				x	x			
2) Flow Rate of Each Zone				x	x			
3) Air-fuel Ratio of Each Zone				x	x			
(4) Reheating Furnace								
1) Temperature of Each Zone				x	x			
2) Pressure of Each Zone				x	x			
3) Wall Temperature				x	x			

Table 14-11 (2) Detailed Schedule of Measurement (ASM)

Measuring Items	Working Day							
	1	2	3	4	5	6	7	8
(5) Combustion Exhaust Gas								
1) Temperature				x	x			
2) Component of Exhaust Gas				x	x			
3) Inlet Temp. of Recuperator				x	x			
4) Outlet Temp. of Recuperator				x	x			
(6) Outside Air Temperature				x	x			
(7) Humidity				x	x			
(8) Data Reduction and Check						x	x	x
3. Field Investigation		x	x	x	x	x	x	x
4. Review and Discussion								x

14-9 Results of Measurement

14-9-1 Results of Measurement and Heat Balance of Reheating Furnace

(1) Result of Measurement

Table 14-12 shows the results of measurement together with related operating data.

Compared with nominal heating capacity, actual productivity is low, at 1/3 to 1/4 of the nominal capacity.

Considering the effect of shut-down, measured data are divided into 3 typical conditions: 1st shift, when heat output includes heating up the furnace; 4th shift, when wall temperature is extraordinarily high; and 5th shift, when wall temperature becomes low.

(2) Heat Balance of Reheating Furnace

Based on measured data, 3 heat balance sheets are calculated. Table 14-13 shows the summary. Sample of calculation is attached in Annex-1. Calculation of heat loss from furnace body is estimated according to Annex-2 (Calculation of Heat Loss from Furnace Body).

(3) General Evaluation of the Measured Data

Among the 3 measured data, the 5th shift data is understood as typical of ASM conditions, when the wall temperature reached stable condition.

The stable condition shows the following features;

1. The unit fuel consumption is 28.7 kg/t (271.6 x 10^3 kcal/t), which is a sound value. This value is lower than the Japan's target value in 1996, 275 x 10^3 kcal/t, obtained from the study by NEDO (New Energy and Industrial Technology Development Organization). ASM has actually sustained superb operation.
2. Air/fuel ratio is 1.25, which is excellent for a steel reheating furnace.
3. Furnace pressure is 0.3-0.8 mm H_2O, which is a sound value. At the charging opening and discharging opening on the furnace side, a very small amount of positive pressure is confirmed.
4. Heat recovery efficiency of the recuperator is 41%, which shows effective functioning.
5. Waste gas temperature at the recuperator inlet point is 618℃, which suggests the effect of an high-efficiency recuperator is small.
6. Combustion air leakage ratio in the recuperator is estimated at 21% of the total blast, which is not such a large amount. (Annex-3)
7. The temperature variation of extracted material shows 60℃, which suggests the possibility

of energy saving when adopting the lowest temperture.

8. The temperature of charged material, which was 300℃ in the hearing data, was ambient temperature at the time of measurement.
9. Furnace wall temperature varies from start-up after weekly shutdown, the highest record being 206℃ (roof, at 4th shift), and drops to 139℃ in the 5th shift, which is still high.

The low fuel consumption value considerbly accords with the Japanese experience, which the fuel consumption is minimized at around 300 kg/hr・m^2 of heating load per hearth (for nominal capacity of ASM, 60,000/(17.2×12.5) = 270 kg/hr・m^2, at actual operation, 150 kg/hr・m^2).

Table 14-12 Results of Reheating Furnace Measurement

Measurement	Item		No.	DATE 08/10/98					09/10/98				
			TIME	10:00	12:00	14:30	16:00		10:00	12:00	15:00	16:00	
FURNACE	TEMPERATURE	°C	2-1					30	30	31	33	33	
			2-2					1030	1039	1050	1078	1097	
			2-4				93	97	102	96	96	95	
			2-5				298	237	300	256	296	310	
			2-7-1	76	78	83	85		101	90	88	87	
			2-7-2	96	104	111	116		132	102	100	100	
			2-7-3	106	112	122	127		160	115	115	116	
			2-7-4	85	89	93	96		121	95	95	95	
			2-7-5	124	132	142	149		182	130	130	130	
			2-7-6	119	131	144	149		179	130	135	135	
			2-7-7	127	134	145	158		173	100	101	107	
			2-7-8	152	170	187	195		206	138	138	140	
			2-10				542		548	555	617	618	
			2-12				220		240	215	242	229	
			2-13-1					760		834	961	942	
			2-13-2					1060		1080	1135	1157	
	PRESSURE	mm water	2-6					0.36	0.3	0.38	0.78	0.73	
	$O_2/CO_2/CO$	%/%/ppm	2-9-1			11.6/ 6.8/ 1	4.4/ 12.3/ 2		4.4/ 12.3/ 2				
			2-9-2			17.6/ 2.5/ 0	15/ 4.4/ 0		15/ 4.4/ 0				
	Billet Quantity	T/hr	2-3	20.16				30	30.3				
	Fuel used	kg/hr		891					870				
		kg/T		44.2					28.7				
OUTSIDE CONDI-TION	Temp	°C	2-16						29	31	33	32	
	Humidity	%							70	59	54	56	
	Pressure	mm Hg							760				

Table 14-13 Summary of Heat Balance Calculation

Shift			1st Shift	4th Shift	5th Shift
Productivity		t/hr	20.2	30.3	30.3
Total Energy Consumption		10^3kcal/t	504.7	319.2	319.0
Combustion Heat Unit consumption		10^3kcal/t	422.0	271.6	271.6
Input	Combustion Heat of Fuel	%	83.6	85.1	85.1
	Sensible Heat of Fuel	%	0.3	0.3	0.3
	Sensible Heat of Combustion Air	%	13.5	10.4	10.4
	Heat Content of Charged Steel	%	0	0	0
	Heat of Formation of Slag	%	2.7	4.2	4.2
Output	Heat Content of extracted Steel	%	32.3	51.6	53.8
	Sensible Heat of Scale	%	0.6	0.9	0.9
	Sensible Heat of Waste Gas	%	36.7	22.6	25.5
	Heat Loss from Furnace Body	%	4.9	6.2	6.0
	Other Heat Loss	%	25.5	18.7	13.8
Remarks	Waste Gas Temperature (Rec. Inlet)	℃	542	548	618
	Roof Temperature (Soaking Zone)	℃	175	206	139
	O_2/CO_2 Content (Rec. Inlet)	%/%	11.6/6.8	4.4/12.3	4.4/12.3
	Air/Fuel Ratio	-	2.15	1.25	1.25

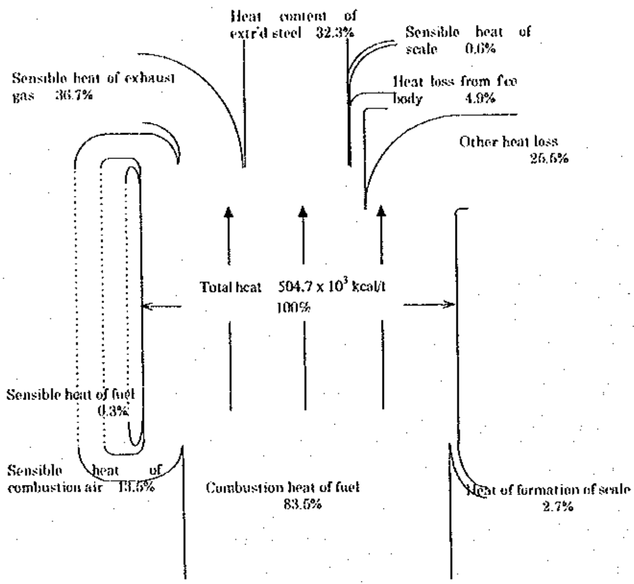


Figure 14-9 (1) Heat Balance of 1st Shift

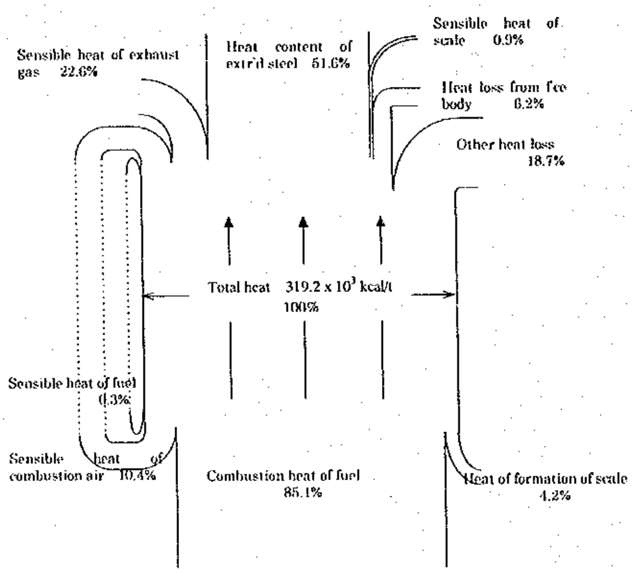


Figure 14-9 (2) Heat Balance of 4th Shift

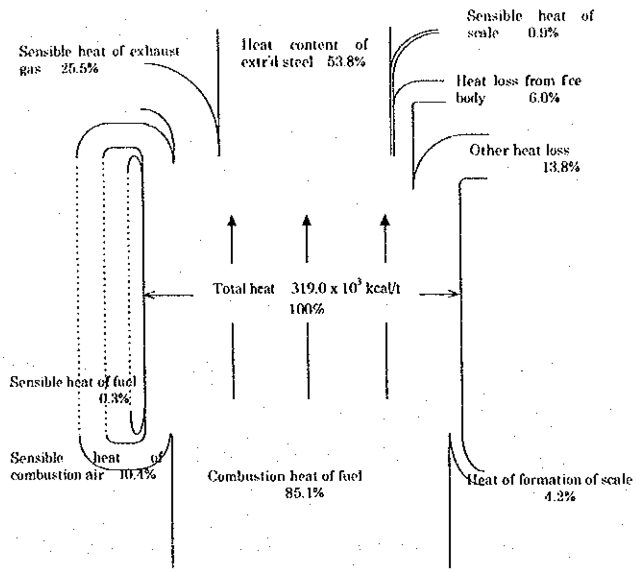


Figure 14-9 (3) Heat Balance of 5th Shift

14-9-2 Electricity

(1) Single Line Diagram

Figure 14-8 shows a single line diagram of the ASM. There are two 132kV incoming lines from TNB. There are three main transformers. Their capacities are 45/56 MVA , 36/41 MVA and 56/56/25 MVA, and their secondary voltages are 15kV for EAF and LF, and 11kV for other plants.

The measuring points are shown by the numbers from 1 to 6 in Figure 14-8.

At the 15kV Bus-bar for EAF, there are automatic reactive power compensators and harmonic filters.

(2) Electricity Consumption Measured at Power Receiving

Trend data of the electricity consumption measured at the power receiving points are shown in Table 14-14 and Table 14-15. The total electricity consumption on 10 October was 1,440 MWh/d. The electricity consumption during the Peak Period based on the TNB tariff system was 815 MWh/d and the Off-Peak Period consumption was 625 MWh/d. The share of Off-Peak consumption was 43.4 percent. This value is appropriate for the factory's 24-hour operation time.

(Share of Off-Peak consumption = Off-Peak consumption / Total consumption × 100)

The maximum and minimum demand (30 minutes) were 78.24 MW and 41.5 MW, and the average was 59.99 MW.

The load factor was 76.7 percent. This value is good, but it is preferable to increase this by means of reducing the maximum demand.

(Load Factor = Average / Max. Demand $\times$ 100 = 59.99 / 78.24 $\times$ 100 = 76.7 %)

(3) Power Receiving Electricity Data

1) Voltage

Figure 14-10 and Figure 14-11 show voltage at the power receiving point on 10 October. The maximum voltage was 138.9 kV and minimum voltage was 132.2 kV.

The voltage regulation was 5.1 percent. This shows that the voltage fluctuation is relatively small.

[Voltage Regulation = (Max. Voltage - Min. Voltage) / Min. Voltage $\times$ 100
= (138.9 - 132.2) / 132.2 $\times$ 100 = 5.1 %]

2) Electricity and Power Factor

Figure 14-12 and Figure 14-13 show electricity and power factor at the power receiving points. The power factor ranged from 0.950 to 0.995, the average being 0.972. Both figures show that the power factor was low when electricity demand was high, but was high when electricity demand was low.

(4) EAF Data

1. Figure 14-14 shows voltage of EAF. Voltage ranged from 27.20 kV to 32.25 kV. The voltage regulation was 18.6 percent. This value is not so small, but it is not a problem. Because, as mentioned above, the voltage regulation at the receiving point is $\pm$2.55 percent.

[Voltage Regulation = (32.25 - 27.20) / 27.20 $\times$ 100 = 18.6 %]

2. Figure 14-15 (1), (2), (3) show electricity and power factor. Maximum electricity demand was 56.8 MW and electricity consumption on 10 October was 872,404 kWh/d. The power factor during operation ranged from 0.763 to 0.902, the average being 0.818. This means that only a few power factors exceed 0.85. Therefore, it would be difficult to say that power factor is too high.
3. The total melting amount on 10 October was 2,197 tons. So unit electricity consumption was 397 kWh/t.

(5) LF Data

1. Figure 14-16 shows one sample of electricity and power factor for LF. Maximum electricity demand was 12.3 MW and electricity consumption during measurement was 99,635 kWh. The power factor during operation ranged from 0.512 to 0.841, the average being 0.785.
2. The total melting amount was 2,056 tons, so unit electricity consumption was 48.5 kWh/t.

(6) New Shredder Plant Data

1. Table 14-16 shows measuring results of the voltage, electric current, frequency, electricity and power factor for the New Shredder Plant.
2. Figure 14-17 shows electricity and power factor. Maximum electricity demand was 4,234 kW. Electricity consumption during operation was 16,693 kWh. The power factor during operation ranged from 0.492 to 0.949, the average being 0.656.
3. The shredding amount was 390 ton, so unit electricity consumption was 42.8 kWh/t.
4. The cause of high unit consumption is low productivity (56 t/h = 390 t/ 7 h). It is necessary to operate with high productivity, and doing so will reduce unit consumption to 35 kWh/t.
5. As Table 14-16 shows, electricity consumption during plant stop page was about 35 kWh/h. This means a 204,400 kWh loss per year, so it is preferable to check and reduce this loss.
   (204,400 [kWh/year] = 35 [kWh/h]×16 [h/day] ×365 [day/year])

(7) Rod Mill I Data

1. Table 14-17 shows the results of measurement on voltage, electric current, electricity, frequency and power factor for the Rod Mill I.
2. Figure 14-18 shows that the voltage is relatively stable. Voltage ranged from 10.70 kV to 11.32 kV. The voltage regulation was 5.8 percent. This is almost same as the receiving point.
   [Voltage Regulation = (11.32 - 10.70) / 10.70×100 = 5.8 %]
3. Figure 14-19 is the trend curve of electricity and the power factor for Rod Mill I. Electricity ranged from 2.70 MW to 4.93 MW and power factor ranged from 0.593 to 1.000, the average being 0.762. It shows that the power factor was low when electricity demand was high, and was high when electricity demand was low.

(8) Power Factor at EAF and LF

As mentioned above, the average power factors in the EAF and LF on October 10 were 0.818 and 0.785. Here we study improving the power factor.

1) Prerequisites

(a) Specification of electric cable

a) Sub station - EAF: $3\times5\times630$ mmsq ($0.0308\,\Omega$/km), 200 m.

b) Sub station - LF: $3\times2\times240$ mmsq ($0.0739\,\Omega$/km), 250 m.

(b) Electricity data on 10 October

a) Average electricity of EAF: 36.4 MW

b) Average electricity of LF: 4.2 MW

c) Average electrical current of EAF: 1,713 A($=36.4\text{MW}/\sqrt{3}\times15\text{kV}\times0.818$)

d) Average electrical current of LF: 206 A($=4.2\text{MW}/\sqrt{3}\times15\text{kV}\times0.785$)

2) Energy Saving Effect after Improving by 1 Percent

(a) Electrical current after improvement

a) EAF: 1,692 A($=36.4\text{MW}/\sqrt{3}\times15\text{kV}\times0.828$)

b) LF: 203 A($=4.2\text{MW}/\sqrt{3}\times15\text{kV}\times0.795$)

(b) Electricity consumption saving amount

a) EAF: $0.0308\,\Omega/\text{km}\times\{(1{,}713/5)^2-(1{,}692/5)^2\}\times3\times5\times200\text{ m}/1{,}000\text{ m} = 264\text{ W}$
$= 0.26\text{ kW}$

b) LF: $0.0739\,\Omega/\text{km}\times\{(206/2)^2-(203/2)^2\}\times3\times2\times250\text{ m}/1{,}000\text{ m} = 34\text{ W}$
$= 0.03\text{ kW}$

3) Conclusion

As mentioned above, the amount of electricity consumption saved by improving the power factor is very small. This means, it is difficult to reduce electric power loss by improving the power factor.

And electric power loss between sub station and EAF and LF is as follows

EAF: $0.0308\,\Omega/\text{km}\times(1{,}713/5)^2\times3\times5\times200\text{ m}/1{,}000\text{ m} = 10{,}845\text{ W} \fallingdotseq 11\text{ kW}$

LF: $0.0739\,\Omega/\text{km}\times(206/2)^2\times3\times2\times250\text{ m}/1{,}000\text{ m} = 1{,}176\text{ W} \fallingdotseq 1.2\text{ kW}$

This means electric power loss between sub station and EAF and LF is also very small.

Table 14-14 Electricity Consumption for Incoming No.1 (Oct. 10)

DATE	TIME	Voltage [kV]				Current [A]				Effective Power [MWh/h]	Frequency [Hz]	Power Factor
		V1	V2	V3	Ave.	I1	I2	I3	Ave.			
10/10	0:30	138.8	138.7	138.9	138.8	171.7	181.3	179.6	177.6	36.78	50.11	0.971
10/10	1:00	134.0	134.9	135.0	134.6	199.2	197.6	204.2	200.4	24.80	49.99	0.971
10/10	1:30	137.5	137.6	137.8	137.6	186.5	190.0	191.1	189.2	39.32	50.00	0.951
10/10	2:00	138.1	138.1	138.6	138.2	179.9	171.5	182.9	178.1	23.20	49.98	0.967
10/10	2:30	137.2	137.5	137.6	137.5	66.5	67.1	68.1	67.2	38.16	49.99	0.967
10/10	3:00	134.4	133.8	135.2	134.5	250.5	241.3	211.7	234.5	28.72	50.02	0.950
10/10	3:30	138.3	137.1	136.7	137.4	72.1	117.4	94.9	94.8	29.18	50.08	0.971
10/10	4:00	133.1	133.6	134.9	133.9	202.8	187.9	200.3	197.0	36.18	50.08	0.964
10/10	4:30	136.5	137.2	136.6	136.8	162.0	177.7	202.2	180.7	31.26	49.95	0.961
10/10	5:00	134.6	134.5	134.2	134.4	182.8	198.4	200.7	194.0	36.44	49.83	0.961
10/10	5:30	133.4	132.7	133.8	133.3	200.8	213.5	183.3	199.2	27.82	49.98	0.967
10/10	6:00	133.9	133.6	133.3	133.6	141.5	189.8	172.1	167.8	31.84	49.94	0.963
10/10	6:30	135.5	135.8	135.6	135.7	178.5	188.5	199.8	188.9	37.62	49.96	0.967
10/10	7:00	138.5	138.3	138.5	138.5	0.0	0.0	0.0	0.0	26.74	50.04	0.970
10/10	7:30	138.8	138.5	138.7	138.6	0.0	0.0	0.0	0.0	32.12	50.06	0.976
10/10	8:00	133.7	134.4	133.5	133.9	206.0	202.8	236.2	215.0	26.12	50.03	0.965
10/10	8:30	135.7	135.1	135.5	135.4	158.5	172.7	158.5	163.3	31.84	50.04	0.962
10/10	9:00	132.6	132.6	132.4	132.5	224.9	229.8	239.8	231.5	24.04	49.93	0.971
10/10	9:30	135.7	135.4	135.7	135.6	0.0	0.0	0.0	0.0	29.94	49.92	0.977
10/10	10:00	133.7	133.3	133.9	133.7	179.2	182.4	172.4	178.0	36.26	49.94	0.957
10/10	10:30	132.9	133.0	133.4	133.1	191.3	179.1	191.5	187.3	31.08	49.94	0.963
10/10	11:00	136.0	136.3	136.2	136.2	148.7	154.1	172.5	158.4	33.62	49.96	0.953
10/10	11:30	136.0	136.8	135.5	136.1	127.5	173.5	197.1	166.0	28.08	49.80	0.979
10/10	12:00	136.3	136.1	136.4	136.3	0.0	0.0	0.0	0.0	29.46	49.96	0.995
10/10	12:30	137.2	137.2	137.2	137.2	118.4	140.0	130.0	129.5	25.18	49.93	0.984
10/10	13:00	137.1	136.9	137.2	137.1	37.5	38.1	39.8	38.5	29.22	50.06	0.995
10/10	13:30	137.1	136.9	137.3	137.1	136.3	131.4	139.7	135.8	30.50	49.96	0.986
10/10	14:00	135.4	134.9	136.4	135.5	203.3	175.8	162.9	180.6	27.72	50.05	0.991
10/10	14:30	135.7	135.5	135.5	135.5	144.6	166.8	156.1	155.8	34.22	49.98	0.984
10/10	15:00	136.8	136.3	136.8	136.6	157.2	159.0	149.3	155.2	24.80	50.02	0.976
10/10	15:30	135.9	135.8	135.9	135.8	140.7	152.2	154.4	149.1	29.92	49.94	0.976
10/10	16:00	136.9	136.6	136.9	136.8	52.8	54.6	54.1	53.8	25.10	49.98	0.985
10/10	16:30	137.0	136.8	137.0	136.9	39.8	40.4	41.9	40.7	33.10	50.04	0.975
10/10	17:00	136.4	136.4	137.1	136.6	195.7	172.6	188.0	185.4	29.68	50.03	0.973
10/10	17:30	135.7	136.3	135.1	135.7	166.8	182.4	219.0	189.4	30.60	50.02	0.980
10/10	18:00	136.6	136.3	136.6	136.5	60.9	62.2	63.2	62.1	20.58	50.03	0.985
10/10	18:30	135.4	134.5	134.7	134.9	158.4	183.3	153.0	164.9	22.96	50.08	0.980
10/10	19:00	134.1	134.2	135.1	134.5	124.9	99.2	102.8	109.0	22.82	50.01	0.979
10/10	19:30	134.9	134.8	134.8	134.8	157.1	172.1	169.0	166.1	34.04	49.96	0.974
10/10	20:00	134.2	134.5	135.0	134.6	172.2	155.3	167.7	165.1	29.62	49.98	0.976
10/10	20:30	134.3	134.7	135.3	134.8	179.5	151.4	175.5	168.8	34.08	50.02	0.968
10/10	21:00	135.1	135.4	134.4	135.0	152.2	209.0	201.9	187.7	25.50	49.97	0.968
10/10	21:30	134.0	134.3	135.0	134.4	184.0	158.4	178.5	173.6	29.26	50.01	0.983
10/10	22:00	136.8	136.7	137.3	137.0	160.6	149.3	156.9	155.6	34.90	49.94	0.962
10/10	22:30	133.6	133.8	134.4	133.9	165.9	155.3	165.7	162.3	27.50	49.90	0.975
10/10	23:00	134.5	134.5	134.9	134.6	180.0	190.4	173.6	181.4	33.90	50.09	0.974
10/10	23:30	133.1	133.1	133.5	133.2	177.6	190.0	183.7	183.8	23.92	50.00	0.980
10/10	0:00	137.2	137.2	137.4	137.3	59.3	60.2	62.0	60.5	35.62	50.04	0.980

Table 14-15 Electricity Consumption for Incoming No.2 (Oct. 10)

DATE	TIME	Voltage [kV]				Current [A]				Effective Power [MWh/h]	Frequency [Hz]	Power Factor
		V1	V2	V3	Ave.	I1	I2	I3	Ave.			
10/10	0:30	138.3	138.4	138.4	138.4	171.2	178.6	185.9	178.5	35.82	50.10	0.970
10/10	1:00	136.4	135.9	136.0	136.1	141.0	140.0	145.7	142.2	24.64	49.75	0.973
10/10	1:30	136.5	136.9	136.8	136.7	195.6	194.7	209.0	199.8	38.92	50.00	0.951
10/10	2:00	137.7	137.6	137.6	137.6	167.6	178.1	170.2	171.9	23.12	50.01	0.966
10/10	2:30	137.2	137.2	137.2	137.2	64.6	64.9	66.7	65.4	38.42	49.99	0.966
10/10	3:00	133.6	134.7	133.7	134.0	220.5	209.3	255.8	228.5	27.98	50.10	0.952
10/10	3:30	138.3	138.3	138.4	138.3	56.0	58.2	59.1	57.8	29.58	50.06	0.969
10/10	4:00	135.1	134.0	134.1	134.4	175.6	180.1	175.7	177.1	35.26	50.04	0.965
10/10	4:30	135.8	135.7	135.4	135.6	183.4	205.0	203.3	197.2	31.10	49.93	0.960
10/10	5:00	133.3	133.8	133.2	133.5	179.2	185.4	187.8	184.1	36.10	49.98	0.961
10/10	5:30	132.2	133.3	132.6	132.7	198.6	199.1	230.0	209.2	27.64	49.81	0.969
10/10	6:00	134.2	133.6	132.9	133.6	141.5	201.1	167.0	169.9	31.64	49.85	0.962
10/10	6:30	135.1	135.4	135.4	135.3	185.2	185.7	191.9	187.6	37.24	49.98	0.965
10/10	7:00	138.1	138.0	138.1	138.1	0.0	0.0	0.0	0.0	27.34	50.03	0.970
10/10	7:30	138.1	138.0	138.1	138.0	55.8	57.6	59.8	57.7	31.70	50.05	0.975
10/10	8:00	133.8	133.2	133.6	133.5	226.3	235.9	209.3	223.8	25.32	50.03	0.967
10/10	8:30	133.7	133.8	134.0	133.8	189.9	182.7	191.0	187.9	31.68	50.04	0.961
10/10	9:00	133.8	134.8	134.4	134.3	138.6	114.4	172.9	141.9	23.90	49.88	0.972
10/10	9:30	135.4	135.2	135.4	135.3	0.0	32.7	34.8	33.1	30.36	49.96	0.976
10/10	10:00	133.5	133.4	133.5	133.5	171.6	180.3	180.5	177.5	35.30	49.95	0.957
10/10	10:30	132.5	132.7	132.8	132.7	192.7	188.1	191.7	190.8	30.80	49.94	0.964
10/10	11:00	135.1	135.5	135.8	135.5	176.3	157.9	178.6	170.9	33.42	49.90	0.953
10/10	11:30	134.9	134.8	133.3	134.4	174.1	224.5	236.8	211.8	27.84	49.72	0.979
10/10	12:00	136.1	135.8	136.1	136.0	0.0	0.0	32.3	0.0	29.92	49.96	0.995
10/10	12:30	136.6	136.9	136.7	136.7	94.6	110.4	114.2	106.4	24.50	49.89	0.983
10/10	13:00	136.8	136.6	136.8	136.7	37.3	37.0	39.5	37.9	29.48	50.03	0.995
10/10	13:30	135.5	136.2	135.6	135.8	143.9	157.8	190.4	164.0	29.70	50.03	0.986
10/10	14:00	136.1	136.2	136.2	136.2	151.4	158.7	162.9	157.7	27.38	50.05	0.992
10/10	14:30	134.1	134.5	134.2	134.3	170.4	173.0	195.8	179.7	34.04	49.94	0.984
10/10	15:00	136.3	136.3	136.9	136.5	149.5	135.7	147.5	144.2	24.66	49.96	0.975
10/10	15:30	135.3	135.3	135.6	135.4	148.2	143.9	152.9	148.3	29.70	49.91	0.976
10/10	16:00	136.6	136.5	136.6	136.6	51.7	52.6	54.2	52.8	25.38	50.01	0.986
10/10	16:30	136.8	136.7	136.8	136.8	37.3	37.5	40.2	38.3	32.90	50.02	0.975
10/10	17:00	136.6	136.3	136.8	136.5	188.3	187.2	177.6	184.4	28.70	50.05	0.972
10/10	17:30	136.8	137.2	136.5	136.8	145.1	159.9	181.2	162.1	30.56	50.10	0.980
10/10	18:00	136.3	136.2	136.3	136.3	59.0	60.5	61.7	60.4	20.92	50.05	0.983
10/10	18:30	135.7	136.2	135.6	135.8	119.7	141.7	152.1	137.8	22.36	50.02	0.981
10/10	19:00	133.0	132.5	132.4	132.6	163.8	189.2	170.4	174.4	22.72	49.94	0.980
10/10	19:30	134.4	134.7	134.8	134.6	166.2	161.4	172.9	166.8	33.68	49.99	0.973
10/10	20:00	134.4	134.8	134.8	134.7	150.3	154.7	164.5	156.5	29.42	50.07	0.977
10/10	20:30	135.5	136.1	136.2	135.9	140.2	127.8	157.8	141.9	33.78	50.00	0.968
10/10	21:00	134.6	135.0	135.3	135.0	156.9	137.8	165.6	153.4	25.36	50.18	0.968
10/10	21:30	136.1	136.0	136.2	136.1	56.6	57.6	58.9	57.7	29.40	50.00	0.984
10/10	22:00	136.3	136.1	136.2	136.2	156.8	165.9	160.9	161.2	34.22	49.97	0.961
10/10	22:30	135.4	135.6	135.6	135.5	47.1	64.3	60.1	57.2	27.36	49.99	0.976
10/10	23:00	132.5	132.8	133.5	132.9	184.5	175.5	194.7	184.9	33.52	50.08	0.974
10/10	23:30	133.6	134.4	134.0	134.0	155.8	162.0	176.6	164.8	23.80	49.95	0.980
10/10	0:00	135.4	135.4	135.5	135.4	171.9	183.1	180.8	178.6	35.52	50.02	0.980

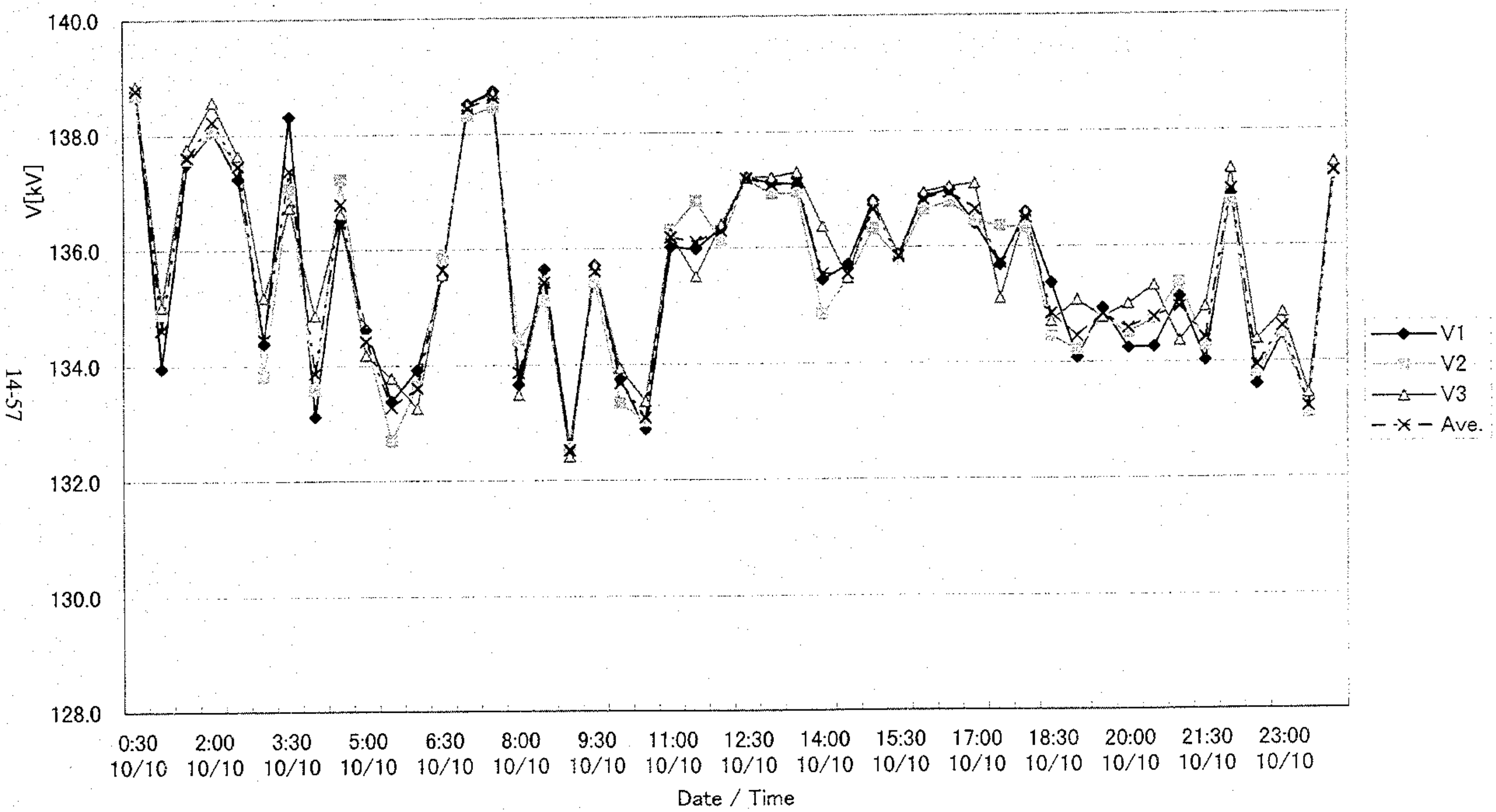


Figure 14-10 Voltage for Incoming 1

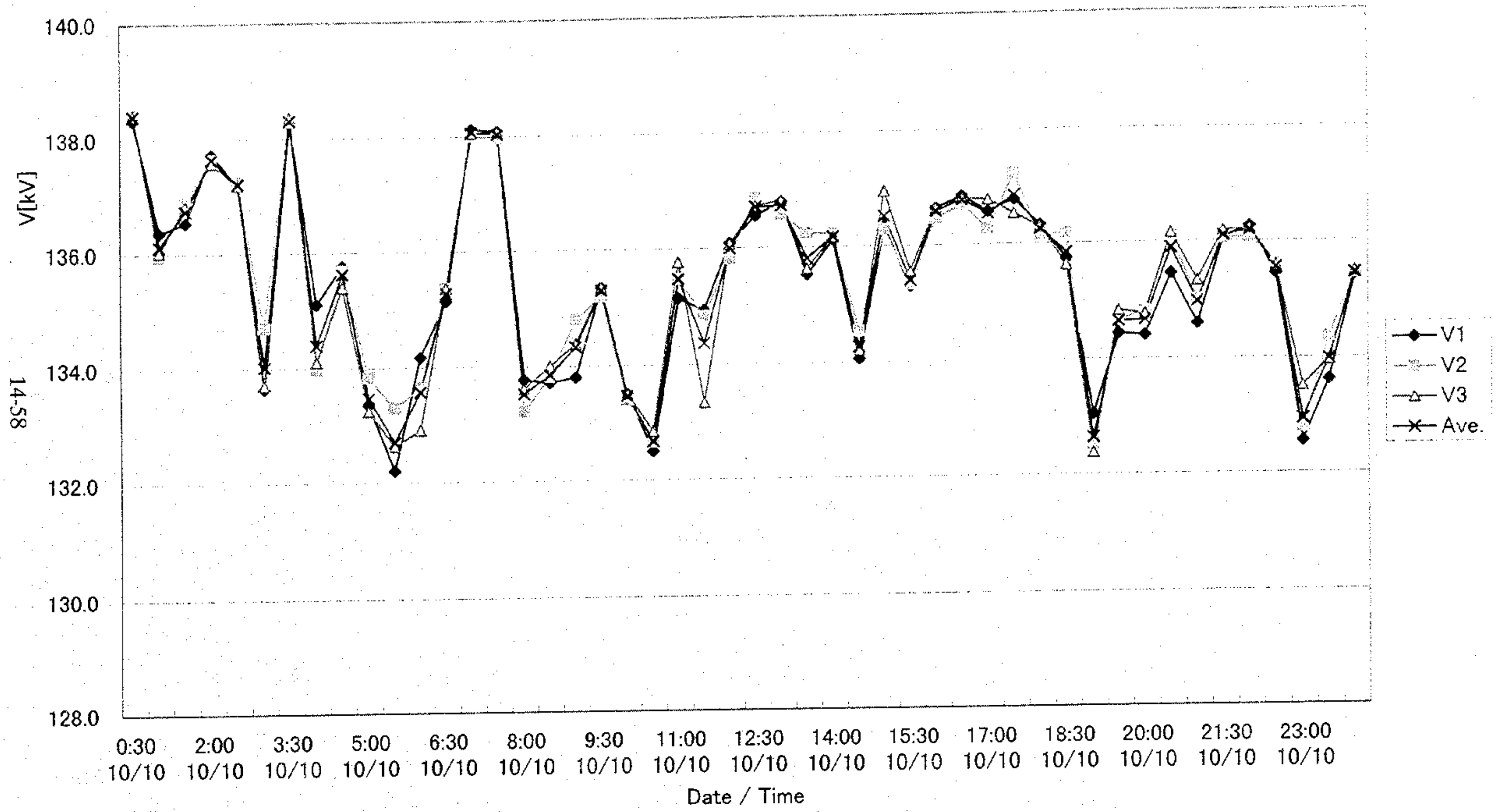


Figure 14-11 Voltage for Incoming 2

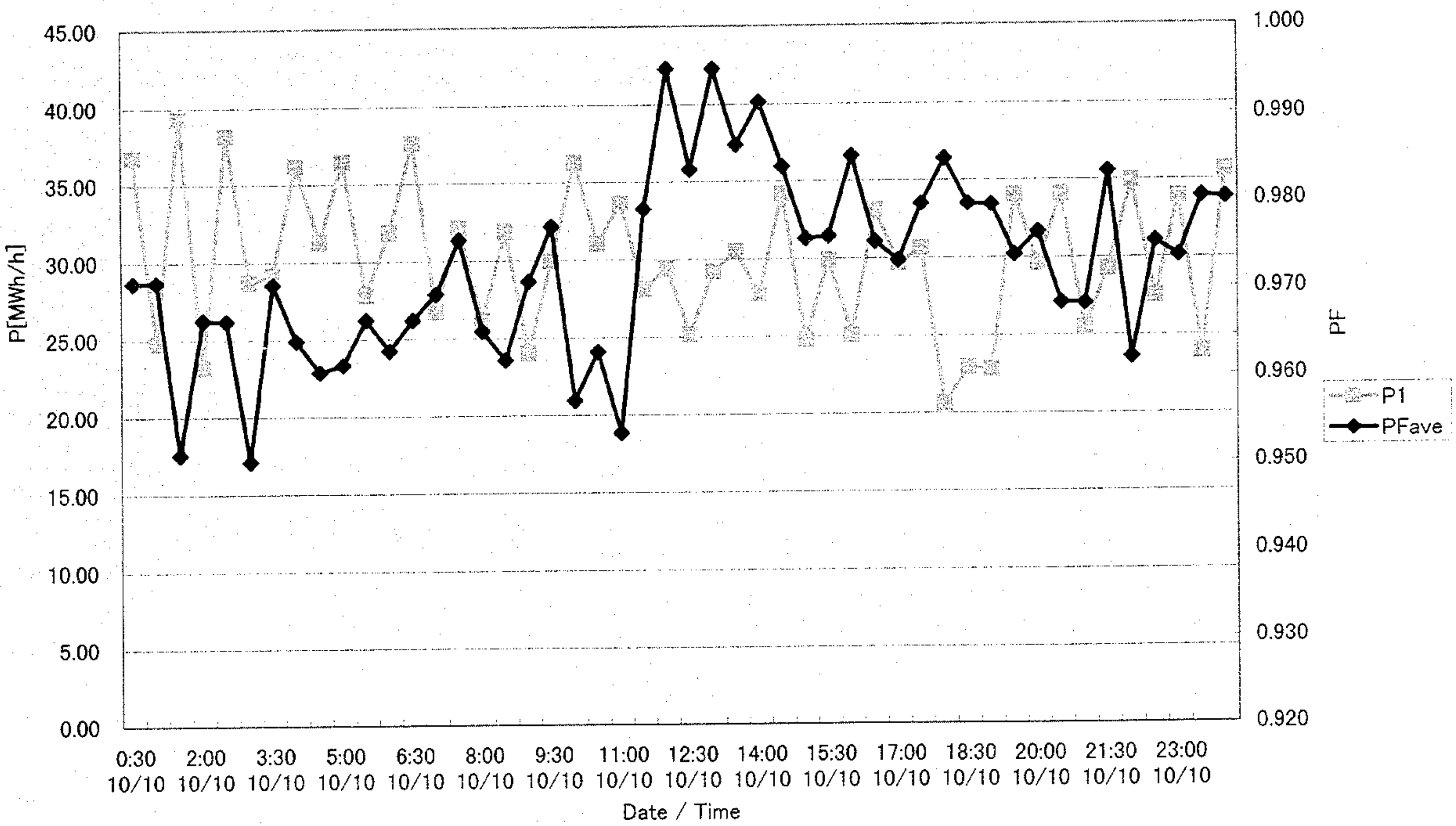


Figure 14-12 Electricity and Power Factor for Incoming No.1

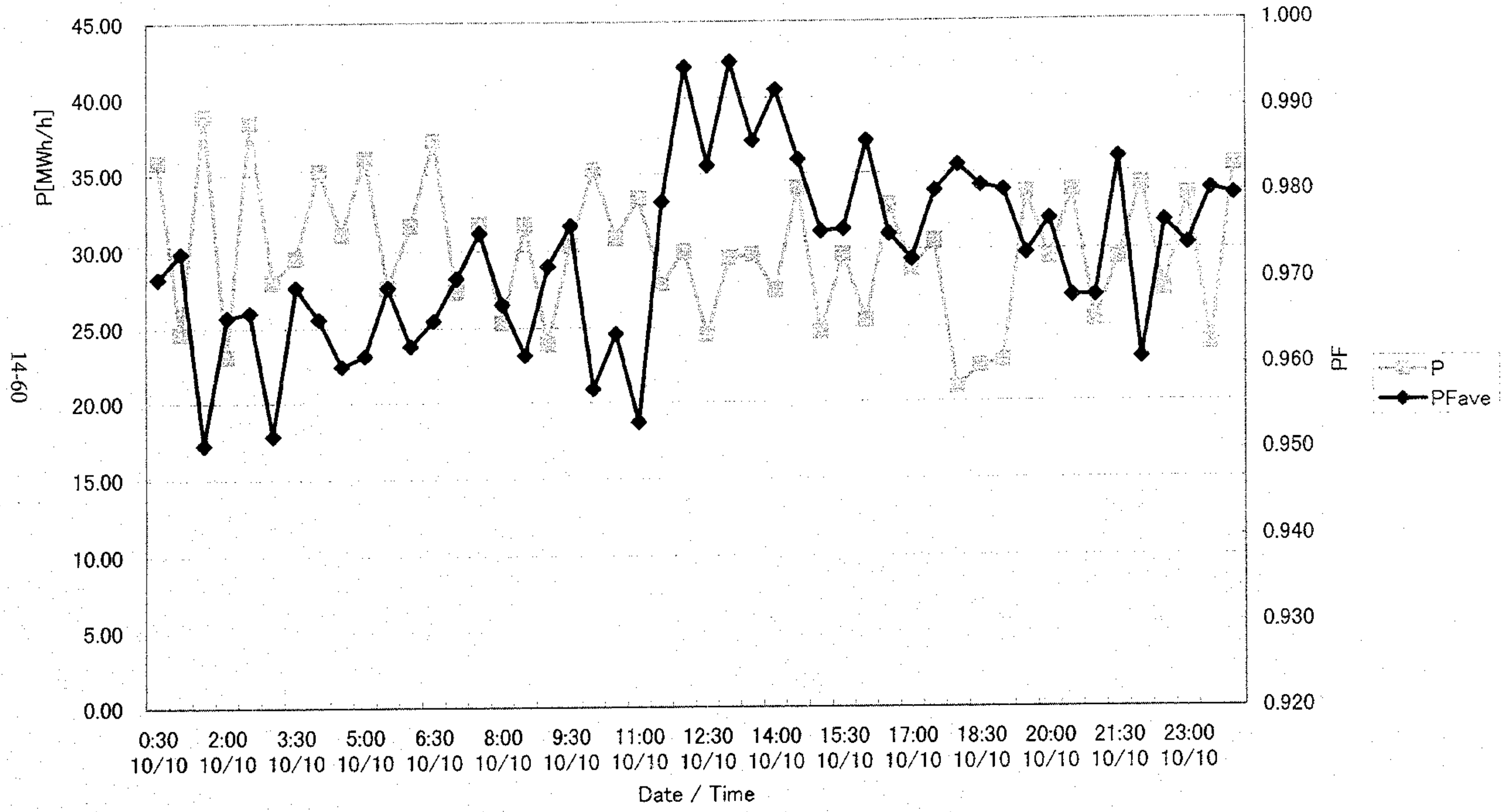


Figure 14-13 Electricity and Power Factor for Incoming No.2 (Oct. 10)

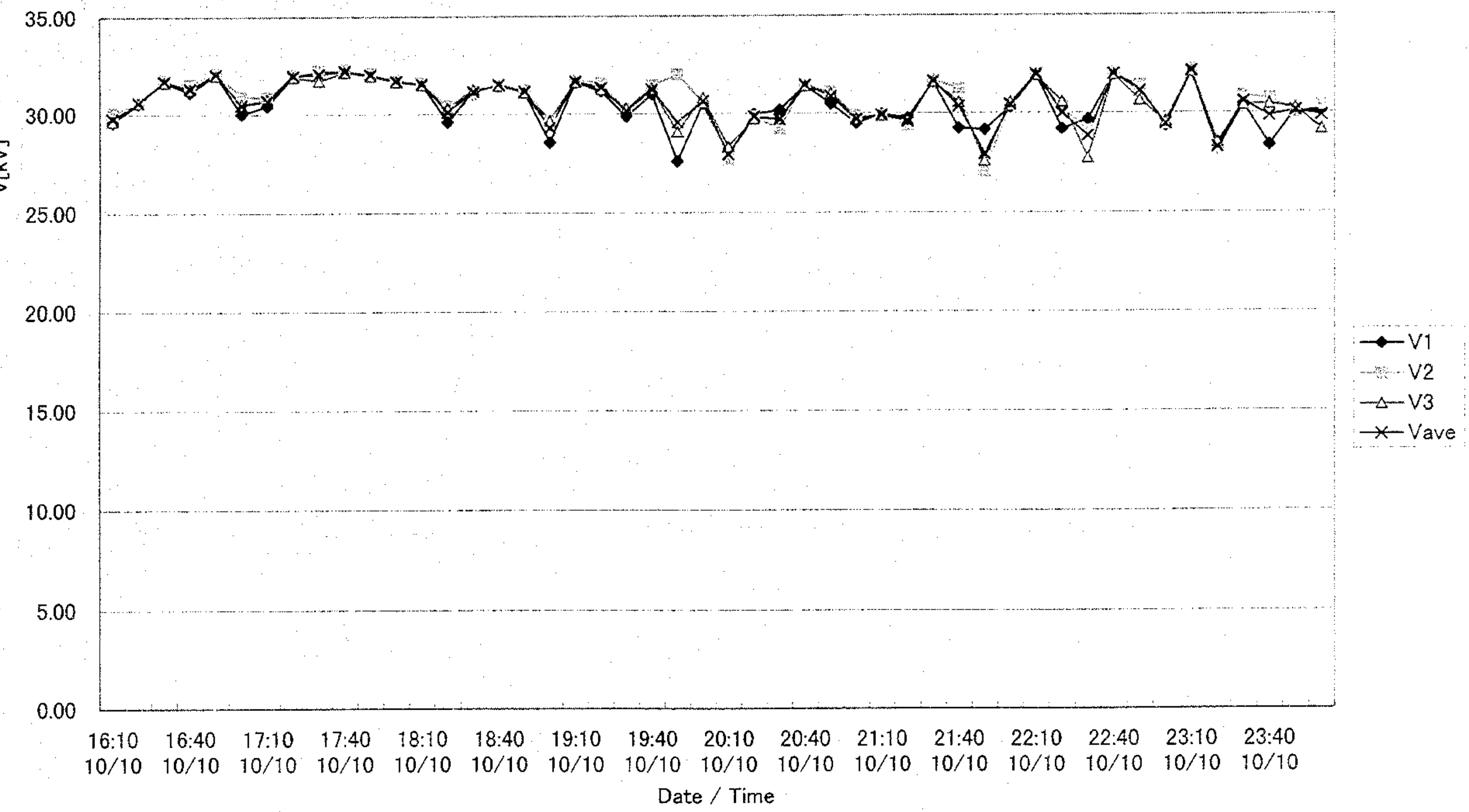


Figure 14-14 Voltage for EAF (Oct. 10-3)

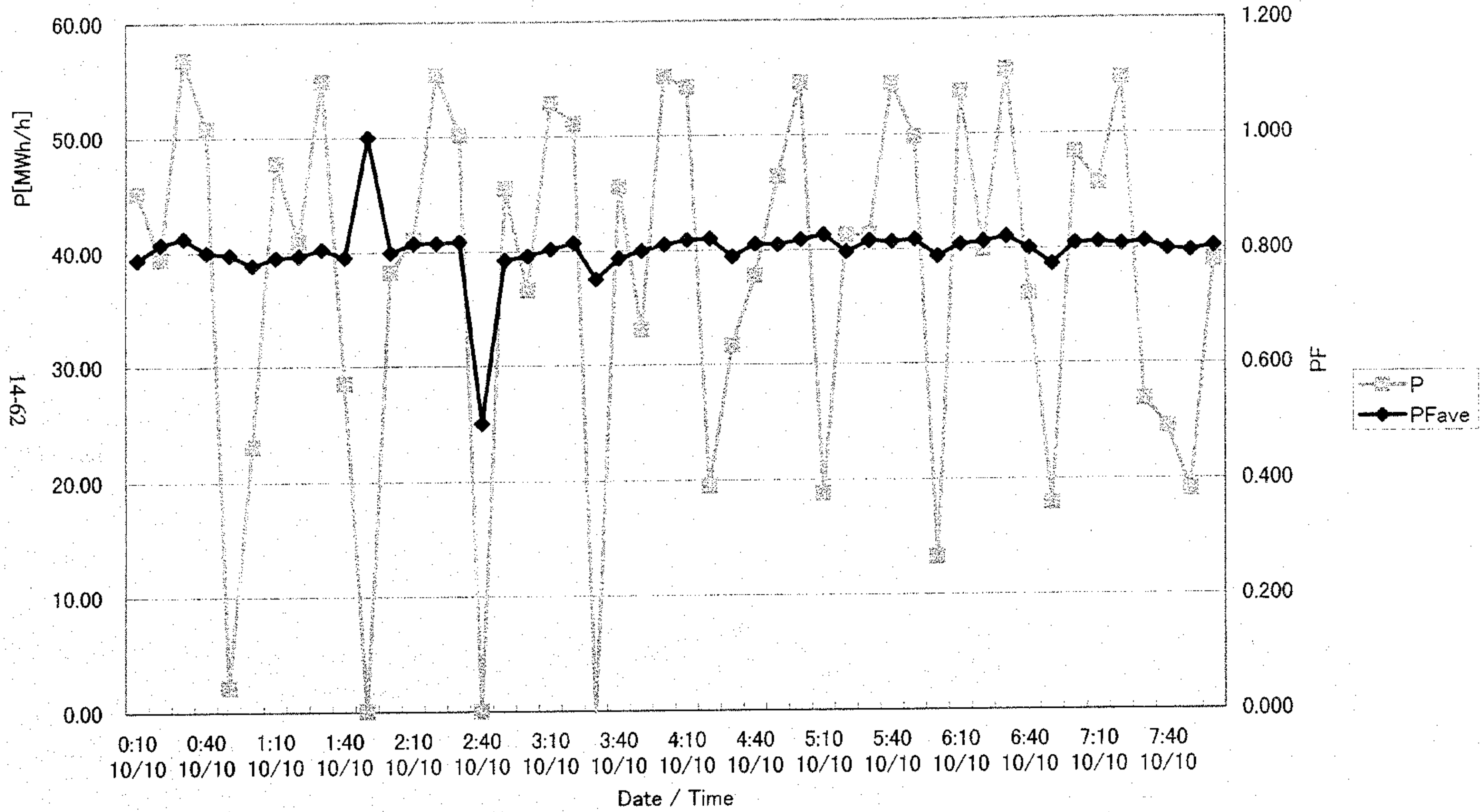


Figure 14-15 (1) Electricity and Power Factor for EAF (Oct. 10-1)

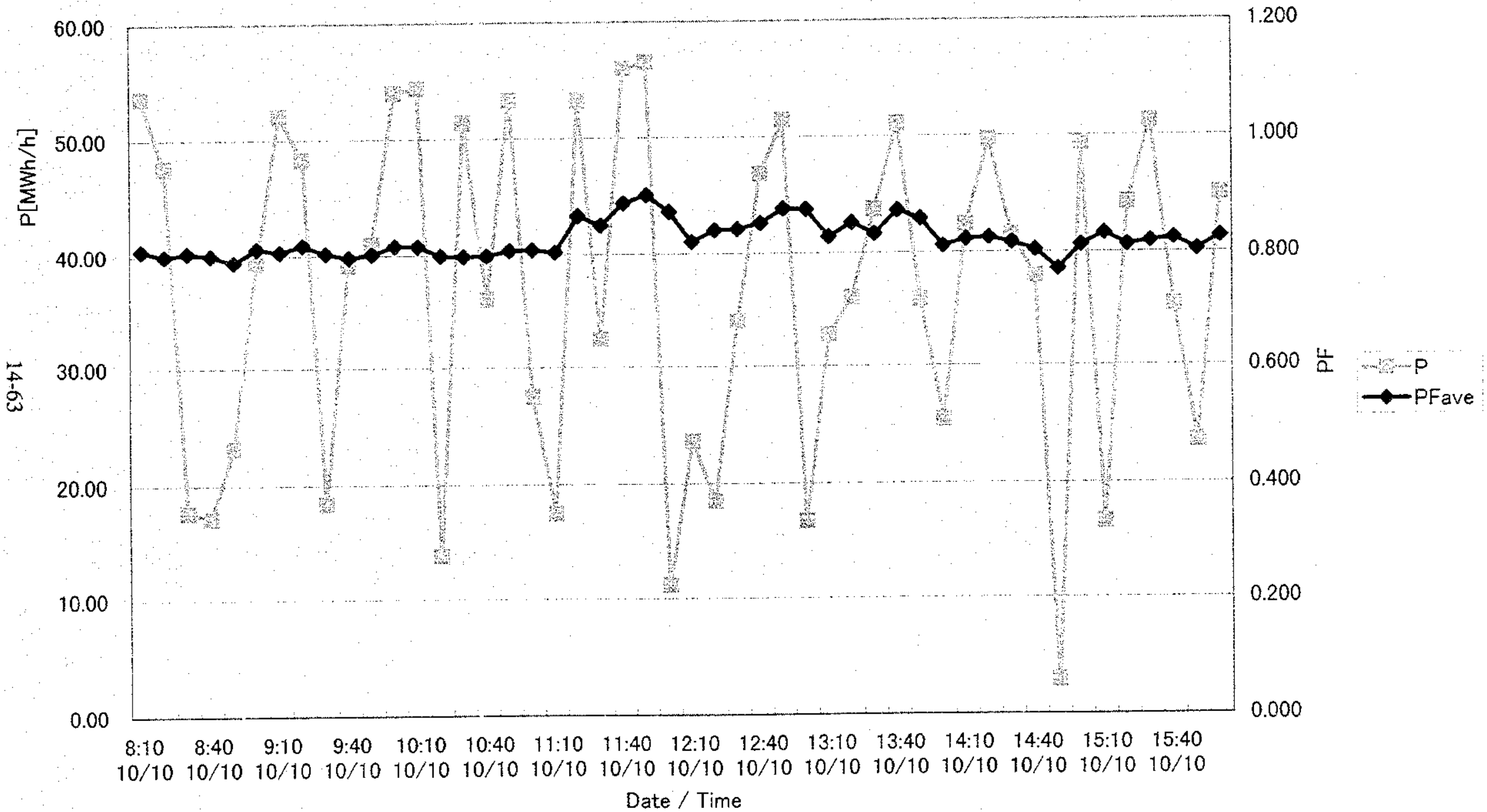


Figure 14-15 (2) Electricity and Power Factor for EAF (Oct. 10-2)

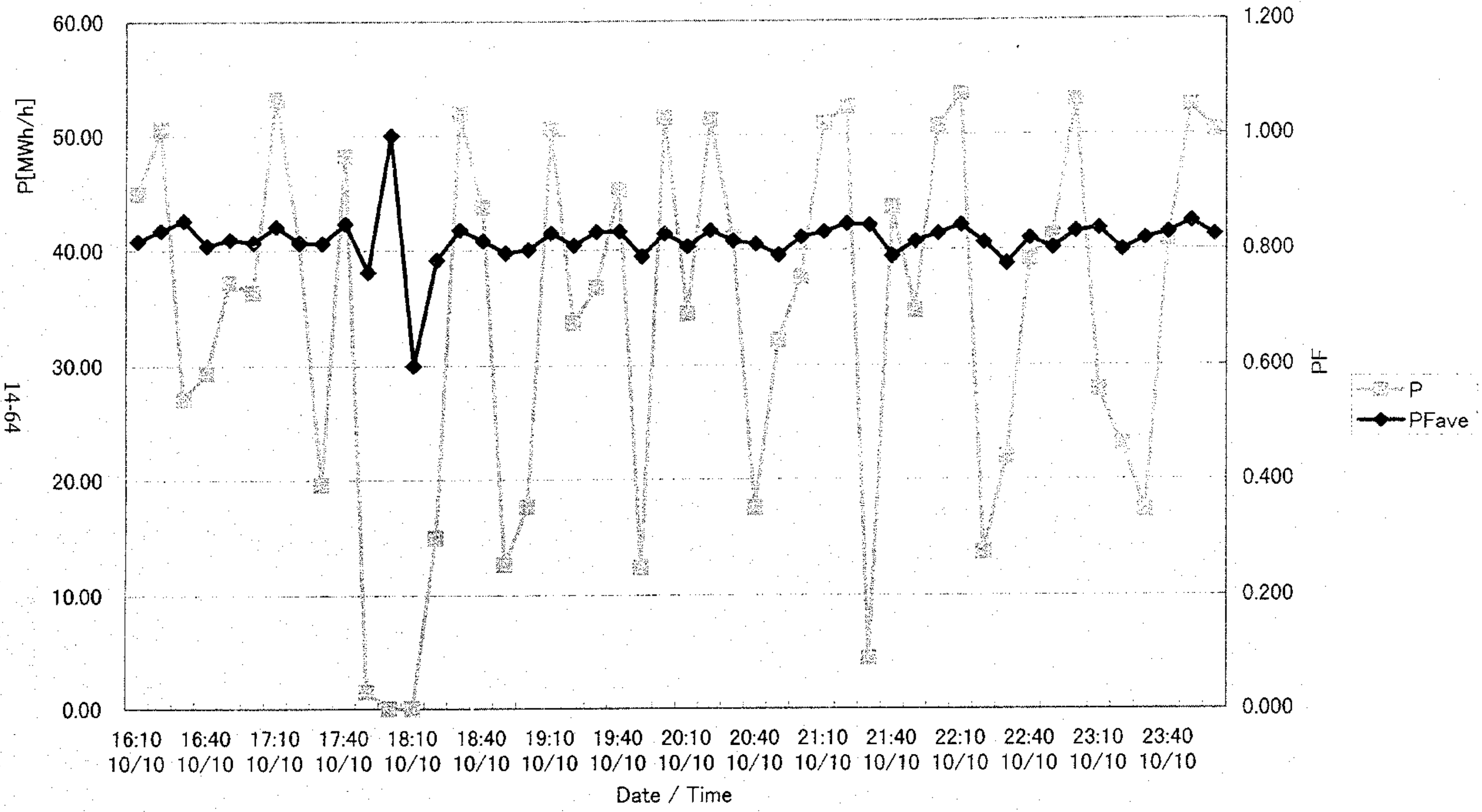


Figure 14-15 (3) Electricity and Power Factor for EAF (Oct. 10-3)

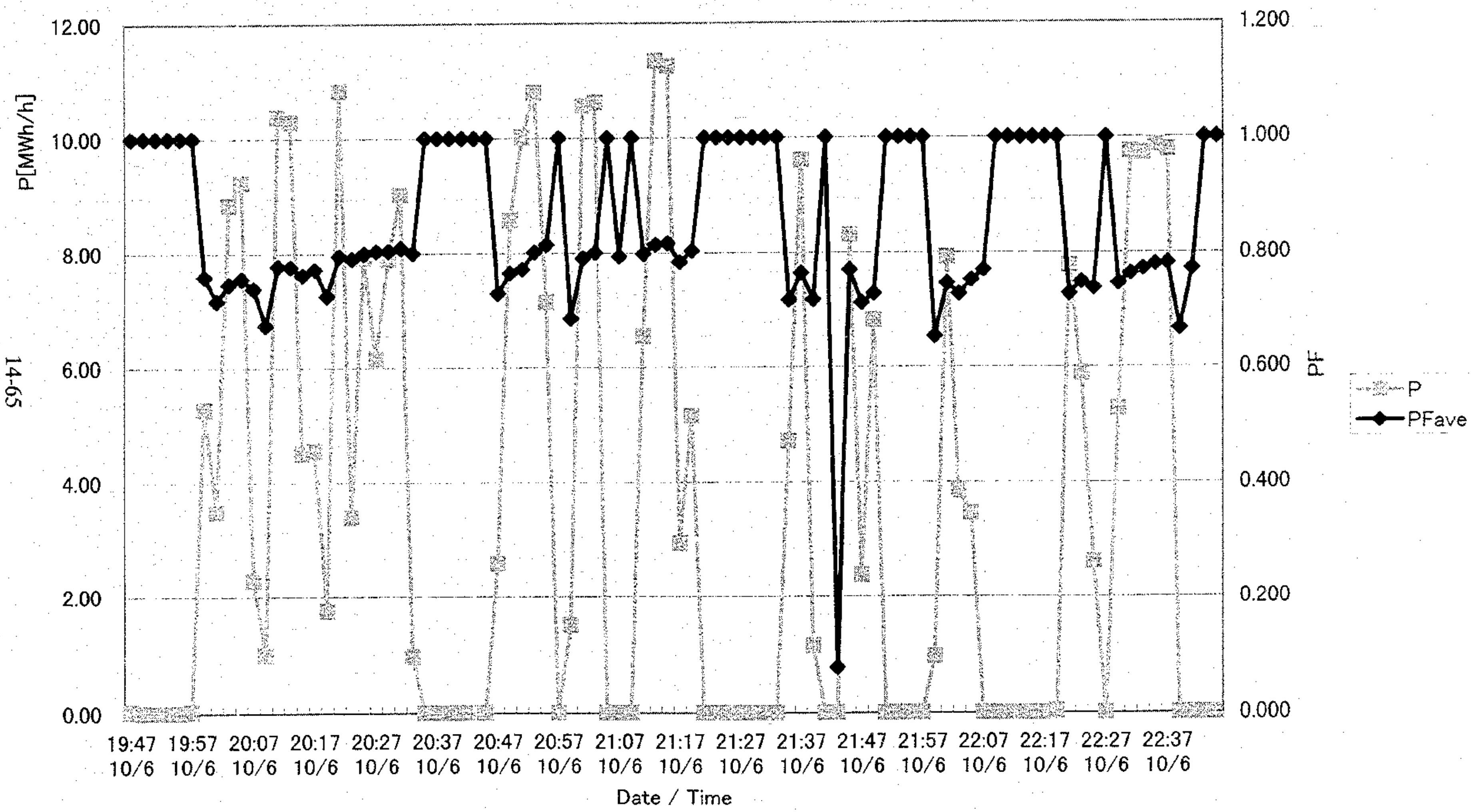


Figure 14-16 Electricity and Power Factor for LF (2)

Table 14-16 Electricity Consumption for New Shredder Plant

DATE	TIME	Voltage [kV]				Current [A]				Effective Power	Power Factor	Frequency
		V1	V2	V3	Ave.	I1	I2	I3	Ave.	[kWh/h]		[Hz]
10/10	18:30	10.94	11.06	11.01	11.00	0.0	0.0	0.0	0.0	30	1.000	50.02
10/10	19:00	11.16	11.23	11.21	11.20	0.0	0.0	0.0	0.0	32	1.000	49.96
10/10	19:30	10.99	11.07	11.05	11.04	0.0	0.0	0.0	0.0	34	1.000	50.00
10/10	20:00	11.07	11.14	11.12	11.11	0.0	0.0	0.0	0.0	42	1.000	50.02
10/10	20:30	11.04	11.11	11.09	11.08	0.0	0.0	0.0	0.0	42	1.000	50.03
10/10	21:00	11.12	11.15	11.14	11.14	0.0	0.0	0.0	0.0	44	1.000	50.00
10/10	21:30	11.04	11.11	11.09	11.08	0.0	0.0	0.0	0.0	42	1.000	49.99
10/10	22:00	11.03	11.10	11.08	11.07	0.0	0.0	0.0	0.0	42	1.000	49.95
10/10	22:30	10.94	11.04	10.93	10.97	0.0	0.0	0.0	0.0	42	1.000	49.69
10/10	23:00	11.05	11.11	11.12	11.09	0.0	0.0	0.0	0.0	50	1.000	50.12
10/10	23:30	10.97	11.07	11.04	11.03	178.9	184.7	181.7	181.8	1208	0.605	49.89
10/10	0:00:00	11.16	11.25	11.23	11.22	164.5	168.1	167.8	166.8	1882	0.492	50.03
10/11	0:30	11.25	11.36	11.31	11.31	230.6	237.8	231.3	233.2	4128	0.708	50.08
10/11	1:00	10.92	10.86	10.92	10.90	171.1	154.0	168.7	164.6	3282	0.676	49.98
10/11	1:30	11.13	11.24	11.20	11.19	15.0	15.7	15.0	15.2	1608	0.581	50.06
10/11	2:00	11.21	11.26	11.26	11.24	17.8	17.8	18.1	17.9	262	0.949	49.77
10/11	2:30	11.23	11.30	11.28	11.27	327.6	327.9	325.8	327.1	4234	0.756	50.01
10/11	3:00	11.26	11.35	11.36	11.33	13.9	14.2	14.1	14.1	3756	0.743	50.19
10/11	3:30	11.06	11.14	11.11	11.10	0.0	0.0	0.0	0.0	42	1.000	50.00
10/11	4:00	11.20	11.29	11.32	11.27	0.0	0.0	0.0	0.0	42	1.000	50.01
10/11	4:30	10.95	11.00	10.97	10.97	334.8	329.9	329.4	331.4	2148	0.585	50.07
10/11	5:00	11.24	11.32	11.29	11.28	331.9	334.4	330.6	332.3	3872	0.744	49.98
10/11	5:30	11.25	11.32	11.30	11.29	228.4	231.5	228.6	229.5	2038	0.507	49.85
10/11	6:00	11.11	11.20	11.17	11.16	159.9	165.6	162.4	162.6	2792	0.611	49.91
10/11	6:30	10.99	11.06	11.07	11.04	16.0	17.0	16.9	16.6	2176	0.571	49.99
10/11	7:00	11.33	11.40	11.38	11.37	0.0	0.0	0.0	0.0	74	0.974	49.99
10/11	7:30	11.18	11.25	11.22	11.21	0.0	0.0	0.0	0.0	32	1.000	50.06
10/11	8:00	11.21	11.29	11.25	11.25	0.0	0.0	0.0	0.0	30	1.000	49.92

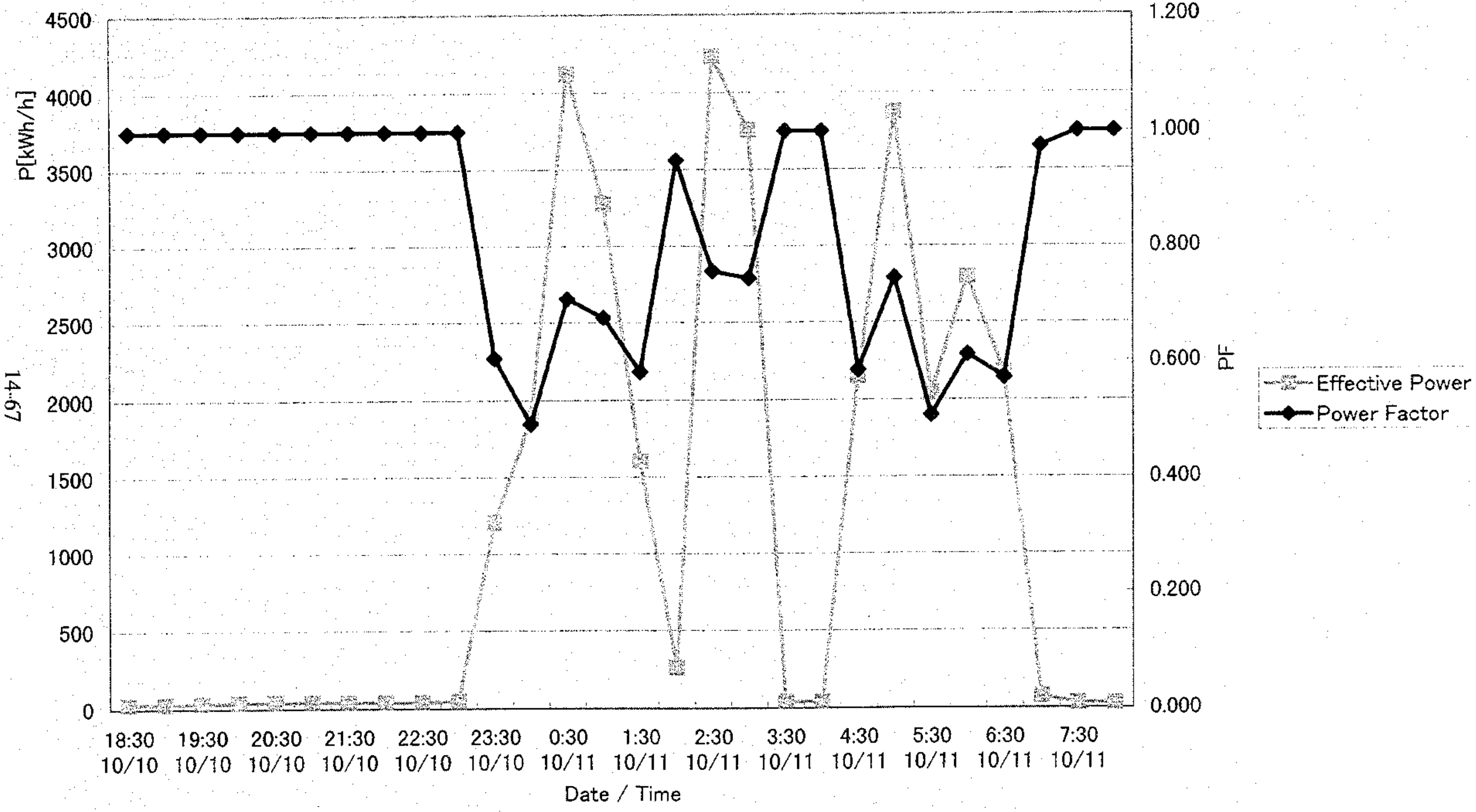


Figure 14-17 Electricity and Power Factor for New Shredder Plant

Table 14-17 Electricity Consumption for Rod Mill 1

DATE	TIME	Voltage [kV]		Current [A]				Power [MWh/h]	Frequency [Hz]	Power Factor
		V1	V2	I1	I2	I3	Ave.			
10/8	17:00	11.09	11.12	139.6	149.3	144.2	144.4	3.296	50.11	0.940
10/8	17:30	11.11	11.13	241.8	254.8	241.7	246.1	3.850	50.08	0.742
10/8	18:00	10.95	10.96	331.0	350.4	336.0	339.1	4.244	50.07	0.660
10/8	18:30	10.98	11.00	160.4	169.2	166.9	165.5	3.400	50.06	0.857
10/8	19:00	11.01	11.02	324.1	341.7	326.3	330.7	4.270	49.97	0.648
10/8	19:30	11.00	11.02	328.7	347.4	331.2	335.8	3.910	49.96	0.707
10/8	20:00	11.02	11.08	138.7	144.9	141.8	141.8	3.920	50.19	0.727
10/8	20:30	11.08	11.09	316.4	335.8	321.0	324.4	4.088	50.05	0.682
10/8	21:00	10.98	11.02	341.5	358.3	346.2	348.7	3.806	50.12	0.740
10/8	21:30	11.02	10.97	325.8	337.8	324.1	329.2	4.140	50.02	0.683
10/8	22:00	10.93	10.97	292.9	306.3	294.0	297.7	4.030	49.92	0.720
10/8	22:30	11.22	11.22	331.1	350.4	334.4	338.6	4.304	50.02	0.652
10/8	23:00	10.70	10.75	268.8	277.1	277.3	274.4	3.706	50.11	0.781
10/8	23:30	10.96	10.98	286.6	302.7	293.0	294.1	4.186	50.01	0.684
10/9	0:00	11.12	11.17	138.7	142.7	137.9	139.8	3.554	50.03	0.851
10/9	0:30	11.08	11.11	141.0	152.2	151.2	148.1	3.206	50.05	0.960
10/9	1:00	10.93	10.94	142.5	143.9	140.4	142.3	4.024	50.02	0.716
10/9	1:30	10.89	10.95	135.4	140.9	135.6	137.3	3.050	49.95	0.997
10/9	2:00	10.90	10.95	138.0	143.1	137.9	139.7	3.042	50.00	0.998
10/9	2:30	11.07	11.12	136.2	139.4	134.1	136.5	3.036	50.01	0.999
10/9	3:00	11.02	10.97	139.0	139.8	141.3	140.0	3.226	49.96	0.981
10/9	3:30	11.02	11.02	144.0	150.6	143.5	146.1	3.120	49.61	0.996
10/9	4:00	11.02	11.05	154.0	163.2	155.7	157.7	3.170	50.00	0.987
10/9	4:30	11.04	11.09	152.7	159.4	152.7	154.9	3.474	49.86	0.906
10/9	5:00	10.99	10.98	157.5	164.2	158.1	159.9	3.496	50.03	0.909
10/9	5:30	11.15	11.21	158.8	166.8	153.0	159.6	3.590	49.93	0.876
10/9	6:00	11.08	11.11	155.8	163.3	155.9	158.3	3.950	50.12	0.767
10/9	6:30	11.13	11.16	447.3	438.4	427.1	437.6	4.176	50.08	0.713
10/9	7:00	11.25	11.29	146.3	155.6	146.5	149.5	3.908	50.12	0.746
10/9	7:30	11.09	11.11	352.8	362.5	354.6	356.6	3.312	50.08	0.930
10/9	8:00	11.08	11.03	155.9	159.3	156.7	157.3	3.816	50.15	0.766
10/9	8:30	10.99	11.01	156.7	165.0	156.7	159.5	3.622	50.01	0.849
10/9	9:00	11.01	11.03	138.5	149.5	147.3	145.1	3.964	49.88	0.732
10/9	9:30	10.96	11.06	403.8	398.4	391.0	397.8	4.932	50.06	0.593
10/9	10:00	11.12	11.16	427.9	425.4	409.2	420.8	4.526	50.05	0.645
10/9	10:30	10.82	10.98	120.6	129.8	119.1	123.1	3.772	49.90	0.731
10/9	11:00	11.12	11.14	120.1	122.4	120.4	121.0	2.700	50.05	1.000
10/9	11:30	10.90	10.97	136.4	140.4	132.0	136.3	2.714	50.06	1.000
10/9	12:00	10.94	10.99	373.7	369.6	351.1	364.8	3.394	50.08	0.923
10/9	12:30	11.05	11.08	372.4	363.9	350.3	362.2	3.774	50.08	0.839
10/9	13:00	11.18	11.21	381.6	380.4	365.2	375.7	4.774	50.11	0.627
10/9	13:30	11.14	11.17	320.0	324.1	310.9	318.4	4.838	50.00	0.616
10/9	14:00	11.09	11.15	337.3	330.8	324.7	330.9	4.666	49.94	0.643
10/9	14:30	11.28	11.32	276.7	271.0	264.0	270.6	4.318	50.06	0.692
10/9	15:00	11.11	11.14	342.7	341.8	327.7	337.4	4.074	50.08	0.769

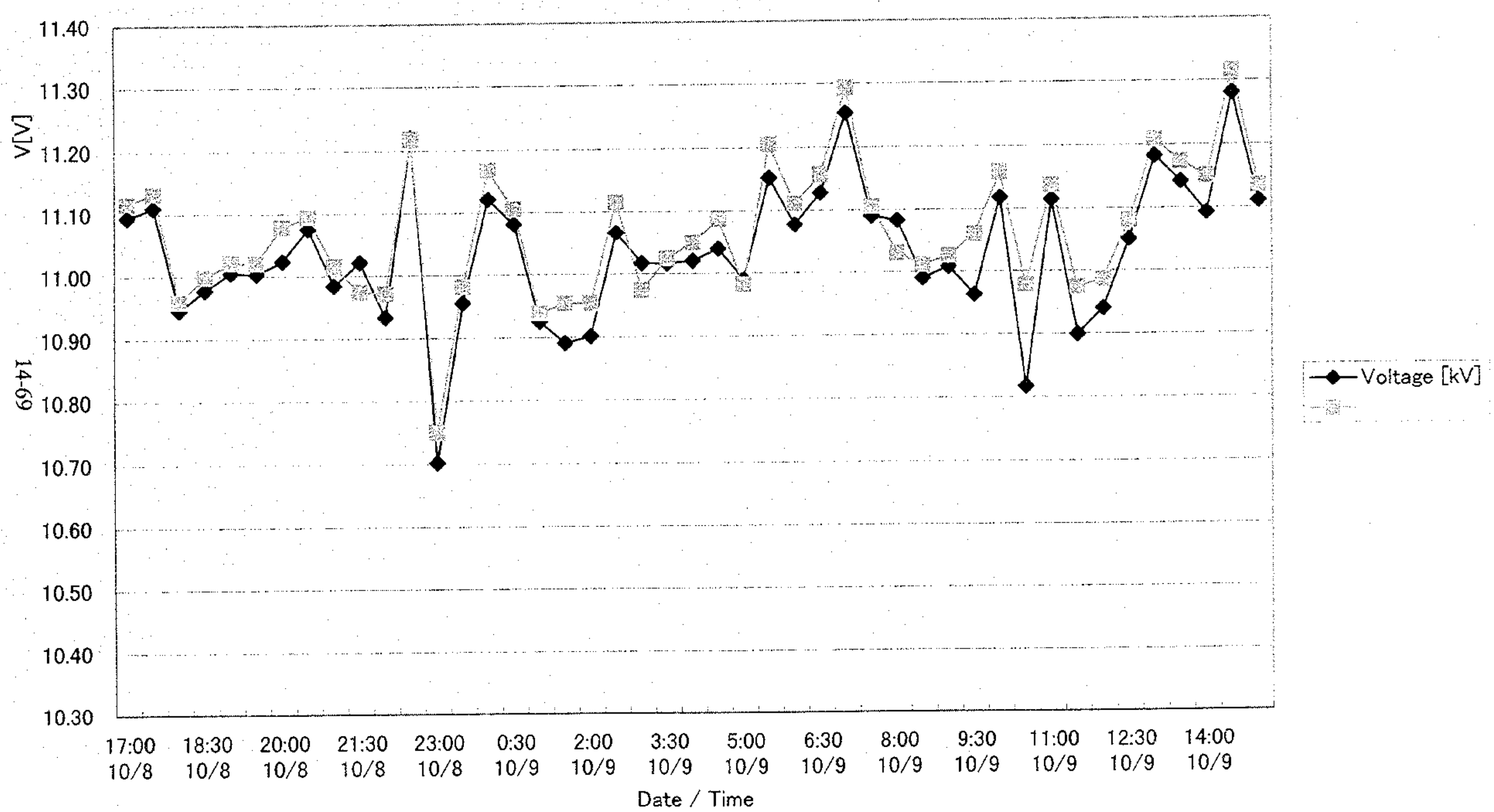


Figure 14-18 Voltage for Rod Mill 1

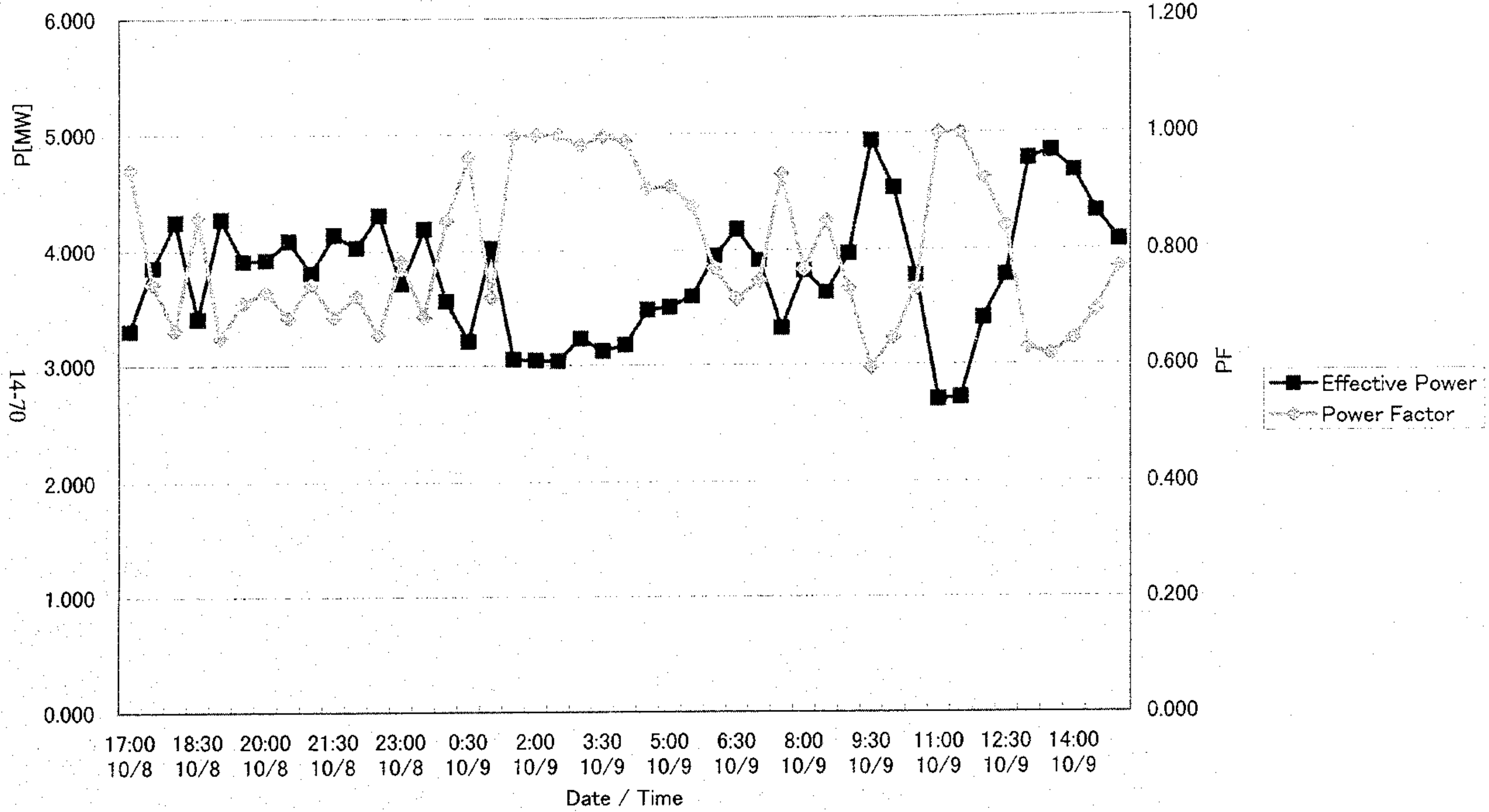


Figure 14-19 Electricity - Power Factor for Rod Mill

14-9-3 Energy Saving in EAF Compared with Japanese Operation Data

By comparing ASM monthly records with similar shops in Japan, a 15-20 kwh/t improvement in the electric power consumption of ASM is expected.

Measurement of the energy heat-balance in an operating electric arc furnace is sometimes recommended as a reasonable method of energy-saving audit.

However, since reasonably accurate measurements can be obtained from the plant's financial data, additional measurements were not performed on this occasion.

(1) Expected Value of Energy Saving in EAF

1) Expected Improvement

Table 14-18 below shows the expected value of electric power consumption, billet yield and carbon addition, estimated by comparing data of ASM EAF monthly records and data of Japanese EAF monthly records, although such conditions as scrap are not clear. Table 14-18 suggests that improving the oxygen lancing operation and carbon addition, and maintaining the same level of oxygen consumption, and provide the same steel yield and reducing electric power consumption.

Table 14-18 Expected Unit Consumption of EAF

		Unit	Present data	Improvement	Expected value	Effect
1	Electric power	kWh/t	415	-	400 or less	15 or more
2	Yield	%(Billet/charge)	91.0	-	0	
3	Oxygen	Nm^3/t	35	Standard		
4	Coke breeze	kg/t	Standard	Slight increase		
5	Oxygen lance	kg/t	N.A	Slight increase		
6	Hearth material	kg/t	N.A	Slight increase		

(2) Procedure of Estimation

1) Basis of Estimation

(a) Actual operation data is collected and after classifying those data, correlation is found. On that correlation, ASM data is plotted and estimated according to a standardized state. Standardizing is done under following conditions;

1. Oxygen consumption correlation is found from actual data, and standardized according to ASM consumption of 35 Nm^3/t.
2. Considering the product mixture of ASM (low carbon=5%, medium carbon=35%, rebar grade=60%), ASM unit consumption is a combination of a Japanese

commercial grade steel shop and a high grade Japanese steel shop.

3. In regard to scrap handling, ASM's import scrap is substantial at 20% and is difficult to classify, so indoor scrap yard handling is congested since tap-to-tap is short at 53 minutes and the indoor scrap yard has shredding equipment. Therefore, setbacks in the melting procedure due to the scrap problem occur more frequently than in Japan.

(b) Japanese data is obtained from confidential monthly reports published by the Japanese Federation of Iron and Steel Makers, omitting high alloy steel shops, 20 steel shops are classified as 7 high grade steel shops, 4 as special scrap steel shops (where scrap mixture deviates from average) and the remainder as commercially operating steel shops.
The examining period was from July 1996 to June 1997, and a total of 240 monthly data is plotted.

(c) ASM data is plotted according to 12-monthly data from July 1996 to June 1997.

2) Classification of Japanese Steel Shops

(a) Studying product mixture and scrap mixture, 7 steel shops are classified as high grade steel shops, and 4 steel shops are classified as special scrap steel shops. (Table 14-19).

(b) The correlation between oxygen consumption and electric power consumption is shown in Figure14-20. It shows that with the increase of unit oxygen consumption, unit electricity consumption decreases. The ASM tendency, whereby electricity consumption increases with increased oxygen consumption, is abnormal. It may indicate some significant change of scrap characteristics, such that improved electric power consumption from 1996 to 1997 occurred as if oxide content decreased.

(c) The correlation between oxygen consumption and steel yield is shown in Figure 14-21. Both Japan and ASM show the same tendency, that with increased oxygen consumption, yield decreases. The ASM value is better compared with Japanese steel shops.

(d) The correlation between oxygen consumption and carbon addition is shown in Figure 14-22. As it shows, with a 1 Nm^3/t increase in oxygen consumption, carbon addition increases 0.2kg/t-1kg/t. ASM increases carbon 0.7kg/t, the medium level among Japanese shops. Considering the data of Figure 14-20, in which ASM shows rather poor heat efficiency, carbon addition might be increased, so that the increased volume of foamed slag conducts arc heat more efficiently.

Table 14-19 Classification of Japanese Steel Shops

Steel shop		Furnace capacity (t)	Product mixture(%)		Scrap deviation		
			Machine structural use	Alloy steel	Typical grade	Charged ratio(%)	Normal level
High grade steel shop	①Ai	80	20	80	Heavy Mill return	50 17	-
	②T.S	110	40	40	Others Trimmings Shredder	60 10 10	-
	③YD	20	30	20	Trimmings Turnings	70 25	-
	④TP	120	2	15	Heavy Turnings Trimmings	30 17 15	-
	⑤GH	70	70		Heavy Trimmings Pig iron	50 12 10	-
	⑥Ks	60	10	2	Heavy Trimmings Pig iron	45 20 10	-
	⑦As	60	20		Heavy Pig iron Turnings Trimmings	50 12 12 5-25	-
Special scrap shop	⑧KK	30	0	0	Shredder	50	0-10
	⑨NS	40	0	0	Turnings	25	0-10
	⑩NK	70	0	0	Heavy	75	40-60
	⑪Go	70	0	0	Pig iron	22	3-10
Commercial grade shop	8 steel shop						

3) Expected Electric Power Saving

From Figure 14-20, the difference between ASM and Japanese data is 5-50kWh/t, according to the classified groups: high grade steel shop, special scrap steel shop and commercial grade steel shop. As an expected saving value, considering unintentional variation of conditions, an improvement of 15kWh/t would be appropriate. (Table 14-20)

Table 14-20 Expected Value of Electric Power Consumption

Classification	Monthly data		Expected value	
	Oxygen consumption (Nm3/t)	Electric power consumption (kWh/t)	Expected value at O2=35Nm3/t (kWh/t)	Improvement (kWh/t)
ASM	34-40	405-443	415	Standard
High grade shop	22-38	335-428	375	40
Special scrap shop	17-68	340-528	410	5
Commercial grade shop	21-45	330-455	365	50

4) Expected Yield Improvement

From Figure 14-21, expected improvement of yield is negligible.

5) Expected Consumption of Carbon Additives

From Figure 14-22, it is not possible to estimate an adequate quantity of carbon additives (coke breeze).

(3) Comments on Possibility of Improvement

1) After classifying Japanese steel shops, some shops were selected as resembling the operating conditions of ASM, and then the expected improvement values were estimated. ASM data, whereby yield and oxygen consumption are high ($35Nm^3/t$) but electric power consumption is not low, suggests that in the ASM furnace, heat transfer is not good. This defect would be overcome by an active boiling reaction in the furnace. This would require additional carbon, and would therefore increase heat generation in the furnace.

2) In order to transfer more effectively the combustion heat of carbon additives, the oxygen lance position should be well into the molten phase, and also influence the metal phase, so that boiling action is not localized only in the slag phase, where violent boiling suddenly occurs.

Table 14-21 Furnace Parameters

Classsific.	Mark	Commence. Date	Nominal Capasity	Shell Diameter	Transformer capacity	Burner	SPH (1) (2)	kVa/t
				m	10^3kVa	pieces		
Special steel	①Ai	82.01	80	6.7	75	3	*	940
	②T.S	74.08	110	7.0	58	4	*	530
	③YD	74.12	20	3.9	16.5	2	*	830
	④TP	70.12	120	6.5	56	7	*	470
	⑤GH	72.01	70	5.8	35	3	*	500
	⑥Ks	81.05	60	5.8	41	1		680
	⑦As	72.12	60	5.7	45		*	750
Special scrap	⑧Kk	62.03	30	4.6	12.5	2		420
	⑨Ns	91.03	40	5.5	60		*	1,500
	⑩Nk	92.12	70	6.7	78	4		1,110
	⑪Go	84.12	70	6.3	50	2	*	710
Commercial grade	⑫Os	63.04	40	4.9	22	3		550
	⑬Gf	75.06	100	6.7	60	3		600
	⑭Tb	62.04	200	8.0	70	15		350
	⑮Tw	71.07	60	5.8	36	4	*	600
	⑯To	92.04	150	8.0	140			930
	⑰Tk	89.08	130	7.0	100		*	770
	⑱Tt	96.10	60	6.5	55		*	920
	⑲T.K	95.05	150	7.2	71.5	5	*	480
	⑳Th	75.04	150	7.0	55	4	*	370
AMSTEEL		93	85	5.8	80			940

Notes: (1) SPH means Scrap Preheater.
(2) * means "with SPH".

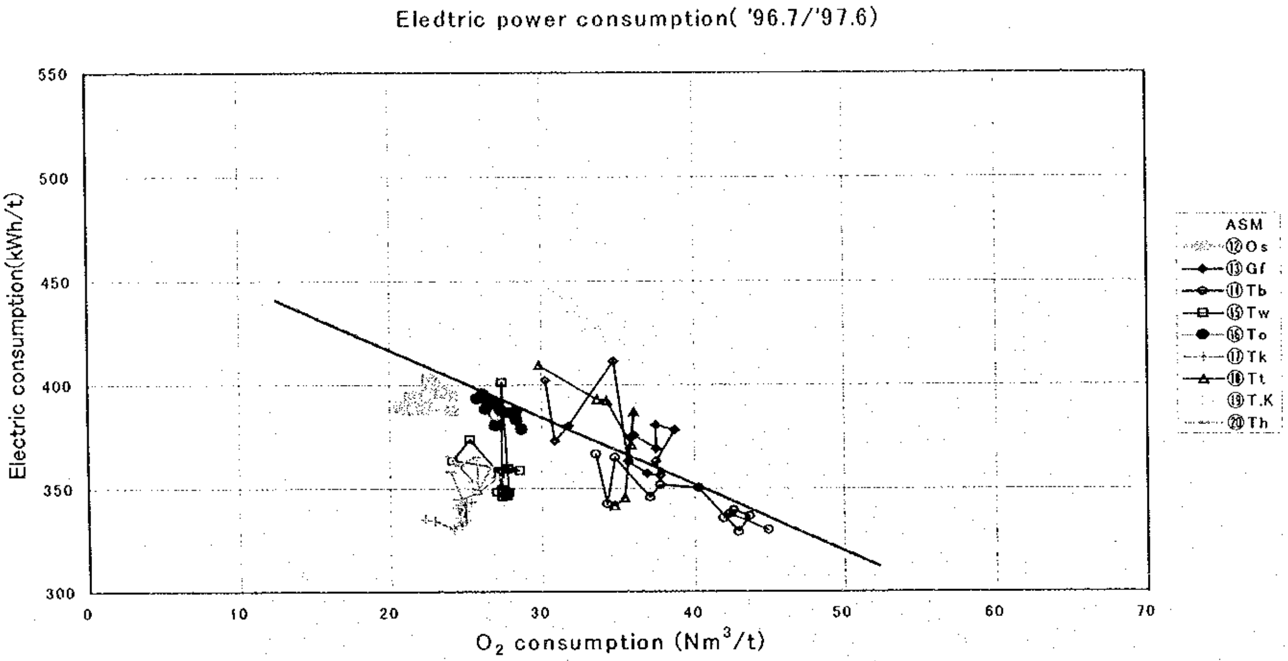


Figure 14-20-1 Oxygen Consumption and Electric Power Consumption (Commercial grade)

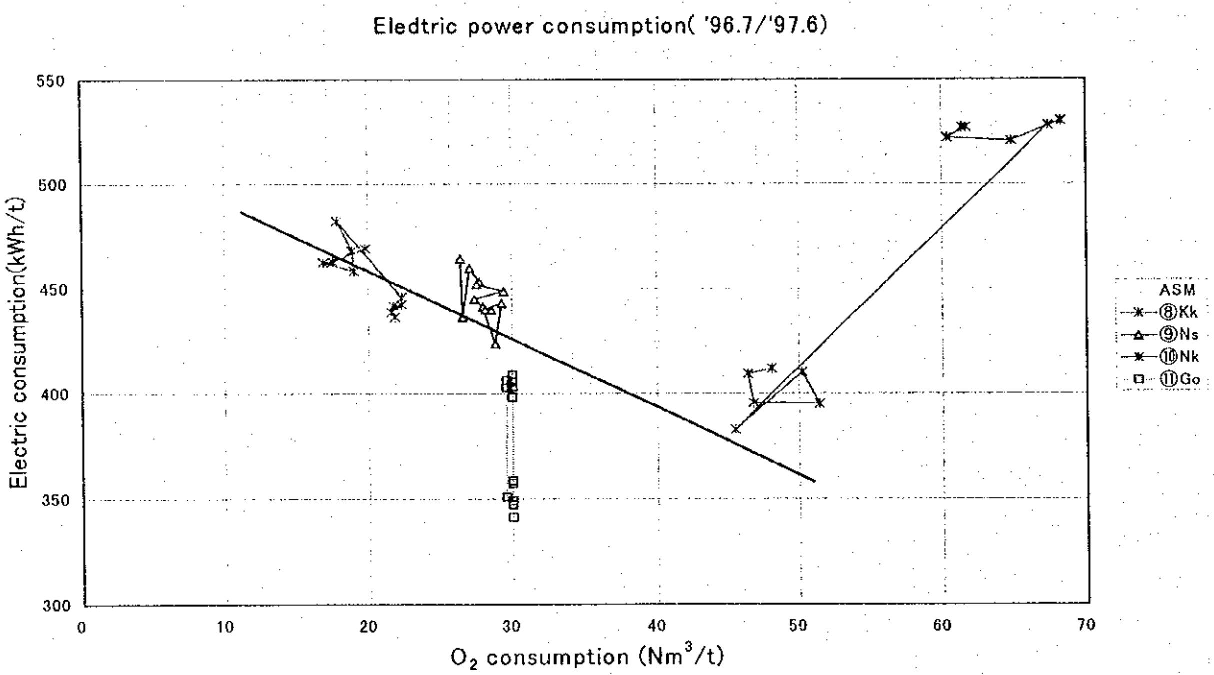


Figure 14-20-2 Oxygen Consumption and Electric Power Consumption (Special scrap)

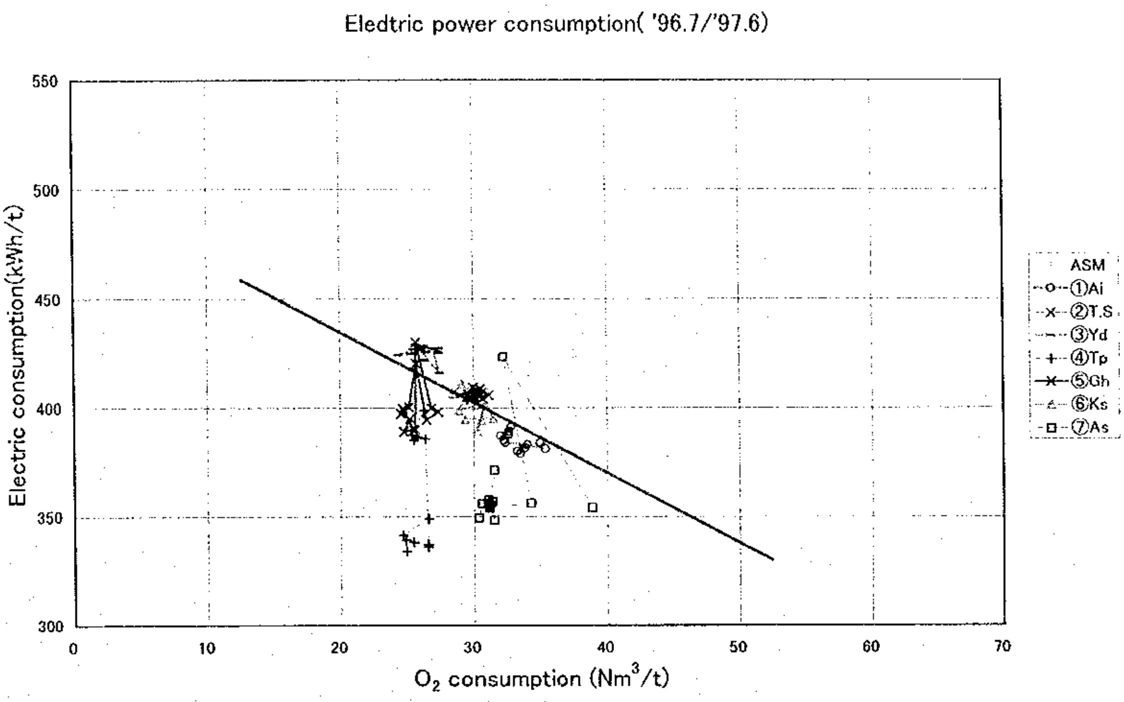


Figure 14-20-3 Oxygen Consumption and Electric Power Consumption (High grade steel)

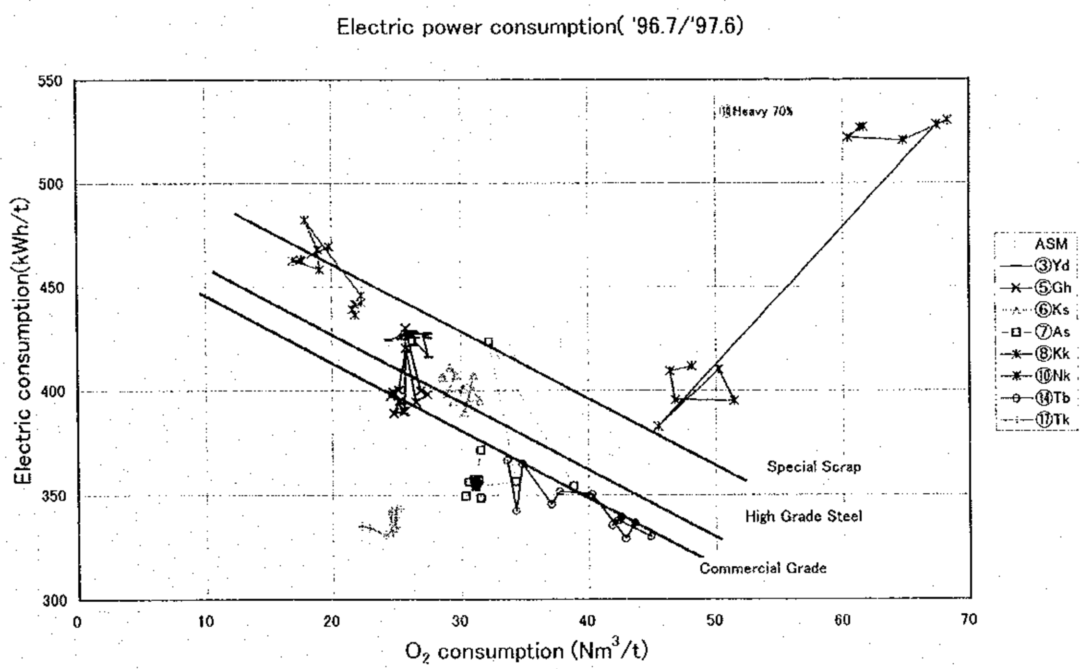


Figure 14-20-4 Oxygen Consumption and Electric Power Consumption (Summary)

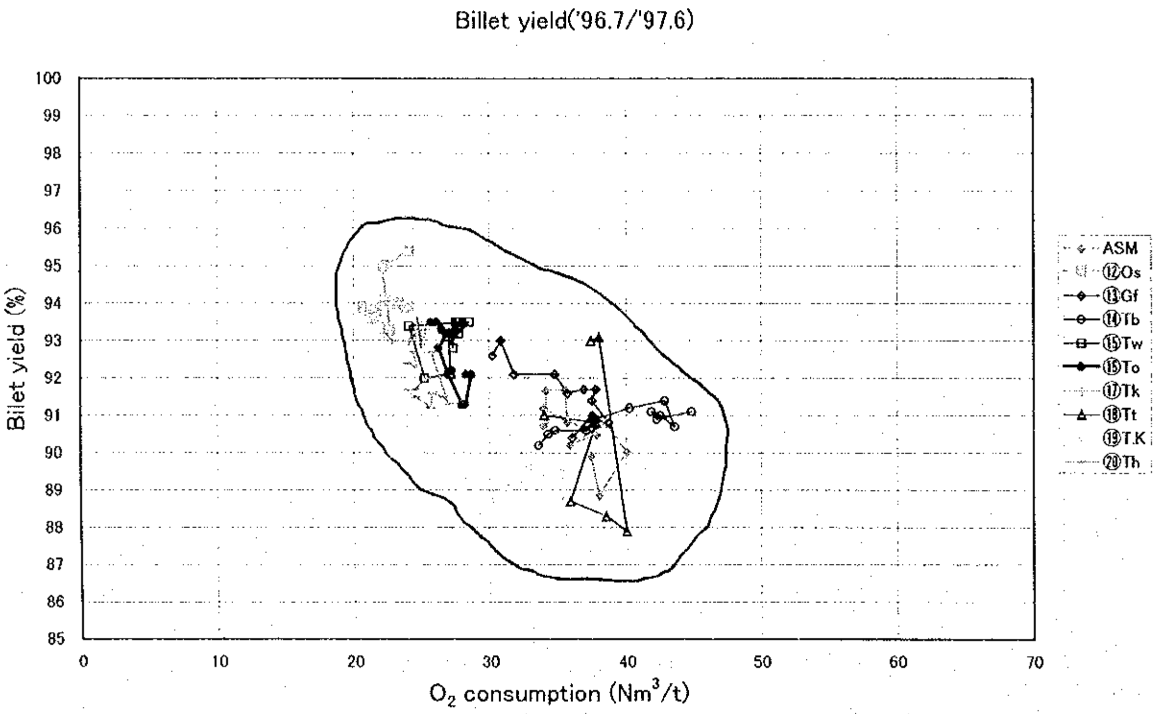


Figure 14-21-1 Oxygen Consumption and Billet Yield (Commercial grade)

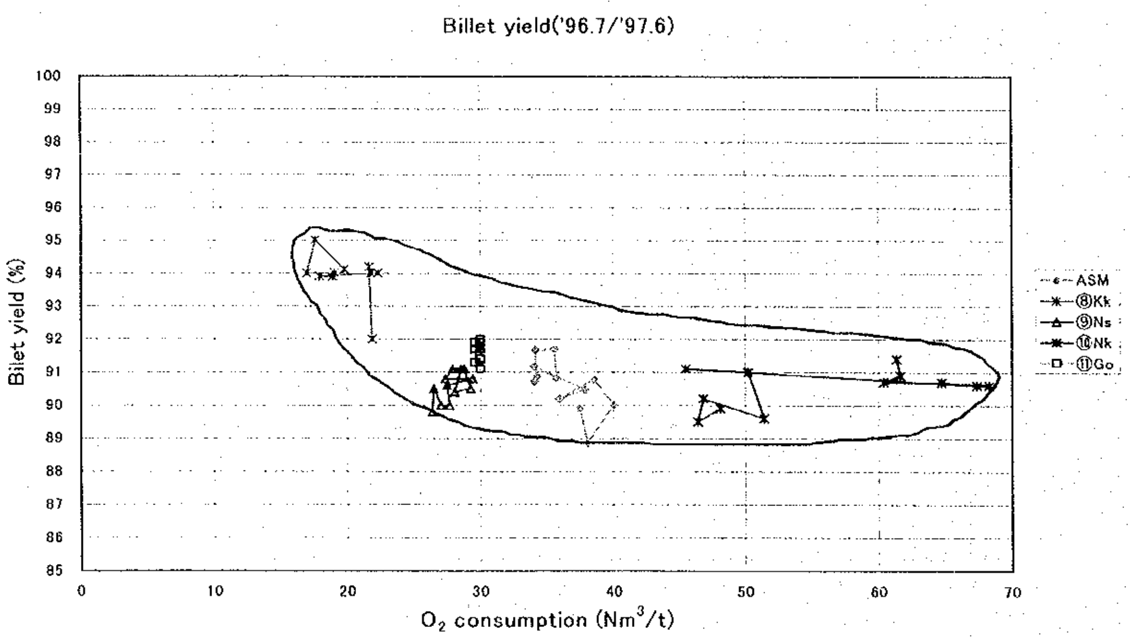


Figure 14-21-2 Oxygen Consumption and Billet Yield (Special scrap)

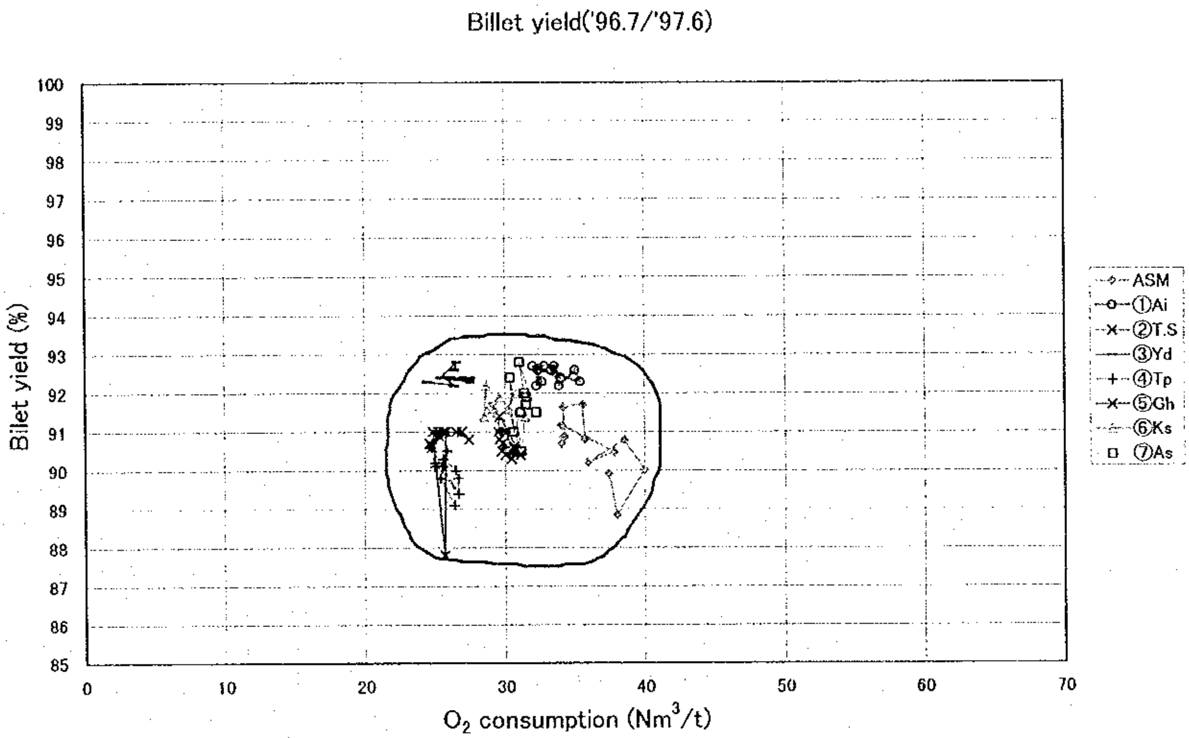


Figure 14-21-3 Oxygen Consumption and Billet Yield (High grade steel)

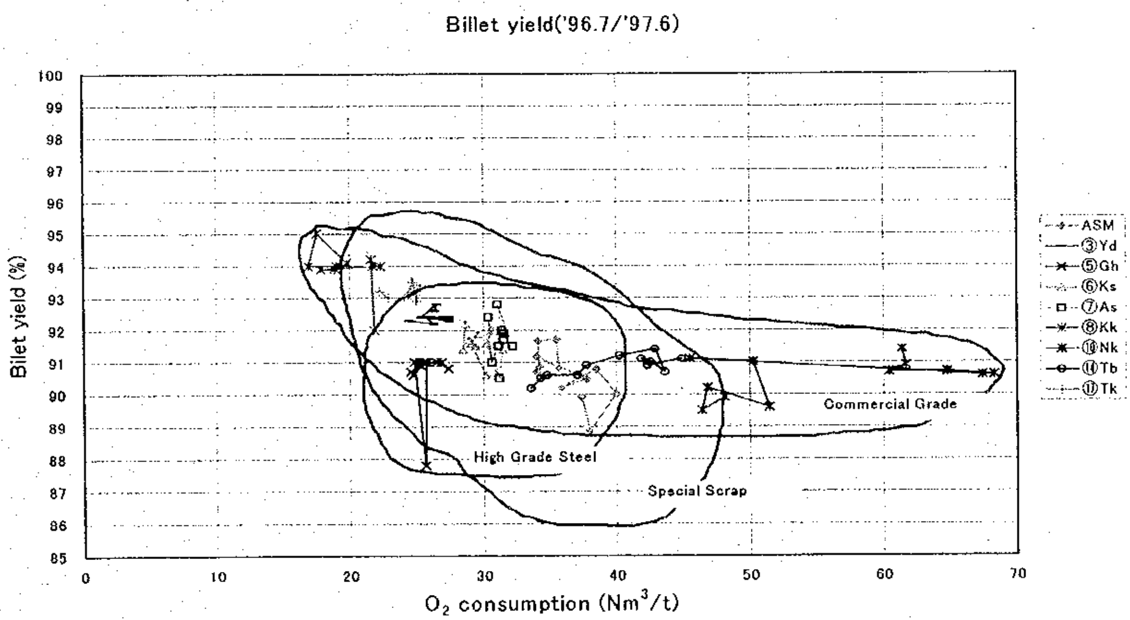


Figure 14-21-4 Oxygen Consumption and Billet Yield (Summary)

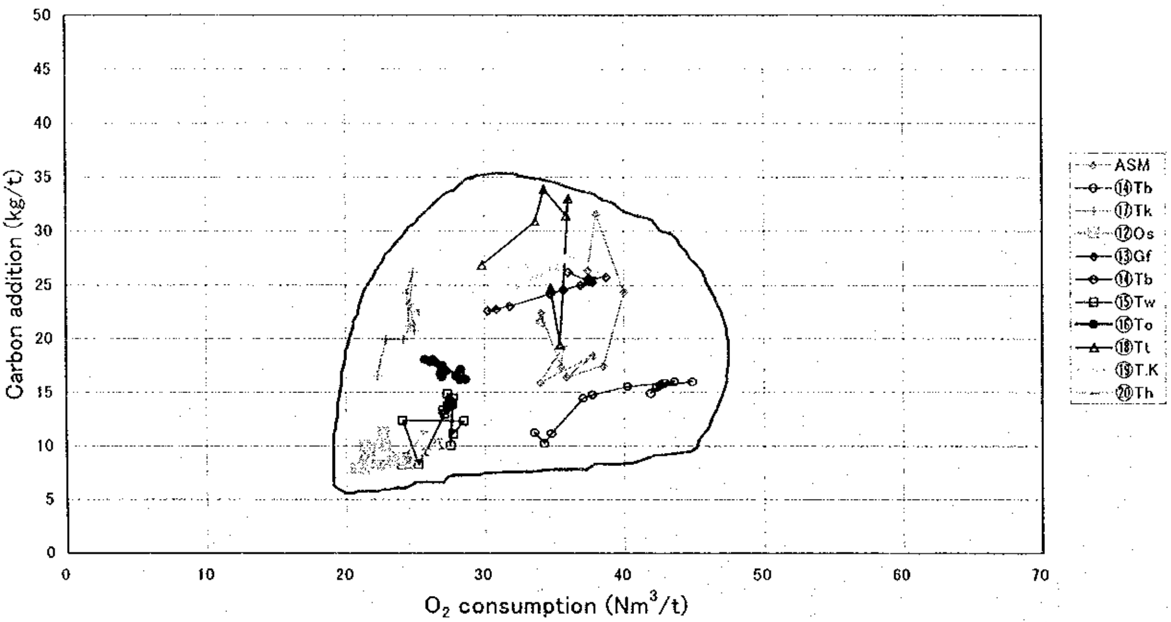


Figure 14-22-1 Oxygen Consumption and Carbon Addition (Commercial grade)

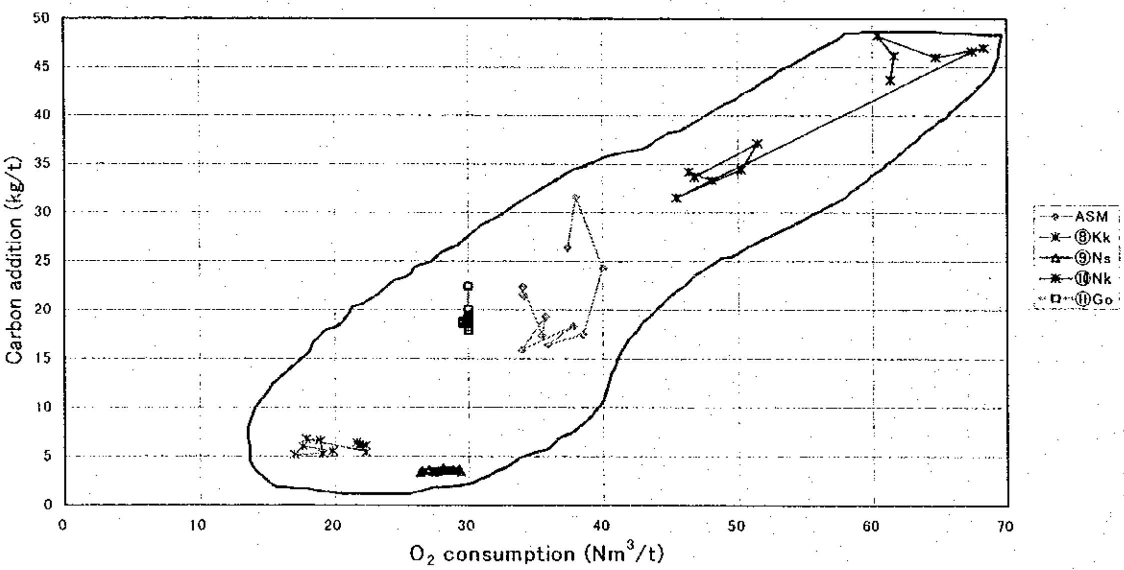


Figure 14-22-2 Oxygen Consumption and Carbon Addition (Special scrap)

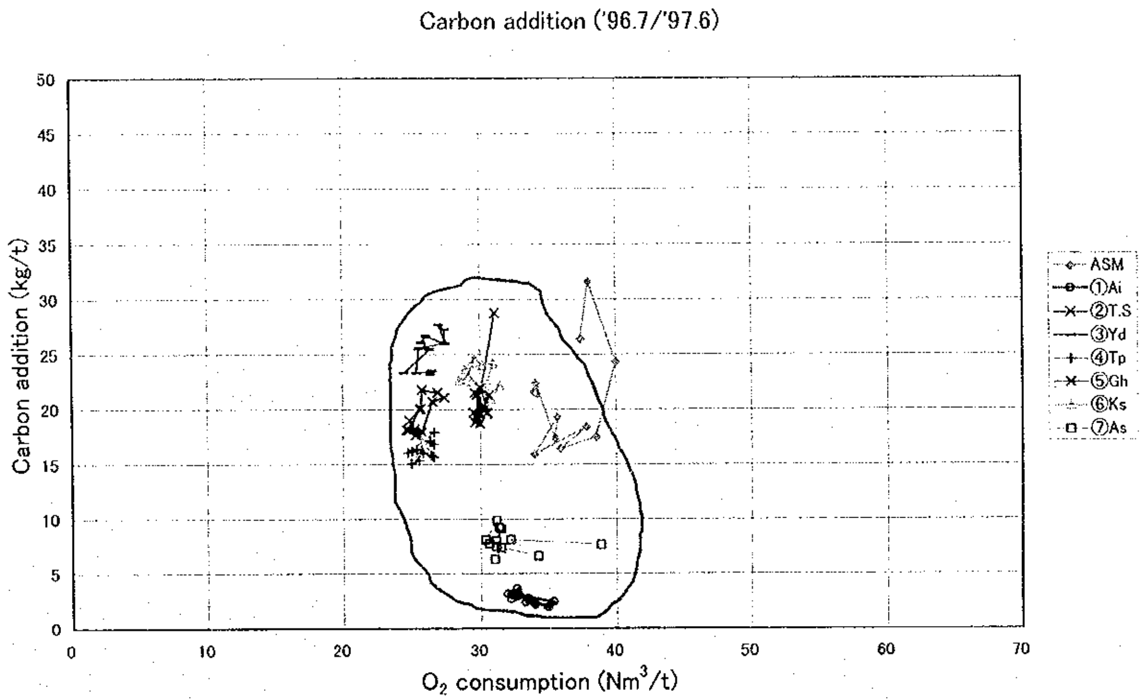


Figure 14-22-3 Oxygen Consumption and Carbon Addition (Highl grade steel)

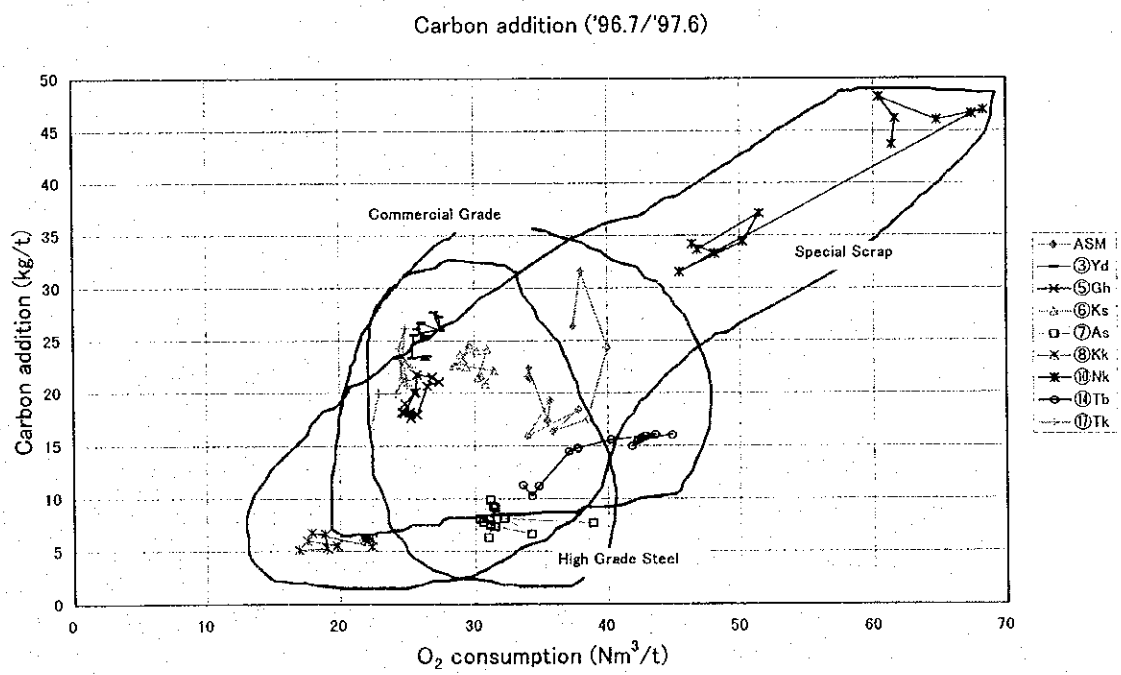


Figure 14-22-4 Oxygen Consumption and Carbon Addition (Summary)

14-10 Energy Flowchart of Factory and Major Energy-Consuming Facilities

(1) Energy Flow Chart

The energy flow chart is shown in Figure 14-23.

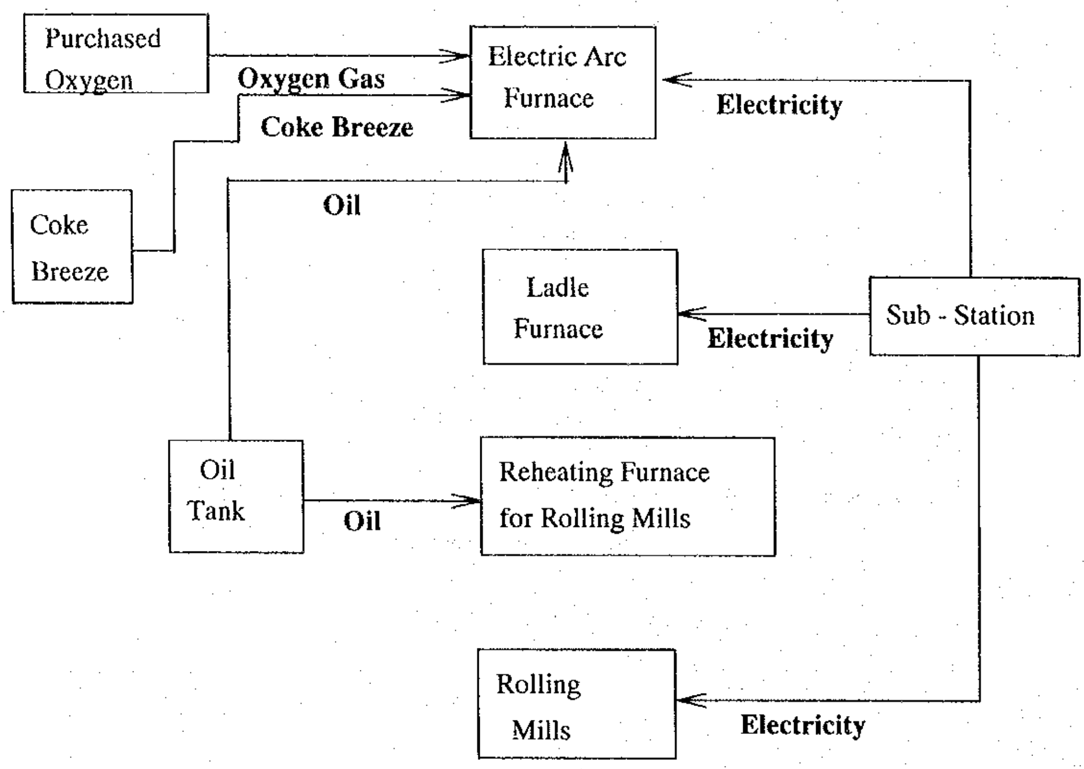


Figure 14-23 Energy Flow in ASM

(2) Major Energy-Consuming Facilities

The energy consumption for each facility is shown in Table 14-22. This shows that

1. 70 percent of the energy consumption is electricity and 22 percent is medium fuel oil.
2. The energy consumption of the EAF is 57 percent, and the LF 5.5 percent; CCM (include auxiliary facilities) is 7.7 percent and rolling mills is 30 percent.
3. 70 percent of the energy consumption and 80 percent of the electricity consumption are consumed in the steel making plant.
4. 76 percent of the medium fuel oil consumption is consumed in the reheating furnaces.

The primary energy flow is shown in Figure 14-24.

Table 14-22 Energy Consumption of Each Facility

(1997)

Facility	Production Amount	Electricity			Medium Fuel Oil			Diesel Oil		Oxygen		Coke breeze	Primary Energy Total	
		Unit	Consumption		Unit	Consumption		Unit	Consumption	Unit	Consumption	Consumption		
	[10^3 t/y]	[kWh/t]	[MWh/y]	[%]	[kg/y]	[10^3 kg/y]	[%]	[kg/t]	[kg/y]	[Nm^3/t]	[10^3 Nm^3/y]	[t/y]	[10^6 kcal]	[%]
EAF	660	420	277,000	62	12	7,923	24	—	—	36	23,887	14,000	813,800	56.9
LF	660	53	35,100	8	—	—	—	—	—	—	—	—	79,000	5.5
CCM (Aux.)	660	73	48,300	11	—	—	—	0.25	165,000	—	—	—	110,400	7.7
Rolling Mills	760	109	82,700	19	33	25,440	76	—	—	—	—	—	428,000	29.9
Total			443,100	100		33,363	100		165,000		23,887	14,000	1,431,200	100
Primary Energy	[10^6kcal/y]		997,000 (69.7%)			317,300 (22.2%)			1,700 (0.1%)		24,200 (1.7%)	91,000 (6.3 %)	1,431,200 (100%)	

Comment:

1. Conversion factor of electricity to primary energy: 2,250 kcal/kWh
2. Low heating value of medium fuel oil: 9,463 kcal/kg
3. Low heating value of diesel oil: 10,300 kcal/kg
4. Conversion factor of oxygen to primary energy: 1,012.5 kcal/Nm^3
5. Low heating value of coke breeze: 6,500 kcal/kg

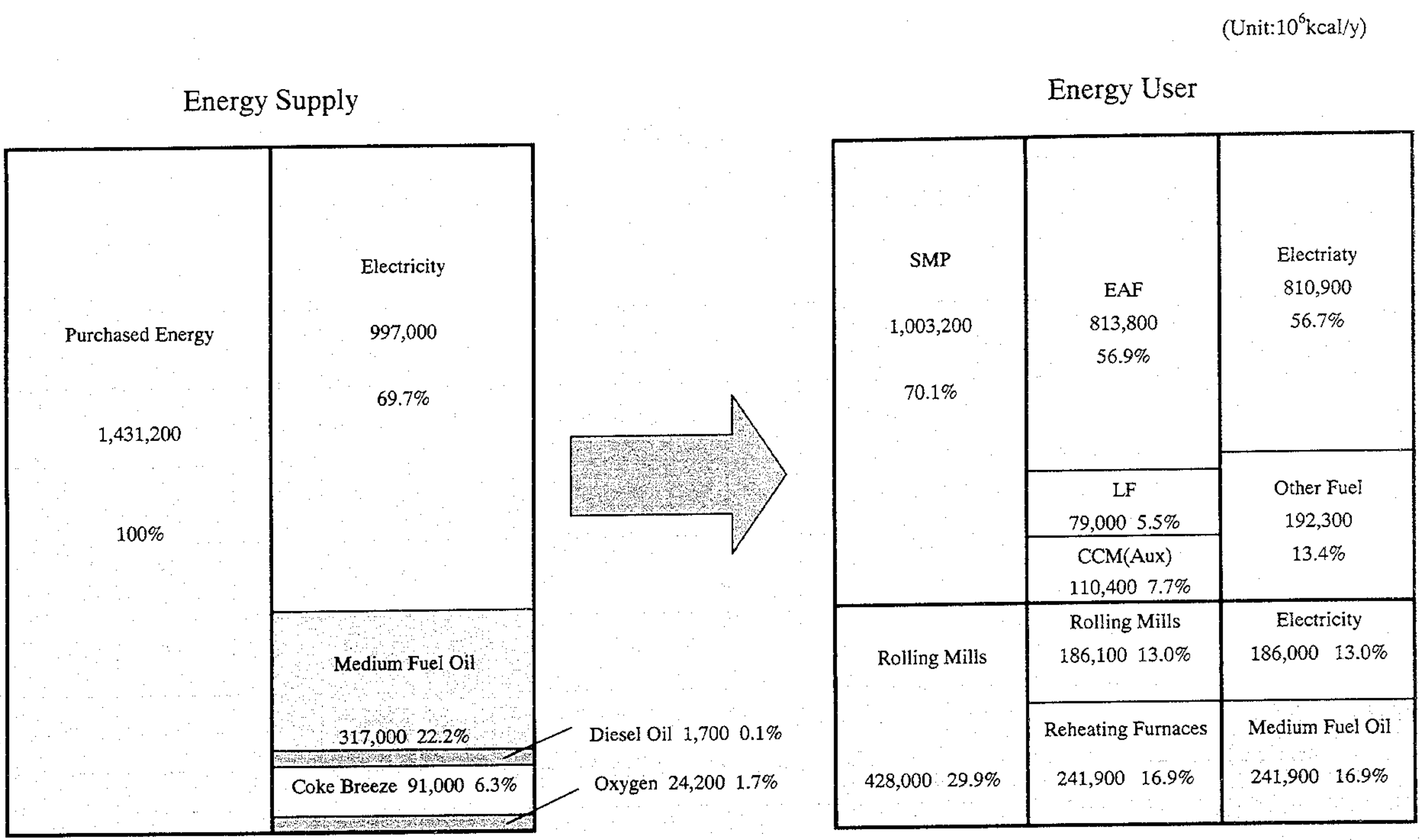


Figure 14-24 Primary Energy Flow

14-11 Measures for Energy Efficiency Promotion

In accordance with the results of energy audit, measures to improve energy efficiency are described and discussed in this section. The major points are as follows.

1. Reduction of temperature variation of extracted material
2. Reduction of air/fuel ratio
3. Reduction of heat loss from furnace wall
4. Replacement of burner with regenerative burner system
5. Introduction of hot billet charging
6. Reduction of electricity consumption for new shredder plant
7. Reduction of electricity consumption for EAF

14-11-1 Reheating Furnace

(1) Reduction of Temperature Variation of Extracted Material

As Figure 14-25 shows, the extracted billet temperature varies from 1030℃ to 1097℃. Even at the lowest temperature, the rolling procedure was performed successfully. This temperature variation was the result of miscalculating the heating pattern change timing. Certainly, this timing speculation is difficult to make, and only the operator can execute it.

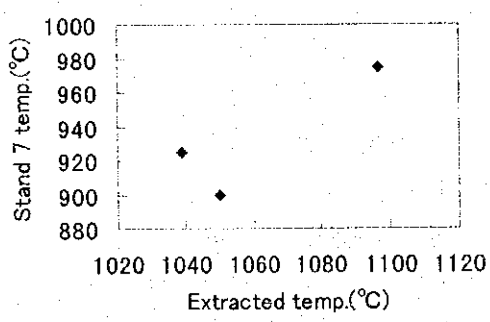


Figure 14-25 Extracted Billet Temperature

At present, the range of extracted temperature is 60℃ and the mean extracted temperature is 1,060℃, and after improvement, the range of extracted to be temperature is expected half of the present data, and the mean extracted temperature is expected to be 1,045℃, ① Energy output reduction is from heat content table — 2320 kcal/t =167040-164720

② Energy input reduction — 4320 kcal/t =2320/(53.8/100)

③ Fuel consumption saving — 0.46 kg/t =4320(kcal/t)/9463(kcal/kg)

(2) Reduction of Air/Fuel Ratio

When the air/fuel ratio(=m) decreases, the exhaust gas amount decreases and thus energy consumption decreases. For this purpose, an oxygen meter in the furnace tail is essential, which is already designed for the reheating furnace and is damaged at present.

For the gaseous fuel, air/fuel ratio of m=1.05 is already regularly achieved, but for liquid fuel, unburned material deposits in the recuperator and so, will accidentally burn and will damage the recuperator. Thus, the air/fuel ratio for liquid fuel of m=1.15 is the optimum value attainable.

Expected fuel consumption reduction is calculated, under the assumptions;

Air/fuel ratio at present m= 1.25,

whereas improved condition m=1.15, which is supported by an oxygen content of 3.0%.

Heat recovery ratio of the recuperator is 41.0%, at present and in improved condition.

Combustion air leakage ratio in the recuperator is 21%.

and in the equations,

Unit fuel consumption Vf = (Qfix - Qsh) / (Hl - Qgin + Qa + Qo)

where Qfix = (Heat content of extracted material) + (Heat content of scale) + (Heat loss from furnace body) + (Other heat loss)

Qsh = (Heat of formation of scale)

Hl = Low heating value of fuel = 9463 kcal/kg

Qgin = Heat content of waste gas in recuperator inlet

Qa = Heat content of combustion air in furnace inlet

Qo = Heat content of fuel oil in furnace inlet.

Thus calculated,

$$Vf = (237700 - 13400) / (9463 - 2620 + 1069 + 29) = 28.2 \text{ kg/t}$$

Fuel saving rate = 1 - 28.2/ 28.7 = 1.7%

(3) Reduction of Heat Loss from Furnace Wall

Generally, during ordinary furnace operation, the furnace wall temperature is said to be around 100℃. As Table14-23 shows, the present wall temperature is as high as over 130℃, and improvement of heat insulation would reduce heat loss.
Recently, a veneering method is said to be the most convenient way of improving insulation ability. The method is to overlay a ceramic fiber blanket on the inside of pre-built wall.

Assuming reasonable heat conductivity for refractories and a blanket thickness of 50mm, energy saving quantity is calculated. The calculated result is summarized in Table 14-23.

Table 14-23 Total Heat Loss Reduction after 50mm Ceramic Fiber Blanket Veneering

Zone, Area	Inside wall temperature (℃)	Outside wall temperature (℃)		Heat flux ($kcal/m^2 \cdot h$)		Heat loss (kcal/t)	
		Present	Improved	Present	Improved	Present	Improved
Soaking zone	1050						
Roof		139	117	1860	1350	7680	5770
Wall		133	119	1220	980		
Heating zone	950						
Roof		104	88	1730	1250	5750	4330
Wall		104	92	1130	900		
Preheating zone	750						
Roof		88	73	1350	980	5630	3400
Wall		88	78	880	710		
Total						19060	13500
							5560

This calculation leads the reduction of energy consumption and fuel consumption,
Fuel consumption Vf = (Qf - Qsh) / (Hl - Qgin + Qa + Qo)
Reduction of fuel consumption dVf = dQf / (Hl - Qgin + Qa + Qo)
= 5560 / (9463 - 2835 + 1158 + 29) = 0.71 kgFuel/t

(4) Replacement of Burner with Regenerative Burner System

The recently developed regenerative burner system, known as the HRS system (High Cycle Regenerative Combustion System), is known to be very innovative. A well known old type regenerative burner consists of brick or nugget, and the blast alternation cycle is tens of minutes. The HRS system consists of thin-wall fine mesh honeycomb ceramics and the alternation time is 30 seconds.

Accordingly, the HRS system is capable of utilizing waste gas deep to 200℃ from a temperature only 100℃ below the furnace temperature.

The problem is, actual application to liquid fuel is still under development.
Assuming the improved condition as;

Waste gas outlet temperature = 250 ℃,

Combustion air leakage ratio = 21%,

The resultant energy consumption is

Combustion air heated temperature = 370℃

Fuel consumption rate = 27.7 kgFuel/t

(5) Introduction of Hot Billet Charging

Nowadays, many steel mills adopt hot charge. When billet is charged under hot conditions, heating energy reduction is more than the increased input energy, because heating energy is the heat content of the heated material divided by the efficiency.

Very favorably, ASM rod mill reheating furnace is adjacent to the continuous caster delivery table. In the continuous caster billet bay, there already is an overhead crane that is capable of transfering hot billets from the continuous caster delivery table to the reheating furnace charging table by using C hook.

An energy saving estimation is a matter of operational feasibility, and depends on the cooperation of the steel making shop and the rod rolling mill.

For a rough estimation, assuming the conditions as:

Tonnage application ratio = 10% of rolling production;

Average charging temperature = 500℃ where heat content is 60kcal/kg;

Energy contribution rate of increase of input heat content of billet = 80%.

The resultant energy saving quantity is;

60,000kcal/t x 0.8 / (53.8/100) / 9463 kcal/kgFuel x 0.1 = 0.9 kgFuel/t

14-11-2 Reduction of Electricity Consumption for New Shredder Plant

As mentioned in sub section 14-9-2 (6), the reduction of electricity consumption during plant stoppage by checking the plant conditions may be able to reduce 35 kWh/h of electricity.

14-11-3 Reduction of Electricity Consumption for EAF

As mentioned in sub section 14-9-3 (3), it may be possible to reduce 15 kWh/t of electricity consumption by active boiling reaction in the furnace and a deep oxygen lance position.

14-12 Selection of Measure for Energy Efficiency Promotion

Table 14-24 below shows a summary of the above-mentioned measures.

Table 14-24 Summary of Selected Measures

S.No.	Item/Description	Measures	Fuel/Electricity saving
1	Reduction of Temp. Variation of Extr'd Material Present Improved R=60℃ 30℃ Average = 1060℃ 1045℃	Standardization of Operation	2340kcal/t /(53.8/100) / 9463 kcal/kgFuel = 0.46 kgFuel/t
2	Reduction of air/fuel ratio Present Improved m = 1.25 1.15 O_2 = 4.4% 3.0%	Oxygen Content Meter	28.7 - 28.2 = 0.5 kgFuel/t
3	Reduction of heat loss from furnace wall Present Improved Heat loss 19060 kcal/t 13500kcal/t	50mm Ceramics Fiber Blanket Veneering	(19060 - 13500) /(9463 - 2835 +1158 + 29) = 0.71 kgFuel/t
4	Replacement of burner to regenerative burner system Assuming combustion air leakage (21%) & waste gas temp. (250℃), fuel saving is 3.3%.	HRS Burner System	28.7 - 27.7 = 1.0 kgFuel/t
5	Introduction of hot billet charging Assuming: Tonnage application ratio = 10% Mean charged temp. = 500℃ Energy contribution rate in increasing input heat content of billet = 80%.	Operation by Crane (installed)	60000kcal/t x 0.8 / (53.8/100) / 9463 kcal/kgFuel x 0.1 = 0.9 kgFuel/t
6	Reduction of electricity consumption for New shredder plant	Checking condition	35kWh/h
7	Reduction of eledtricity consumption for EAF	Standardization of Operation	15kWh/t

14-13 Cost of Measures for Energy Efficiency Promotion

14-13-1 Cost Estimation of Measures for Reheating Furnace

(1) Reduction of Temperature Variation of Extracted Material

No hardware is necessary for this measure.

(2) Reduction of Air/Fuel Ratio

1) Oxygen content meter with accessories
2) Supplementary software for oxygen content control of exhaust gas
3) Installation work
4) Supervisory work

Construction cost total is ¥5,400,000.

(3) Reduction of Heat Loss from Furnace Wall

1) Veneering material (408 m^2) and adhesives
2) Installation work
3) Supervisory work

Construction cost total is ¥9,000,000.

(4) Replacement of Burner with Regenerative Burner System

1) Regenerative burner with auxiliary parts (10 pairs)
2) Combustion control system for alternating and pressure
3) Furnace shell reconstruction
4) Duct and piping works
5) Transportation
6) Supervisery work and performance test

Construction cost total is ¥237,500,000.

(5) Introduction of Hot Billet Charging

No hardware is necessary for this measure.

14-13-2 Cost Estimation of Measures for New Shredder Plant

No hardware is necessary for this measure.

14-13-3 Cost Estimation of Measures for EAF

It is not necessary of hardware for this measure.

14-14 Potential of Energy Efficiency Promotion

14-14-1 Potential of Energy Efficiency Promotion Measures for Reheating Furnace

As 14-11 indicates, each measure has the following potential.

(1) Reduction of Temperature Variation of Extracted Material

Fuel saving quantity is 0.46 kgFuel/t.

(2) Reduction of Air/Fuel Ratio

Fuel saving quantity is 0.5 kgFuel/t.

(3) Reduction of Heat Loss from Furnace Wall

Fuel saving quantity is 0.71 kgFuel/t.

(4) Replacement of Burner to Regenerative Burner System

Fuel saving quantity is 1.0 kgFuel/t.

(5) Introduction of Hot Billet Charging

Fuel saving quantity is 0.9 kgFuel/t.

14-14-2 Reduction of Electricity Consumption for New Shredder Plant

It is possible to reduce 35kWh/h duirng plant stoppage, and plant stoppage time is 16 h/day. Therefore, a 204,400 kWh/year saving can be expected by reduction of electricity consumption loss.

(Saving amount = 35 kWh/h × 16 h/day × 365 day/year)

Energy saving potential is 460×10^6 kcal/y based on primary energy base. The energy saving potential per unit billet ton is 700 kcal/t.

(Energy saving potential = 204,400 kWh/y × 2,250 kcal/kWh

Unit saving potential = 460×10^6 kcal/y / 660,000 ton/year)

14-14-3 Reduction of Electricity Consumption for EAF

It is possible to reduce 15 kWh/t, and billet production is 660,000 ton/year. Therefore, a 9,900,000 kWh/y saving can be expected by improving operating methods.

(Saving amount = 15 kWh/t × 660,000 ton/year)

Energy saving potential is $22{,}275 \times 10^6$ kcal/y based on primary energy base. The energy saving potential per unit billet ton is 33,750 kcal/t.

14-15 Effectiveness of Energy Efficiency Promotion

14-15-1 Estimation of Effect of Measures for Reheating Furnace

As a summary of 14-14-1, an estimation of the effect of measures for the reheating furnace is 3.57 kg-fuel/t, or 1,350 t fuel/year annually.

14-15-2 Reduction of Electricity Consumption for New Shredder Plant

Saving of electricity consumption in the peak period:	178,850 kWh/y
Saving of electricity consumption in the off peak period:	25,550 kWh/y

14-15-3 Reduction of Electricity Consumption for EAF

Saving of electricity consumption in the peak period:	5,775,000 kWh/y
Saving of electricity consumption in the off peak period:	4,125,000 kWh/y

14-16 Benefit of Measures for Energy Efficiency Promotion

In this section, benefits are estimated of the seven measures for energy efficiency promotion for which effectiveness have been estimated in the previous section, based on the prices of energy for ASM.

14-16-1 Energy Prices for ASM

(1) Fuel

The price of Medium Fuel Oil (MFO) is RM 317 per kl, being converted to RM 323.5 per ton by the assumed density.

(2) Electricity

The current price of electric power conforms to category E-3 (special rate for qualified customers) of TENAGA NASIONAL's tariff, effective from May 1, 1997, in the case of ASM. The following rates are applied, according to this category of tariff.

-Peak load rate (between 800 and 2200 hours):	0.178 RM/kWh
-Off-peak load rate (between 2200 and 800 hours):	0.098 RM/ kWh
-Maximum demand charge:	16.2 RM/kW/month

14-16-2 Benefits of Measures

(1) Reduction in Temperature Variation of Extracted Material

The benefit derived from this measure is estimated at 56,542 RM/year by the calculations shown in Table 14-25 below.

Table 14-25 Estimation of Benefit from "Reduction in Temperature Variation of Extracted Material"

	Item	Estimated Values	Remarks
①	Fuel Saving	0.46 kg-Fuel/ton-billet	Potential from the section 14-14
②	Annual Fuel Saving	174.8 ton-Fuel/year	① x 380,000 ton-billet/year / 1,000
③	Saving in Fuel Bill	56,542 RM/year	② x 323.5 RM/ton-Fuel

(2) Reduction in Air/Fuel Ratio of Reheating Furnace

61,459 RM/year of benefit is estimated for this measure, as Table 14-26 shows.

Table 14-26 Estimation of Benefit from "Reduction in Air/Fuel Ratio of Reheating Furnace"

	Item	Estimated Values	Remarks
①	Fuel Saving	0.5 kg-Fuel/ton-billet	Potential from the section 14-14
②	Annual Fuel Saving	190 ton-Fuel/year	① x 380,000 ton-billet/year / 1,000
③	Saving in Fuel Bill	61,459 RM/year	② x 323.5 RM/ton-Fuel

(3) Reduction in Heat Loss from Reheating Furnace Wall

By the calculations shown in Table 14-27 below, the benefit derived from this measure is estimated at 87,272 RM/year

Table 14-27 Estimation of Benefit from "Reduction in Heat Loss from Reheating Furnace Wall"

	Item	Estimated Values	Remarks
①	Fuel Saving	0.71 kg-Fuel/ton-billet	Potential from the section 14-14
②	Annual Fuel Saving	269.8 ton-Fuel/year	① x 380,000 ton-billet/year / 1,000
③	Saving in Fuel Bill	87,272 RM/year	② x 323.5 RM/ton-Fuel

(4) Replacement of Reheating Furnace Burner with Regenerative Burner System

The benefit derived from this measure is estimated at 122,918 RM/year by the calculations shown in Table 14-28.

Table 14-28 Estimation of Benefit from "Replacement of Reheating Furnace Burner with Regenerative Burner System"

	Item	Estimated Values	Remarks
①	Fuel Saving	1.0 kg-Fuel/ton-billet	Potential from the section 14-14
②	Annual Fuel Saving	380 ton-Fuel/year	① x 380,000 ton-billet/year / 1,000
③	Saving in Fuel Bill	122,918 RM/year	② x 323.5 RM/ton-Fuel

(5) Introduction of Hot Billet Charging

A 110,627 RM/year benefit derived from this measure is estimated by the calculations shown in Table 14-29.

Table 14-29 Estimation of Benefit from "Introduction of Hot Billet Charging"

	Item	Estimated Values	Remarks
①	Fuel Saving	0.9 kg-Fuel/ton-billet	Potential from the section 14-14
②	Annual Fuel Saving	342 ton-Fuel/year	① x 380,000 ton-billet/year / 1,000
③	Saving in Fuel Bill	110,627 RM/year	② x 323.5 RM/ton-Fuel

(6) Reduction in Electricity Consumption for New Shredder Plant

A 34,339 RM/year electricity bill saving is estimated by this measure for the new shredder plant, as Table 14-30 shows.

Table 14-30 Estimation of Benefit from "Reduction in Electricity Consumption for New Shredder Plant"

No.	Item	Estimated Value	Remarks
	Electricity Saving		
①	Electricity saving at peak time	178,850 kWh/year	
②	Electricity saving at off-peak time	25,550 kWh/year	
	Saving in Electricity Bill		
③	Electricity saving at peak time	31,835 RM/year	① x 0.178 RM/kWh
④	Electricity saving at off-peak time	2,504 RM/year	② x 0.098 RM/kWh
⑤	Saving in Electricity Bill	34,339 RM/year	③ + ④

(7) Reduction in Electricity Consumption for EAF

A 1,432,200 RM/year electricity bill saving is estimated by this measure for the EAF, as Table 14-31 shows.

Table 14-31 Estimation of Benefit from "Reduction in Electricity Consumption for EAF"

No.	Item	Estimated Value	Remarks
	Electricity Saving		
①	Electricity saving at peak time	5,775,000 kWh/year	
②	Electricity saving at off-peak time	4,125,000 kWh/year	
	Saving in Electricity Bill		
③	Electricity saving at peak time	1,027,950 RM/year	① x 0.178 RM/kWh
④	Electricity saving at off-peak time	404,250 RM/year	② x 0.098 RM/kWh
⑤	Saving in Electricity Bill	1,432,200 RM/year	③ + ④

14-17 Financial Evaluation of Measures

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

- Reduction in Air/Fuel Ratio of Reheating Furnace
- Reduction in Heat Loss from Reheating Furnace Wall
- Replacement of Reheating Furnace Burner with Regenerative Burner System

The financial evaluation is not conducted for four measures requiring no investment, "Reduction in Temperature Variation of Extracted Material", "Introduction of Hot Billet Charging", "Reduction in Electricity Consumption for New Shredder Plant" and "Reduction in Electricity Consumption for EAF".

14-17-1 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 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).

14-17-2 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

3) Corporate tax rate: 28 percent

4) Depreciation: The straight-line method is applied. The depreciation rate is 5% per year for the plant and machinery.

5) Fixed investment: Table 14-32 summarizes the fixed investment cost for the measures, which were obtained by converting the Japanese Yen values in the section 14-13.

Table 14-32 Fixed Investment Cost for Measures

Measures	Fixed Investment Cost (RM)
Reduction in Air/Fuel Ratio of Reheating Furnace	173,898
Reduction in Heat Loss from Reheating Furnace Wall	289,831
Replacement of Reheating Furnace Burner with Regenerative Burner System	7,648,305

14-17-3 Results of Financial Evaluation

Table 14-33 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 14-34 through 14-36.

Table 14-33 Results of Financial Evaluation

Measures	FIRROI before tax	FIRROI after tax	Payback Period
Reduction in Air/Fuel Ratio of Reheating Furnace	34.9%	26.0%	3.7 years
Reduction in Heat Loss from Reheating Furnace Wall	29.5%	21.9%	4.3 years
Replacement of Reheating Furnace Burner with Regenerative Burner System	-14.1%	-10.1%	n.a.

14-17-4 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.

For the first two measures, "Reduction in Air/Fuel Ratio of Reheating Furnace" and "Reduction in Heat Loss from Reheating Furnace Wall", favorable FIRROIs exceeding the above opportunity cost of capital, together with payback periods in the reasonable range were obtained. Accordingly, these measures can be regarded as financially feasible, under the conditions set for the study.

As for the third measure, "Replacement of Reheating Furnace Burner with Regenerative Burner System", FIRROI values are negative and the payback period exceeds 15 years, because of a relatively large investment cost and somewhat low benefits. This measure is considered financially unfeasible.

Table 14-34 Cash Flow Table (Measure: Reduction in Air/Fuel Ratio of Reheating Furnace)

Unit: RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	173,898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459
Less: Corporate tax increased	0	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774	14,774
Incremental Cash Flow (before Tax)	-173,898	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459	61,459
Incremental Cash Flow (After Tax)	-173,898	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685	46,685
Cumulative net cash flow	-173,898	-127,213	-80,528	-33,843	12,842	59,528	106,213	152,898	199,583	246,268	292,954	339,639	386,324	433,009	479,694	526,380
Depreciation	0	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695	8,695

Table 14-35 Cash Flow Table (Measure: Reduction in Heat Loss from Reheating Furnace Wall)

Unit: RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	289,831	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272
Less: Corporate tax increased	0	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379	20,379
Incremental Cash Flow (before Tax)	-289,831	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272	87,272
Incremental Cash Flow (After Tax)	-289,831	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893	66,893
Cumulative net cash flow	-289,831	-222,937	-156,044	-89,150	-22,257	44,637	111,530	178,424	245,317	312,211	379,104	445,998	512,891	579,785	646,678	713,572
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depreciation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 14-36 Cash Flow Table (Measure: Replacement of Reheating Furnace Burner with Regenerative Burner System)

Unit: RM

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Less: Fixed investment	7,648,305	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plus: Reduction in operating cost	0	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918
Less: Corporate tax increased	0	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659	-72,659
Incremental Cash Flow (before Tax)	-7,648,305	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918	122,918
Incremental Cash Flow (After Tax)	-7,648,305	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577	195,577
Cumulative net cash flow	-7,648,305	-7,452,728	-7,257,150	-7,061,573	-6,865,995	-6,670,418	-6,474,840	-6,279,263	-6,083,685	-5,888,108	-5,692,530	-5,496,953	-5,301,375	-5,105,798	-4,910,220	-4,714,643
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depreciation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

14-18 Recommendations for Energy Efficiency Promotion

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

(1) Measures Requiring Investment

Among the three measures that require investment, the following two measures are recommended based on the financial evaluation.

(a) Reduction in Air/Fuel Ratio of Reheating Furnace in Rod Rolling Mill

During the energy audit, an air/fuel ratio of 1.25 was measured for the reheating furnace. It is recommended that the ratio be reduced to 1.15 of the optimum attainable value. Reduction in the air/fuel ratio results in a decrease in exhaust gas volume, which contributes toward energy saving in the reheating furnace. With this measure, an investment is required for installation of an oxygen content meter at the reheating furnace tail, replacing the broken one. This investment is financially feasible under the conditions of the study.

(b) Reduction of Heat Loss from Reheating Furnace Wall in Rod Rolling Mill

A reheating furnace wall temperature of over 130℃ was measured during the energy audit, although it is generally around 100℃ for ordinary furnaces. It is recommended that insulation be improved for reducing heat loss from the wall. The most convenient way of improving insulation is a veneering method, which involves overlaying a ceramic fiber blanket on the inside of the pre-build wall. The investment cost and benefit by fuel saving were estimated for this measure, assuming reasonable refractory heat conductivity and a blanket thickness of 50mm. This measure is regarded as financially feasible from the results of the financial evaluation, based on the investment cost and benefits.

(2) Measures Not Requiring Investment

Other recommended measures are mainly based on operational changes, requiring no investment.

(a) Reduction in Temperature Variation of Extracted Material in Rod Rolling Mill

It was found that the extracted billet temperature varied from 1,030℃ to 1,097℃, and the rolling procedure was performed successfully, even at the lowest temperature in the variation. It is recommended that the range of extracted billet temperature be reduced by half and the mean temperature be reduced to 1,045℃ by improved estimation of heating pattern changes. About a RM 57,000 annual fuel oil saving is expected by this measure.

(b) Introduction of Hot Billet Charging in Rod Rolling Mill

Hot billet charging to the reheating furnace is a popular energy-saving measure adopted by many steel mills. ASM has very favorable conditions to introduce hot billet charging. In fact, its rod mill reheating furnace is adjacent to the continuous caster delivery table and there is an overhead crane capable of transferring hot billets from the continuous caster delivery table to the reheating furnace charging table. It is recommended that hot billet charging be introduced in ASM. It is expected that 342 ton of medium fuel oil or RM 111,000 of the fuel bill will be saved annually by this measure, depending on the operation, especially the cooperation of the steel making shop and the rod rolling mill.

(c) Reduction in Electricity Consumption of New Shredder Plant

It was found during the energy audit that electricity was consumed at a rate of around 35 kWh/hour in the new shredder plant, even when the plant stopped. It is recommended that the cause of this loss be investigated and that the heat loss be prevented.

(d) Reduction in Electricity Consumption of Electric Arc Furnace (EAF)

The electricity consumption of ASM's EAF is somewhat higher than Japanese steel shops. ASM's data suggests that heat transfer in the EAF is rather poor according to analysis comparing data of Japanese shops. This problem would be solved by an active boiling reaction in the EAF, which would require additional carbon and would therefore increase heat generation. It is recommended that the oxygen lance position be well into the molten phase and also influence the metal phase, so that the boiling reaction is not localized only in the slag phase. About a 15 kWh/ ton electricity saving in the EAF is anticipated by this measure.

Annex 1. Heat Balance Calculation Sheet (5th shift)

(1) Standard of Heat Balance

As the standard state, charged steel heat content is zero at ambient temperature, and mass flow is specified at charged steel 1 ton and fuel heating value is low heating value.

(2) Measured Data

1) Heated Material

Charged material	Charged temperature	Extracted temperature	Scale loss
[t/hr]	[℃]	[℃]	[kg/t]
30.3	33	1088	10

2) Fuel

Fuel name	Consum -ption	Fuel composition							Density	High heating value	Feeding tempera-ture	Specific heat
	[kg/h]	C%	H%	O%	N%	S%	H_2O%	Ash%	[kg/l]	[kcal/kg]	[℃]	[kcal/kg·℃]
M.F.O	870	84.8	12.2	0.1	0.4	2.3	0.1	0.1	0.98	10,125	97	0.45

3) Exhaust gas (Recuperator inlet)

Temperature	Dry Exhaust gas composition			
[℃]	CO_2%	O_2%	CO%	N_2%
618	12.3	4.4	0.0	83.3

4) Cooling water(Walking hearth furnace has no water cooled parts)

5) Combustion air temperature :303℃

6) Ambient temperature : 33℃

7) Furnace wall and roof temperature

	Preheating zone(℃)	Heating zone(℃)	Soaking zone(℃)
Wall	88	104	133
Roof		104	139

(3) Calculation of Material Input Amount and Material Output Amount

1) Material input amount

① Charged material amount Rolling stock 1 ton

② Fuel oil (M.F.O) amount

870/30.3=28.7 kg/t

③ Combustion air amount

Theoretical combustion air (A_0)

A_0 =(1/100)[8.89xc + 26.7 x (h − o/8) + 3.33 x s]

=(1/100)[8.89x84.8 + 26.7x(12.2 − 0.1/8) + 3.33x2.3]

=10.7 $m^3{}_N$/kg Fuel

Air/fuel ratio (m)

$m=21/[21-79\{(O_2 - 0.5CO)/N_2\}]$

=21/[21 − 79{4.4/83.3}]

=1.25

Combustion air for fuel 1kg (A)

A = m*A_0

=1.25×10.7 $m^3{}_N$/kg Fuel

Thereby,

Combustion air amount at ton of heated material

= 1.25×10.7×28.7

=384 $m^3{}_N$/t

Whereas A_0 :Theoretical combustion air ($m^3{}_N$/kg Fuel)

c : Carbon content of fuel (%)

h : Hydrogen content of fuel (%)

o : Oxygen content of fuel (%)

s :Sulfur content of fuel (%)

A :Combustion air for fuel 1kg ($m^3{}_N$/kg Fuel)

m :Air fuel ratio

O_2 :Oxygen content of exhaust gas (%)

CO :CO content of exhaust gas (%)

N_2 :Nitrogen content of exhaust gas (%)

2) Material output amount

① Extracted material amount

From charged material, scale off loss of 10.0 kg/t is removed. So,

1 − 0.010 = 0.990 t

② Scale amount

Scale is composed of FeO, Fe2O3, Fe3O4, etc., but typically, Fe content in scale is 75.5%.

So, (Scale amount) = (Scale loss)/(Fe content in scale)

= 10.0/0.755 = 13.2 kg/t

③ Dry exhaust gas amount

$G' = G_0 + (m - 1)A_0$

Whereas, G_0 :Theoretical exhaust gas amount

$= (1/100)[8.89xc + 21.1(h - o/8) + 3.33xs + 0.80xn]$

$= (1/100)[8.89x84.8 + 21.1x(12.2 - 0.1/8) + 3.33x2.3 + 0.80x0.4]$

$= 10.1$ $m^3{}_N$/kg Fuel

$G' = 10.1 + (1.25 - 1)x\ 10.7$

$= 12.8$ $m^3{}_N$/kg Fuel

Thereby,

Dry exhaust gas amount at ton of heated material

= 12.8 x28.7

= 367 $m^3{}_N$/t

④ Water vapor in exhaust gas

As water content in burning air is negligible, water is generated from fuel,

$(1/100)(9h + w) = (1/100)(9\times12.2 + 0.1) = 1.10$ kg/kg Fuel

Water vapor standardized at charged material is,

1.10×28.7 = 31.6 kg/t

(4) Calculation of Heat Input and Heat Output

1) Heat input

① Combustion heat of fuel

$Hl = Hh - 600(9h/100 + w/100)$

$= 10125 - 600(9x0.122 + 0.001) = 9463$ kcal/kg Fuel

Combustion heat standardized at charged material is,

9463x28.7 = 271600 kcal/t

② Sensible heat of fuel

As specific heat of M.F.O is 0.45 kcal/(kg·℃),

28.7x0.45x(97 − 33) = 800 kcal/t

③ Sensible heat of combustion air

As specific heat of air is 0.32 kcal/($m^3{}_N$·℃), preheated combustion air blows in with the sensible heat of

(384x0.32)x(303 − 33) = 33200 kcal/t

④ Sensible heat of charged material (Heat content of charged steel)

Sensible Heat of charged material is calculated as follow.

(Heat content of charged steel) = (Heat content of steel at charged temperature) − (Heat content of steel at ambient temperature)

As rolling material is charged at 30℃ and ambient temperature is 30℃,

$1000\mathrm{x}\{-2.3 -(-2.3)\} = 0$ kcal/t

⑤ Heat of formation of scale

While heating steel, scale, which is composed of FeO, Fe_2O_3, and Fe_3O_4, is formed on the surface of steel. Heat of formation of scale could be calculated from content of FeO, Fe_2O_3, and Fe_3O_4 and those heat of formation, but, as convenient method, heat of formation of scale is 1335 kcal/kg of Fe in scale.

(Heat of formation of scale) = 1335 ×(Weight loss while heating steel) = 1335×10.0 ≒ 13,400 kcal/t

2) Heat output

① Heat brought out by steel (Heat content of extracted steel)

Heat brought out by steel is calculated as follow.

(Sensible heat of extracted steel) = (Amount of extracted steel)×{(Heat content of steel at extracted temperature) −(Heat content of steel at ambient temperature)}

Heat content at every temperature is shown in Table 1.

As extracted temperature is 1088℃, and ambient temperature is 33℃, and interpolation and extrapolation of Table 1 ,

$(1000 -10.0)\mathrm{x}\{171.4 -(-2.0)\} = 171700$ kcal/t

② Sensible heat of scale

As average specific heat of scale, 0.215 kcal/(kg·℃) is applicable. Temperature of scale while it removes from furnace is the same as extracted material removes from the furnace.

13.2x 0.215x (1088 −33) = 3000 kcal/t

③ Sensible heat of dry exhaust gas

As average specific heat value of exhaust gas, 0.34 kcal/(m^3_N·℃) is applicable,

367x 0.34x(618−33) = 73000 kcal/t

④ Sensible heat of water vapor in exhaust gas

As average specific heat value of water vapor, 0.45 kcal/(kg·℃) is applicable,

(31.6)x0.45x(618−33) = 8300 kcal/t

⑤ Heat brought out by cooling water

As ASM preheating furnace is walking hearth and has no water-cooled equipment, heat brought out by cooling water is zero,

0x1x(to - ti) = 0 kcal/t

⑥ Heat loss from furnace body (convection and radiation)(Ref. Annex-2)

(a) Preheating zone

As temperature of wall and ceiling is 88℃, heat flux is 880, and 1350 (kcal/m^2h) for wall and ceiling, respectively, and surface area of those are 38.7 m^2 and 100.9 m^2, respectively,

Qa=(1/30.3)x(880x38.7 + 1350x100.9) = 5600 kcal/t

(b) Heating zone

As temperature of wall and ceiling is 104℃ and 104℃, heat flux is 1130 and 1730 (kcal/m^2h) for wall and ceiling, respectively, and surface area of those are 60.4 m^2 and 61.4 m^2, respectively,

Qb=(1/30.3)x(1130x60.4 + 1730x61.4) = 5800 kcal/t

(c) Soaking zone

As temperature of wall and ceiling is 133℃ and 139℃, heat flux is 1220, and 1860 (kcal/m^2h) for wall and ceiling, respectively, and surface area of those are 61.9 m^2 and 84.4 m^2, respectively,

Qc=(1/30.3)x(1220x61.9 + 1860x84.4) = 7700 kcal/t

So, total heat loss from surface body is,

Q= Qa + Qb + Qc = 5600 + 5800 + 7700 = 19100 kcal/t

⑦Other heat loss

Other heat loss is the rest of subtraction of summary of①~⑥of heat output from summary of heat input.

(271,600 + 800 + 33,200 + 0 + 13,400) −(171,700 + 3,000 + 73,000 + 8,300 + 0 + 19,100)

= 43,900 kcal/t

The result is summarized in Table 2.

Table -1 Heat Content of Steel (Heat necessary to heat up from 50℃ (kcal/kg steel)

Steel kind / Temp.℃	Killed steel 0.08%C	Mild steel 0.23%C	Medium carbon steel 0.4%C
50	0	0	0
100	5.8	5.8	5.8
150	11.8	11.8	11.8
200	18.0	18.0	17.9
250	24.5	24.4	24.2
300	31.1	31.1	30.8
350	37.9	37.9	37.6
400	45.1	45.0	44.6
450	52.5	52.5	51.9
500	60.4	60.4	59.7
550	68.7	68.8	67.9
600	77.6	77.7	76.4
650	87.0	87.1	85.1
700	97.2	97.2	94.3
750	110.8	114.3	113.2
800	122.3	125.7	120.6
850	132.6	134.5	126.7
900	142.3	142.3	133.2
950	150.1	150.0	140.7
1000	157.9	157.7	148.1
1050	165.8	165.5	155.7
1100	173.7	173.2	163.2
1150	181.6	181.1	170.9
1200	189.5	189.0	178.7
1250	197.4	197.1	186.7
1300	205.4	205.3	194.9

Table- 2. Heat Balance Sheet of Reheating Furnace for Steel Rolling Mill
(Standard state: 25℃, Low heating value, at charged steel 1 ton)

Heat input			Heat output		
Item	10^3kcal/t	%	Item	10^3kcal/t	%
Combustion heat of fuel	271.6	85.1	Heat content of extr'd. steel	171.7	53.8
Sensible heat of fuel	0.8	0.3	Sensible heat of scale	3.0	0.9
Sensible heat of comb. Air	33.2	10.4	Sensible heat of exhaust gas	81.3	25.5
Sensible heat of atomizer	0	0	Heat loss by imperfect combustion	0	0
Heat content of charged steel	0	0	Heat loss brought out by cinder	0	0
Heat of formation of scale	13.4	4.2	Heat brought out by cooling water	0	0
			Heat loss from F'ce body	19.1	6.0
			Other heat loss	43.9	13.8
Heat recovery by recuperator	(34.1)	(10.7)	Heat recovery by recuperator	(34.1)	(10.7)
Total	319.0	100.0	Total	319.7	100.0

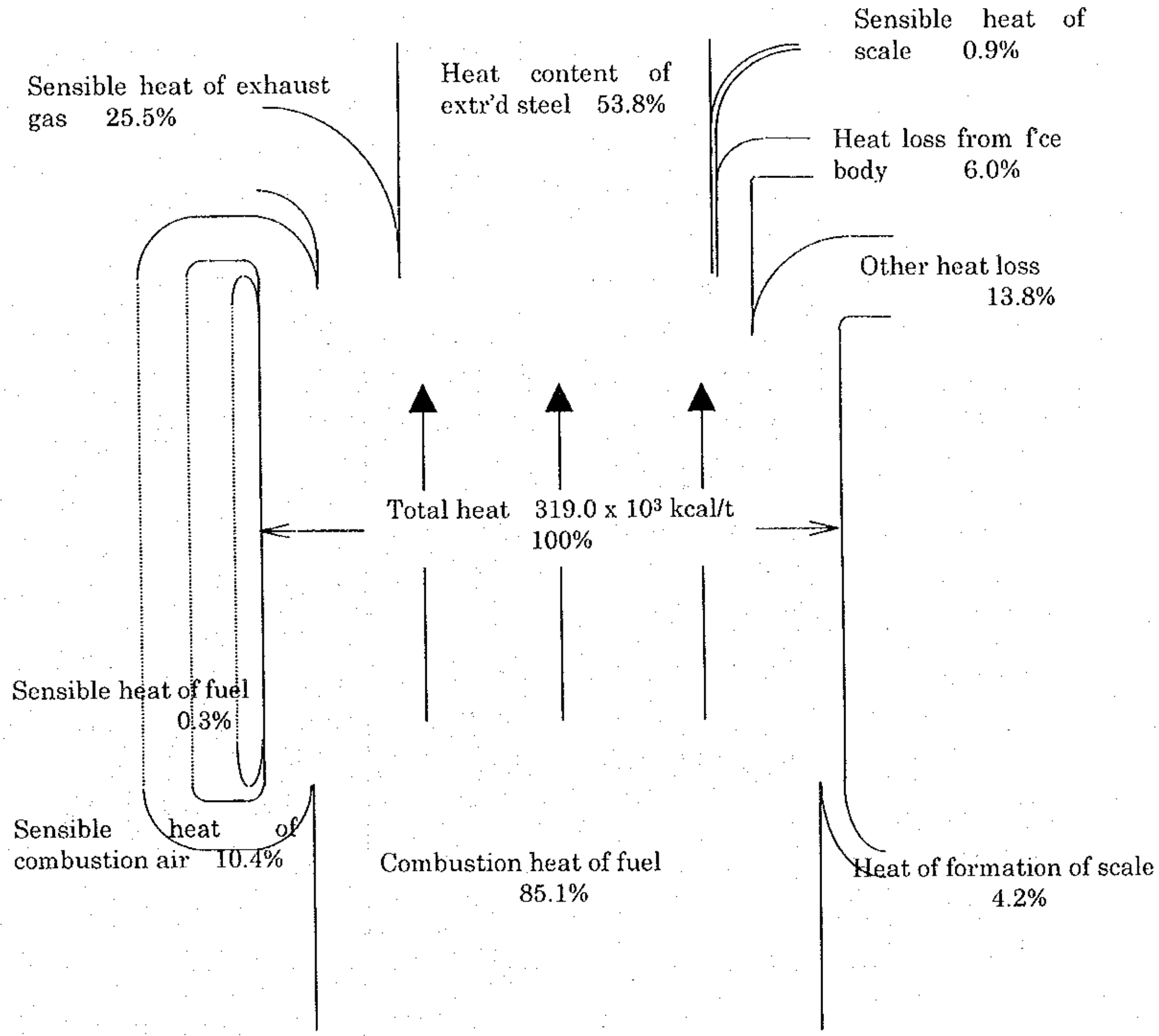


Figure 1 Heat Balance of Reheating Furnace

Annex 2 Calculation of Heat Loss from Furnace Body

(1) Heat Loss Calculation from Known Temperature Surface

1) From surface, heat is extracted either through natural convection and through radiation, so, when surface temperature is known,

$$Qsr= a \times (t-b)^{1/4} + 4.88 \times c \times [\{(t+273)/100\}^4 - \{(b+273)/100\}^4] \quad (1)$$

Where, a: parameter depending surface inclination, ceiling =2.8, wall =2.2, hearth = 1.5

t: furnace outside wall temperature (℃)

b: ambient temperature (℃)

c: furnace outside wall radiation parameter

Material	Condition	Temperature (℃)	Radiation parameter
Aluminum	Polished	227-580	0.039-0.057
	Rough surface	26	0.055
	Oxidized	200-378	0.11-0.19
Steel	Polished	427-1,025	0.14-0.38
Oxidized iron	Dark brown surface	100	0.31
	Hot rolled	21	0.65
	600℃ oxidized	200-600	0.79
	Ingot, rough surface	928-1,118	0.87-0.95
Aluminum painted	-	100	0.27-0.62
Aluminum oxide		r.t. - 1,000	0.8-0.5
Magnesia		r.t. - 1,000	0.7-0.4
Mullite		900-1,500	0.72-0.65

2) Comparison of the equation (1) with recommended value

Following table shows the comparison of the equation (1) with recommended value, on the actual condition of reheating furnace wall, where equation (1) modifies;

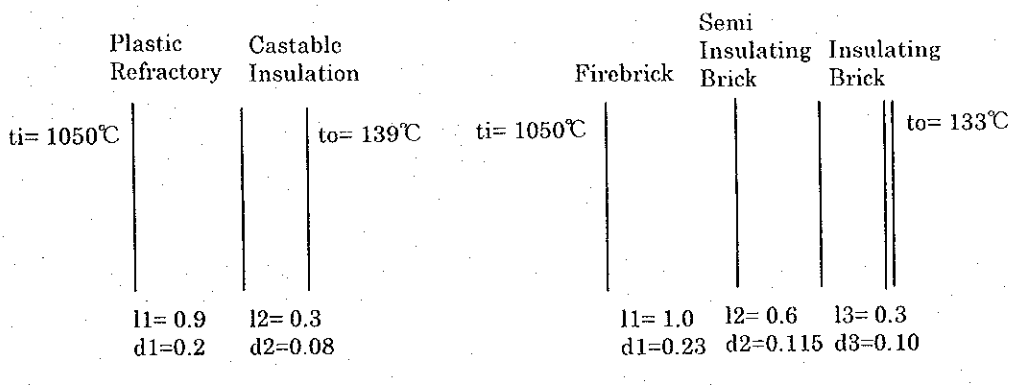
$$Qsr= 2.2 \times (t-b)^{1/4} + 4.88 \times 0.6 \times [\{(t+273)/100\}^4 - \{(b+273)/100\}^4] \quad (2)$$

Wall Temperature		℃	80	100	120	140
Heat Los, recommended value	a	$kcal/m^2 \cdot h$	580	880	1,220	1,600
Heat Los, Equation (2)	b	$kcal/m^2 \cdot h$	271	326	458	612
Ratio	a/b	-	2.71	2.70	2.66	2.61

Accordingly, multiplying factor of 2.6/2.7 (for wall) or 2.2/2.3 (for roof) should be applied when equation (2) is used.

(2) Heat Transfer through Wall Body

1) Furnace roof refractries are composed of 2-layers structure, inner 200mm thick plastic



Roof Structure　　　　Side Wall Structure

refractory 42/44% Al_2O_3 layer, and outer 80mm thick castable insulation layer. Also, wall structure is, from inner, 230mm thick fire brick (42/44% Al2O3) layer, 115mm thick semi insulating brick, 100mm thick insulating brick, (6mm thick) steel shell.

Heat flux through multi-layer structure is calculated according following formula;

Q=(ti-to)/{(d1/l1)+(d2/l2)+･･+(dn/ln)}　　　　(3)

where, ti: wall inner side temperature (℃)

to: wall outer side temperature (℃)

d1: 1st layer thickness (m)

l1: thermal conductivity of 1st layer (kcal/m･h･℃)

d2: 2nd layer thickness (m)

l2: thermal conductivity of 2nd layer (kcal/m･h･℃)

Applying above formula and consulting thermal conductivity data, ASM rodmill reheating furnace, roof

Qroof=(ti-to)/{(0.2/0.9)+(0.08/0.3)}=(ti-to)/0.49　　　　(4)

Qwall=(ti-to)/{(0.23/1)+(0.115/0.6)+(0.1/0.3)+(0.006/46)}=(ti-to)/0.75　　　　(5)

2) Comparison of the equation (4) and (5) with recommended value

Following table shows the comparison of the equation (4) and (5) with recommended value, on the actual condition of reheating furnace roof and wall on the 5th shift.

Data Period				5th Shift	
Place				Soaking Zone	
				Roof	Wall
Calculation Premises	Reference measured Value		℃	1146	
	ti, Estimated Value		℃	1050	1050
	to, Actual Value		℃	139	133
Calculated Value		b	$kcal/m^2 \cdot h$	1860	1220
Recommended Value		a	$kcal/m^2 \cdot h$	1800	1470
Ratio		a/b	-	1.0	1.2

As shown above, if the estimation of furnace inside wall temperature is adequate, calculation is reasonable.

(3) Heat Loss Reduction Applying Veneering Techniques

As heat loss from furnace body is as large as 6.0% of total energy consumption (5th shift), heat loss reduction technichs is effective.

On the inside wall of furnace body, ceramic fiber blanket is attached and veneered, and thus, eqations (4) and (5) are modified,

$$Qroof=(ti-to)/\{(db/0.25) +0.49 \} \quad (6)$$

$$Qwall=(ti-to)/\{(db/0.25) + 0.75 \} \quad (7)$$

Where, db: thickness of ceramics fiber blanket (m)

0.25: thermal conductivity coefficient of ceramics fiber blanket (kcal/m·h·℃)

Also, on the outer side of wall, conducted heat , which is calculated by above eqations (6) and (7), is released by radiation. From this relation, multiplying factor (m) is examined through eqation on the actual condition,

$$Qroof = mQsr$$

Using m value, which was thus obtained, and assuming wall outside temperature to, to is obtained through stepwise calculation which minimizes the difference

$$dQ = Qroof - mQsr. \quad (8)$$

Example1): (Soaking zone roof, thickness of fiber blanket = 50mm, $160kg/m^3$ blanket)

a) (m at actual condition)

$$Qroof = (1050 - 139) / 0.49 = 1859$$

$$m = 1859/[2.8x (139-30)^{1/4} + 4.88 x 0.75 x [\{(139+273)/100\}^4 - \{(30+273)/100\}^4]$$

$$= 2.45$$

b) (to and heat loss calculation)

$Qr=(1050-to)/(db/0.25+0.49)$

$Qsr=2.45x[2.8x(to-33)^{1/4}+4.88x0.75x[\{(to+273)/100\}^4-\{(33+273)/100\}^4]]$

From following results, to=117℃ and heat loss = 1350 kcal/m²·h

to	℃	120	119	118	117	116
dQ	kcal/m²·h	-56	-34	-10	12	36
Qr	kcal/m²·h	1,348	1,349	1,351	1,352	1,354
Qsr	kcal/m²·h	1,404	1,383	1,361	1,340	1,318

Example 2) (Total heat loss reduction after 50mm fiber blanket veneering)

As same calculation as Example 1), following table is the result.

Zone, area	Inside wall temperature (℃)	Outside wall temperature (℃)		Heat flux (kcal/m²·h)		Heat loss (kcal/t)	
		Present	Improved	Present	Improved	Present	Improved
Soaking zone	1,050						
Roof		139	117	1,860	1,350	7,680	5,770
Wall		133	119	1,220	980		
Heating zone	950						
Roof		104	88	1,730	1,250	5,750	4,330
Wall		104	92	1,130	900		
Preheating zone	750						
Roof		88	73	1,350	980	5,630	3,400
Wall		88	78	880	710		
Total						19,060	13,500
						5,560	

This reduction of energy consumption reduct fuel consumption,

Vf = (Qf - Qsh) / (Hl - Qgin + Qa + Qo)

dVf = dQf / (Hl - Qgin + Qa + Qo) = 5560 / (9463 - 2835 + 1158 + 29) = 0.71 kgFuel/t

Annex-3 Energy Saving by Replacing of Burner to Regenarative Burner System

(1) Summary

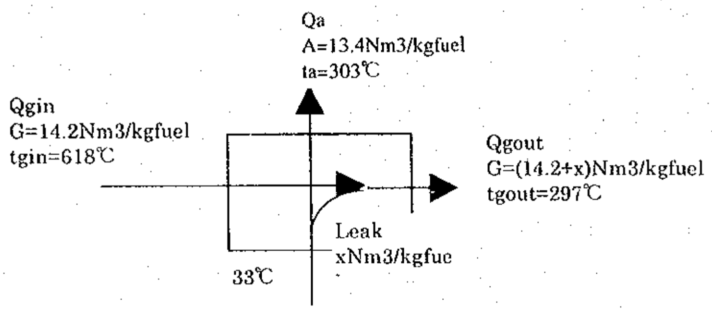
Considering ASM's fuel oil condition, waste gas temperature at outlet of regenerative burner shloud be 250℃. Thus the fuel consumption relating parameters will be;

Parameters			Unit	Present	Improved
Fuel consumption			kg Fuel/t-Bl	28.7	27.7
Combustion air temperature			℃	303	369
Presumption	Air/fuel ratio		-	1.25	1.25
	Fixed energy consumption (Qfix*[1])		kcal/kg-Fuel	237.7	237.7
	Recuperator/ H.R.system	Internal leakage	%	21	21
		Waste gas inlet temp.	℃	618	618
		Waste gas outlet temp.	℃	297	250

Qfix*[1]= (Heat content of extracted material) + (Heat content of scale) + (Heat loss from furnace body) + (Other heat loss).

(2) Calculation

1) Present recuperator



(a) Internal leakage

Based on the 5th shift data (Annex-1.), and presumable heat loss rate from recuperator casing of 2% of input heat, heat balance equation gives the following calculation;

[Input]

Waste gas input heat: Qgin = Gxcpgx(tgin-33) =14.2x0.342x(618-33) = 2,840 kcal/kgfuel

[output]

Heat loss from casing: Qcase = 2,840 x 0.02 = 57 kcal/kgfuel

Waste gas output heat: Qgout = Gxcpgx(tgout-33) =14.2x0.342x(297-33) = 1,282 kcal/kgfuel

Leakage air output heat: Qlout = x xcpax(tgout-33)= x x 0.32 x (297-33) = 84.4 x kcal/kgfuel

Combustion air output heat: Qa = Axcpax(ta - 33) = 13.4x0.32x(303-33) = 1,158 kcal/kgfuel

Fuel oil output heat: Qo = 1 × coil × (97 - 33) = 1 x 0.45 x (97 - 33) = 29 kcal/kgfuel

Total input = Total output; thus 2,840 = 57 + 1,282+ 84.4x + 1158 + 29 x= 3.7 Nm^3/kgfuel

Thus, internal leakage rate = 3.7/(13.4 + 3.7) = 21.6 %

(b) Confirmation of fuel consumption eqation: Vf = (Qfix - Qsh) /(Hl - Qgin + Qa + Qo)

Refering the figure and data in Annex-1, eqation; Total heat input = Total heat output modifies as follow:

Total heat output = (Heat content of extracted material) + (Heat content of scale) + (Heat loss from furnace body) + (Other heat loss)
+ Vf(Qa + Qo +Qrcr + Qgout + Ql)
= Qfix + Vf(Qa + Qo +Qrcr + Qgout + Ql)

Total heat input = Vf((Qa + Qo) + Hl) + Qsh

Then, Vf = (Qfix - Qsh) /(Hl - Qgin + Qa + Qo) (1)

Where

Qfix = (Heat content of extracted material) + (Heat content of scale) + (Heat loss from furnace body) + (Other heat loss)
= (171.7 + 3.0 + 19.1 + 43.9) x 10^3 = 237.7 x 10^3 kcal/t

Hl = 9,463 kcal/kgfuel

Qsh = (Heat of formation of scale) = 13,400 kcal/t

Qgin = (Waste gas heat content at recuperator inlet) = 2,835 kcal/kgfuel

Qgout = (Waste gas heat content at recuperator outlet) = 1,282 kcal/kgfuel

Qrcr = (Heat loss from recuperator casing) = 57 kcal/kgfuel

Ql = (Leaked air heat content at recuperator outlet) = 312 kcal/kgfuel

Qa = (Combustion air heat content at recuperator outlet) = 1,158kcal/kgfuel

Qo = (Fuel oil heat content at recuperator outlet) = 29 kcal/kgfuel

Confirmation;

Vf(actual value) = 28.7 kgfuel/ t

Substituting the actual value in the eqation (1)

Vf(calculated from eqation) = (237,700 - 13,400) / (Hl -Qgin + Qa + Qo)
= 224,300 / (9,463 - 2,835 + 1,158 + 29)
= 28.7kgfuel/t

2) Estimation of fuel consumption after regenerative burner

For the sulfuric acid corrosion prevenntion, waste gas outlet temperature shall be 250℃, and presumable internal leakage will be 21%, same as present.

Suppposing combustion air temperature = ta ℃,

(internal leakage air amount) = x =(14.2/(1-0.216)) x 0.216 = 3.7 Nm^3/kgfuel

(Waste gas heat content at recuperator outlet) = Qgout = (14.2 + 3.8) x 0.337 x (250-33)

= 1,309 kcal/kgfuel

(Combustion air heat content at recuperator outlet) = Qa = 13.4 x 0.32 x (ta - 33)

= 14.2 x 0.342 x (618 - 33) - Qgout - Qo - Qrcr = 1,446

∴ ta= 33 + (1446/(13.4 x 0.32)) = 370 ℃

Vf = (Qfix - Qsh) /(Hl - Qgin + Qa + Qo) = (224.3x10^3)/ (9,463 - 2,835 + 1,446+ 29)

= 27.7 kgfuel/t

Fuel oil saving rate = (Vf1 -Vf2) / Vf1 = 3.5%