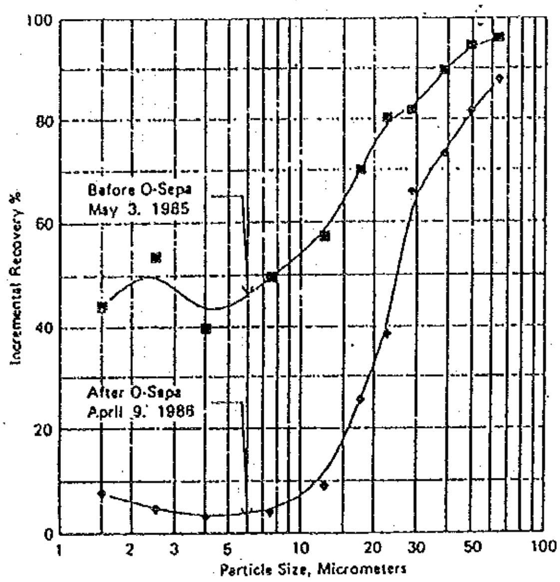
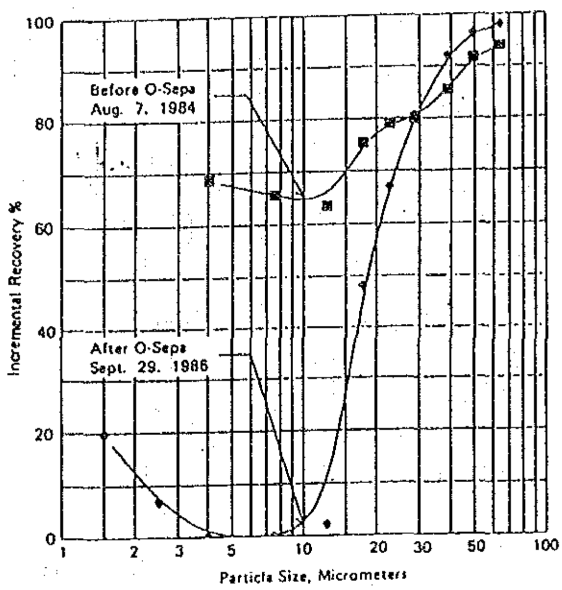


Cement

Before O-Sepa		After O-Sepa	
P70/P30	= N/A	P70/P30	= 1.79
P50	= 8u	P50	= 25u
ABP	= 44%	ABP	= 4%
E60u	= 96%	E60u	= 86%
WACL	= 3.15	WACL	= 0.67

Bild 5: Tromp-Kurven vor und nach Einsatz des O-Sepa-Sichters
Tromp curve before and after O-Sepa separator

Figure 5.4.29



Cement

Before O-Sepa		After O-Sepa	
P70/P30	= N/A	P70/P30	= 1.56
P50	= N/A	P50	= 18u
ABP	= 65%	ABP	= 0%
E60u	= 93%	E60o	= 98%
WACL	= 4.61	WACL	= 3.02

Bild 6: Tromp-Kurven vor und nach Einsatz des O-Sepa-Sichters
Tromp curve before und after O-Sepa separator

Figure 5.4.30

(5) Electrical equipment

A) Outline of electrical equipment of the factory

The distribution system diagram of the factory is shown in Figure 5.4.3. Two 120kV receiving lines are provided, but one line only is used for receiving and another line is kept as a reserve line at the present time. The receiving power is stepped down to 6.6kV with a 25MVA transformer at the receiving substation, for distribution to the plant. The bus is a 6kV dual bus of a very simple form as shown in the one line diagram. The power for large loads is supplied directly from the bus, and the power to other loads is supplied at 6kV or 400V from three substations (A, B and C).

The contracted power and power rates are shown in Table 5.4.12. However, it is anticipated that the power rates will be revised in 1992.

Table 5.4.12 Contracted power and power rates

Time		Contract kW	Demand Chg. Ft/kW/y	Energy Chg. Ft/kWh
Daytime	6:00-16:30 Oct. -Feb. 6:00-18:00 Mar. -Sep.	21,500 21,500	2,040 2,040	3 3
Peak Time	16:30-21:00 Oct. -Feb. 18:00-21:00 Mar. -Sep.	7,500 7,500	4,440 4,440	4.5 4.5
Nighttime	21:00- 6:00	23,000	1,020	1.5

Notes: 1. The time zone setup on holidays is same as above.
2. The contracted power is of 15-minute demand.
3. The power factor discount is indicated below.

Power Factor	0.91 ~	0.92 ~	0.94 ~	0.96 ~	0.98 ~ 1.00
Reduction %	1	2	3	4	5

The number of running ball mills is reduced as a peak cut measure.

Furthermore, as the countermeasures for improving the power factor, fixed condensers of 1,500kVA × 4 are provided along the 6kV bus of the receiving substation, and condensers of 500~600kVA are located at substations A, B and C to make automatic power factor adjustment to 1.000~1.600 kvar.

B) Situations of receiving power

The results of measurement between the evening of September 3 and the afternoon of September 4, 1991 are shown in Figure 5.4.31. A reduction of load from 17MW to 6MW is observed from 18:41 to 22:00, and it is considered that the load adjusting capacity is sufficient. It may be due to problems in the operation or due to the relation with the electric power company, but there are certain differences in time from the values in the period of 18:00 to 21:00, which is the peak time zone. The power factor is over 98% during the peak time zone, but is less than 98% in other time zones.

As it is scheduled that the power rate scheme will be changed this year, the load arrangement and power factor control should be reviewed when the new scheme becomes apparent. It should be considered to execute severer power control including expansion of condensers and employment of demand controllers if necessary.

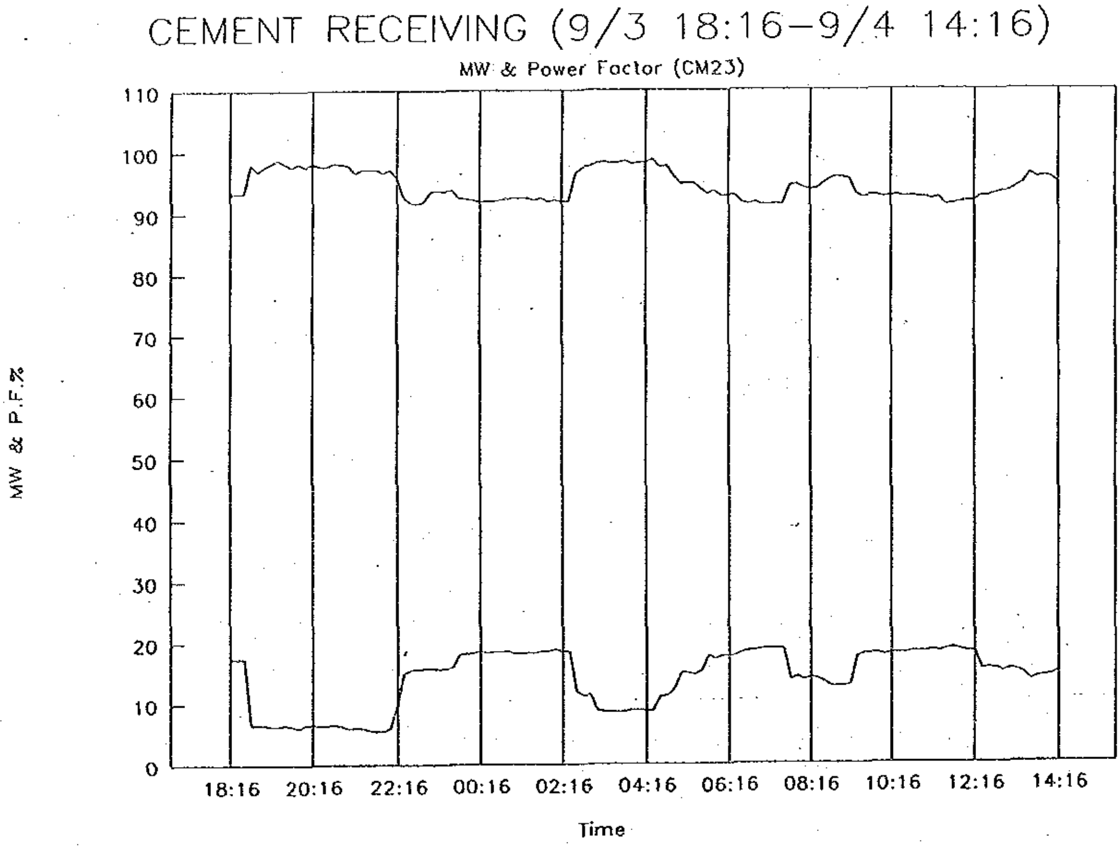


Figure 5.4.31 Situations of power receiving

C) Countermeasures for improvement and their effect

a. Air compressors for cement packers

The following three air compressor systems are provided.

① 2.5 bar silo bottom fluidizing layer system

② 4.5 bar packer plant system

③ 2.5 bar homogenizer system

Measurement was taken with system ② only because of such reasons that system ① is under the work for replacement with a new compressor and system ③ is of low operation rate. We were informed that replacement of the air compressor of system ② is also being planned.

The specifications for the compressors are shown in Table 5.4.13, and a rough system diagram of the packer plant system is shown in Figure 5.4.32.

Table 5.4.13 Specifications for compressors

No.	Type	Flow	Motor
5	Reciprocation	2,400 m^3/h	250 kW
6	Reciprocation	2,400 m^3/h	250 kW
7	Screw	1,500 m^3/h	200 kW

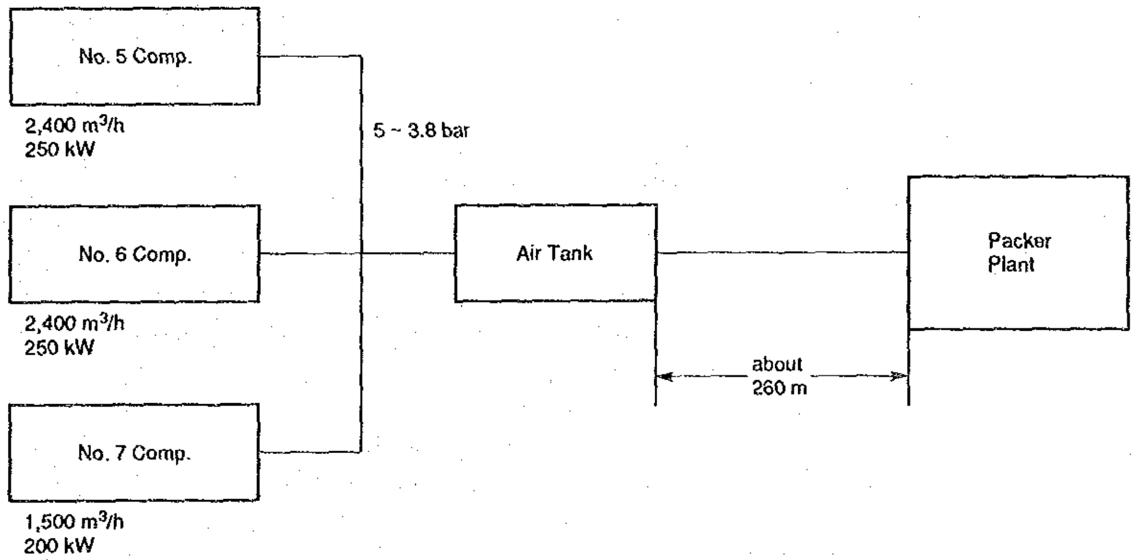


Figure 5.4.32 Compressed air system diagram of the packer plant system

The packer plant is located at a distance of about 260 m from the compressor room, and compressed air is supplied from No. 5, 6, 7 air compressors. The air compressors are manually controlled for the pressure range of 5~3.8 bar. No. 5 air compressor is used as the base machine and load variation is dealt with by No. 7 air compressor. If the supply capacity is still insufficient, No. 6 air compressor is run in addition.

The results of measurement of electric power taken on September 5 and 6, 1991 are shown in Figure 5.4.33. The pressure could not be measured because no pressure gauge mounting seat is available. But it is considered that the pressure is as indicated by the broken line shown in Figure 5.4.33 in outline as estimated from the fact that control is made in the range of 5~3.8 bar.

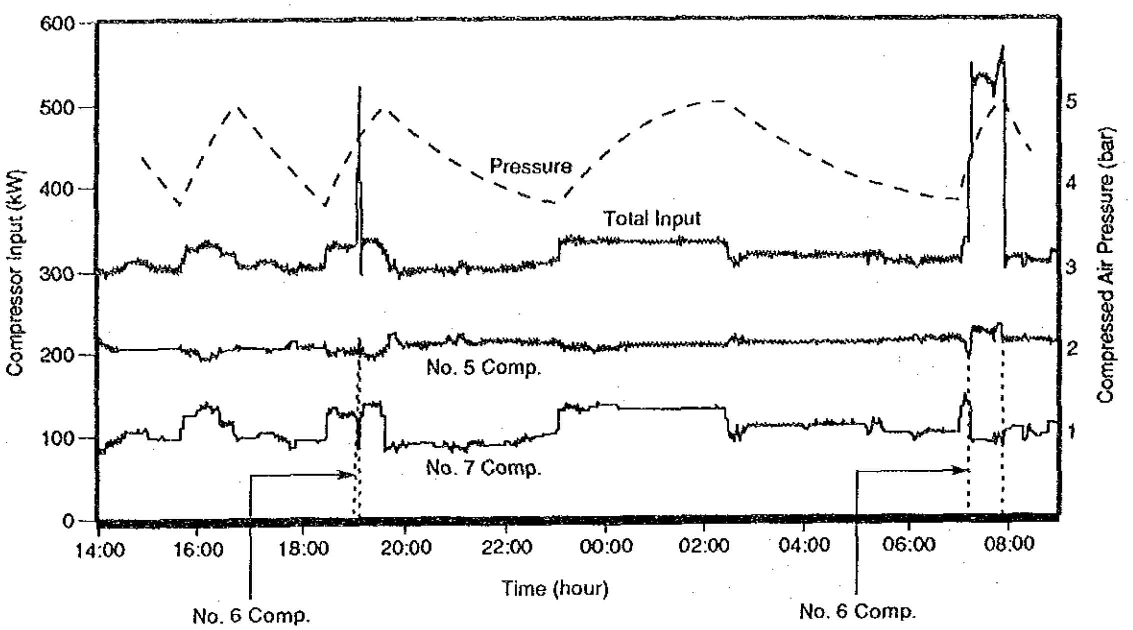


Figure 5.4.33 Results of measurement of electric power

The current pressure control range is 5~3.8 bar, and the difference is 1.2 bar, which is too large. It is considered that such a large difference is unavoidable because of use of manual control at the present time, but it is possible to reduce the control width to 0.2~0.3 bar when automatic delivery pressure control is implemented. The current mean pressure is 4.4 bar, but it will become 3.9 bar if the control range can be reduced to 4~3.8 bar. It is said in general that the required power can be reduced by 4% by lowering the delivery pressure by 1 bar. Since pressure drop by 0.5 bar can be expected in this case, electric energy saving by 2% can be anticipated.

As the mean power during measurement was 220kW with No. 5 machine, 102kW with No. 7 machine and 322kW in total, reduction of power by 6.4kW can be anticipated.

The annual savable electric energy and saving amount are as follows.

6.4 kW × 6,780 h/y = 43,400 kWh/y
43,400 kWh/y × 3 Ft/kWh = 130,200 Ft/y

It is necessary to examine the whole systems in the following sequence in order to implement energy saving with the air compressor equipment in the future.

① To review the minimum required pressure for the packer plant

Reduce the pressure of the air compressor system while checking the performance of the compressed air operated equipment, and check the minimum required pressure.

② To check for air leakage from the compressed air systems

Measure the air leakage rate and repair the leaking points. The leakage rate is not ignorable because air leaking noise is heard everywhere in the packer plant. (See the Guideline for the method for measurement of air leakage.)

③ To optimize the equipment capacity

As the required pressure and required delivery rate of compressed air are determined as a result of the operations of ① and ② above, determine the finally air compressor capacity, control method, air reservoir capacity, etc. with increase of the demand in the future and other factors taken into account.

④ To run compressors at high efficiency

The points of running at high efficiency are shortening of running time in unloaded state, prevention of excessive pressure and control at high efficiency (running of high efficiency machine with priority, selection of compressor of good unload characteristics at the time of partial load running).

b. Illumination

It was observed that mercury vapor lamps on the ceiling (400W × 40 lamps) and mercury vapor lamps mounted to machine tools are kept lit at around 16:00 when the outside was still bright at the maintenance workshop (about 30 m × 60 m) without attendance of anybody after termination of work for the day. It is recommended to make it a habit to put off unnecessary lamps by taking such measures that a person responsible to put out lamps, and the switches for lamps which may be opened by anybody when he notices are determined in advance and are so marked.

Furthermore, since this workshop has top light windows, even if it may be hard to put off the mercury vapor lamps for individual machine tools, it is considered possible to reduce the ceiling illumination to a major extent in the daytime. It is recommended that light reducing tests are conducted while listening to the opinions of workers and the optimum number of lamps is finally determined.

5.5 Results of investigation at a steel factory

5.5 Results of investigation at a steel factory

5.5.1 Outline of the factory

(1) Company name and factory name : Dunaferr Dunai Vasmü

(2) Category of business : Metallurgy, Iron & Steel

(3) Principal product name and production capacity

Principal products	:	Steel Plate Coil, Spiral Pipe, Bar
Production capacity	:	Hot Coil 1,500,000 t/y

(4) No. of employees : Entire combine : about 12,000
Steel department : about 6,000
Hot roll : about 900

(5) Location of factory : 2401 Dunaújváros Pf.110

(6) History of the factory

This is a steelmaking factory complex established in 1950 and located 50 km south of Budapest. It is the largest ironworks in the nation with two blast furnaces of 1,000 m^3 class, coke oven, hot strip mill, cold strip mill, power plant, etc.

It was operated by the government before, but was reorganized to a conglomerate having many private limit liability companies in each of metallurgy division, secondary and tertiary products division, service division and operations division in March, 1991. Delegation of authority was made to a major extent to each limited liability company to permit free activities. It is scheduled that these limited companies will be further reorganized to joint stock companies in the future.

The objective of investigation of this time is the reheating furnace in the hot strip mill of this factory.

The hot strip mill started its operation in 1960. With two reheating furnaces, coil box, roughing mill, 5-stand finishing mill and down coiler, this mill has a production capacity of 1.5 million t/y. The dimensions of the slabs treated here are 2.9 ~ 8.4 m in length, 950 ~ 1,530 mm in width and 240 mm in thickness. The produced coils are of thickness 1.8 ~ 12 mm, maximum weight 15 t.

Two reheating furnaces are of pusher type and the capacity is 170 t/h. But the actual production is limited to 120 ~ 160 t/h as restricted by the capacity of downstream processes. No. 2 furnace was modified to a major extent in 1988, and No. 1 furnace constructed in 1974 was also modified: the difference in the structure between them is small.

Waste heat boiler is provided besides recuperators, and steam is delivered to the factory steam system.

Furthermore, the heat of the furnace cooling water is used for heating hot water for heating. Slabs are conveyed at high temperature from the continuous casting equipment. But there are differences in the length of time before being charged into furnaces, and the hot charge rate is 40 ~ 50%.

(7) Investigation period September 9 - September 13, 1991

(8) Investigators

Mitsuo Iguchi	Leader
Teruo Nakagawa	Subleader, Measuring Engineer
Toshio Noda	Steelmaking Process Engineer
Toshio Onishi	Heat Control Engineer
Tetsuo Oshima	Heat Control Engineer
Kazuo Usui	Electrical Control Engineer

AEEF Member

Mr. János Becz	Team Leader
Mr. Ferenc Pardavi	Electrical Engineer
Mr. Kornél Jonás	Mechanical Engineer
Mr. Endre Slenker	Electrical & Measurement Engineer
Mr. József Stieber	Instrument Engineer

MVMT Member

Mr. Lajos Ropolyi	Mechanical Engineer
Mr. Gábor Mohácsi	

(9) Interviewees

Mr. Vilmos Réti	Technical Development Manager
Mr. Tibor Kodas	Manager
Mr. Péter Sándor	Chief Energy Engineer
Mr. János Bak	Energy Engineer
Mr. Lajos Nikl	Energy Engineer
Mr. András Gulyás	Assistant Manager
Mr. Sándor Alpech	Chief of Furnace
Mr. Tibor Polgar	Foreman

(10) Progress of hot strip production (Table 5.5.1)

Furnace		1986	1987	1988	1989	1990
No.1	t	0	40,165	565,250	491,868	474,572
No.2	t	807,179	747,631	301,567	520,220	528,425
Total	t	807,179	787,796	866,817	1,012,088	1,002,997

(11) Progress of energy consumption (Table 5.5.2)

Furnace		1986	1987	1988	1989	1990
No.1	TJ	0	106	1,397	1,379	1,190
No.2	TJ	1,919	1,865	602	1,187	1,284
Power	MWh	6,358	5,284	5,657	8,635	8,866

For 1990 (Table 5.5.3)

Furnace	Coke Oven Gas		Natural Gas		Total
	10^3 m^3	GJ	10^3 m^3	GJ	GJ
No.1	1,244	21,014	34,364	1,168,569	1,189,583
No.2	24,397	411,810	25,605	872,261	1,284,171

(12) Progress of energy unit consumption (Table 5.5.4)

Furnace		1986	1987	1988	1989	1990
No.1	MJ/t		2,639	2,471	2,803	2,507
No.2	MJ/t	2,377	2,494	1,996	2,282	2,430
Total	MJ/t	2,377	2,502	2,306	2,535	2,466
Power	kWh/t	7.9	6.7	6.5	8.5	8.8

(13) Operating hours (Table 5.5.5)

Furnace		1986	1987	1988	1989	1990
No.1	hr	0	507	6,785	7,693	6,377
No.2	hr	7,876	7,467	4,316	7,853	7,235

Reference operating hours for examination of countermeasures

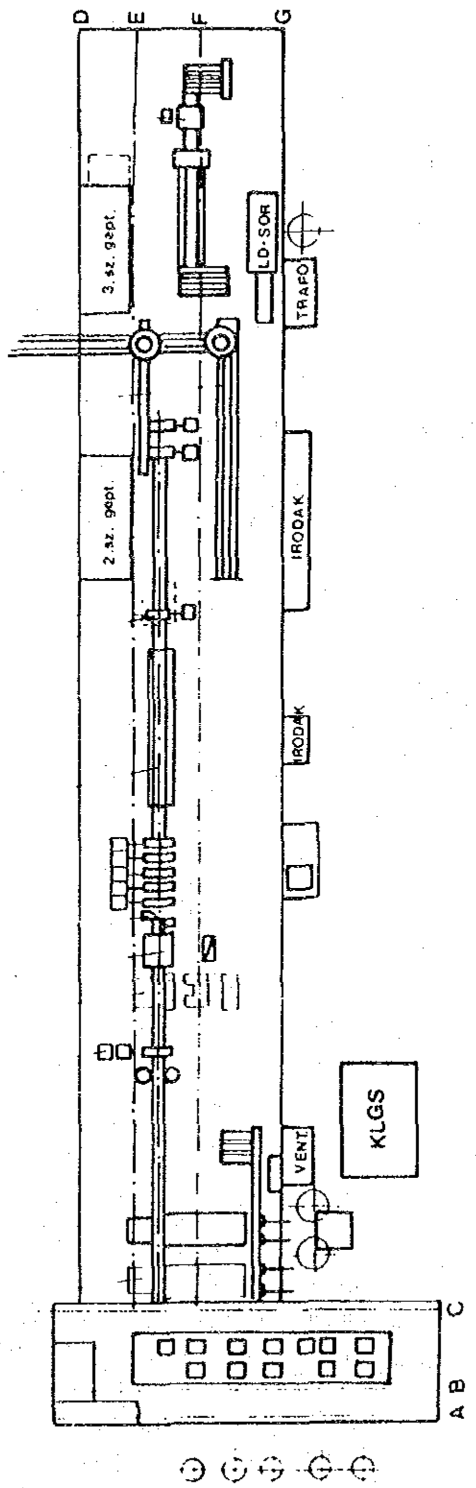
24 hours/day × 300 days/year = 7,200 hours/year

(14) Energy prices

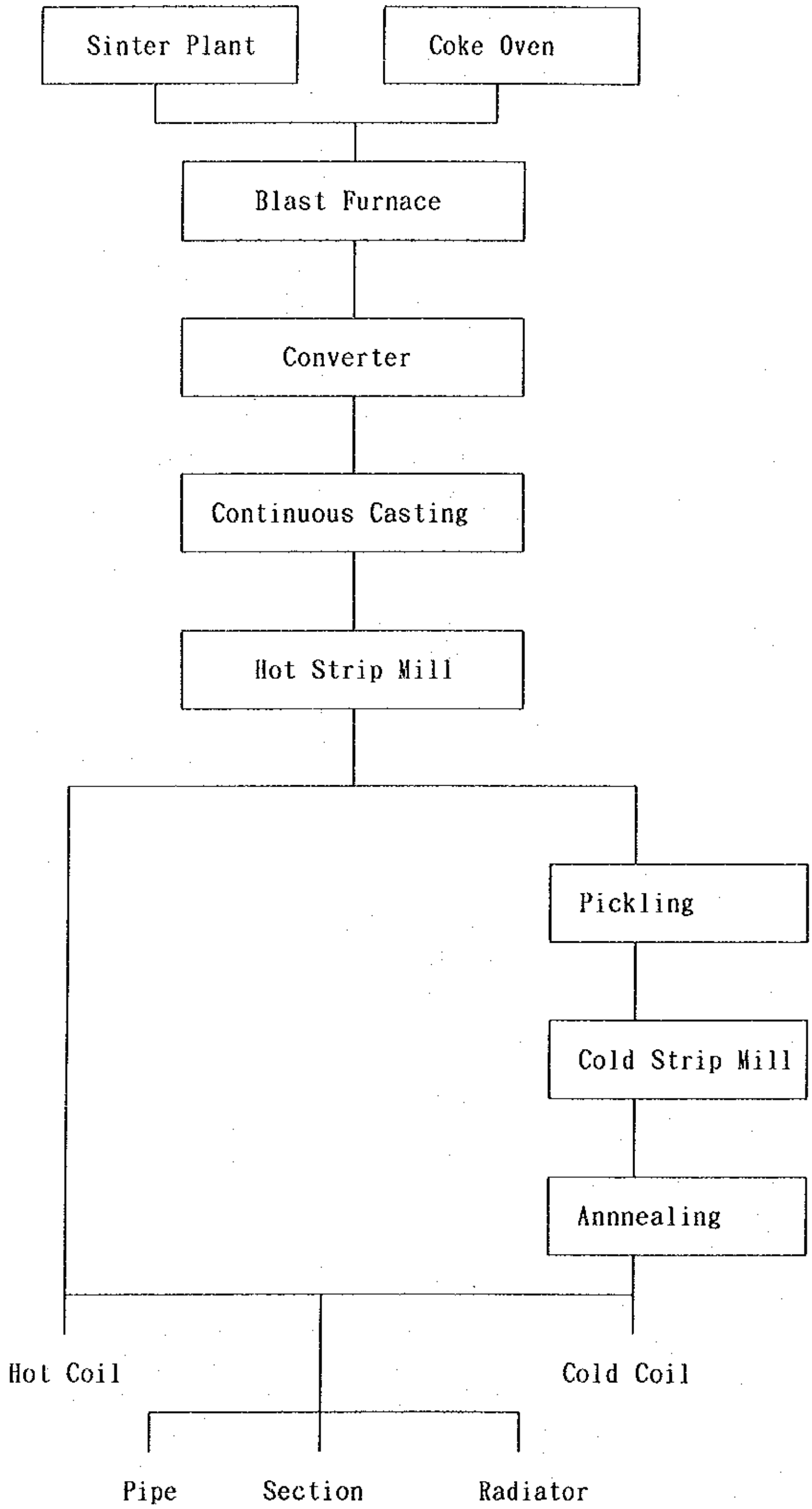
Natural Gas 10.8 Ft/Nm³

Electric Power 3.6 Ft/kWh

(15) Factory layout drawing (Figure 5.5.1)



(16) Manufacturing processes (Figure 5.5.2)



(17) Electric power one line diagram (Figure 5.5.3)

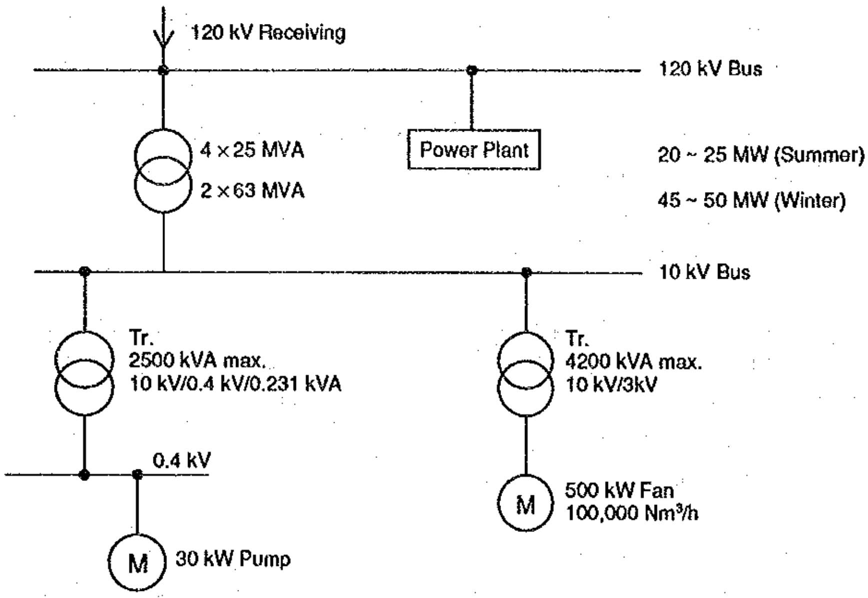


Figure 5.5.3

5.5.2 Situations of energy management

(1) Setting the target

To promote improvement such as cost reduction, quality enhancement and accident prevention besides energy saving which essentially require participation of employees, it is first necessary for the top management to decide the basic policy that these movements are important items for management of the business and that whole-company efforts are concentrated in these movements and to request all employees to provide cooperation for promotion of these movements. Evolution to whole-company movements will not occur unless the attitude of the management side is clearly shown to enthusiastically deal with energy saving.

Furthermore, it is necessary to indicate the target of achievement, achievement period, criteria of investment and so forth as concrete numeric values; and to break down the total target value to the target value of each process so that each employee can make efforts with a familiar theme.

Such a guideline as reduction of energy by 1% was indicated from the upper organ to this factory while it was operated by the government. But no clear policy has yet been established in the transient situations after reform of the business configuration which occurred in the spring of 1991. We were told that it was under examination. The economic situations are unstable and it is understood that the factory is in difficult situations. But it is requested that an energy conservation plan is incorporated and is promoted as a part of the long-term management program so as to be able to cope with the international competition based on the market principle.

(2) Systematic activities

Each one of principal processes has become an independent limited liability company and a conglomerate is constituted by these independent limited liability companies. In this scheme it is expected that each company has far larger authorities compared to the case where it is only a department of a big business and that more flexible and quick measures can be taken.

The operation of the hot rolling mill, on the other hand, is closely related to other departments such as upstream process, downstream process and energy department. In the same department, running of reheating furnaces is largely affected by running of the rolling process. Therefore, rational operation cannot be executed unless the tie with these relevant departments is smooth. It is considered that the headquarters of the conglomerate executes such coordination, but it is recommended that a cross-sectional committee organization that permits good understanding among processes regarding more practical and technical problems is established.

It is recommended that periodic meetings of each layer are organized in the hot rolling mill so that the intention of the superintendent is conveyed to the on-site employees and that problems occurring on the field are correctly delivered to the superintendent.

(3) Management by data

Recording of operation data of the factory is necessary for judgment of results and for assurance of the product quality. In addition, when such data are carefully analyzed, they provide information that become clues for locating problems and for improvement.

The fuel consumption of the reheating furnaces is recorded every hour and its evaluation is made at the end of the month at this factory. When abnormal consumption is indicated, troubleshooting is also conducted. The unit consumption by product type is also calculated. If the result values of these indices are informed to the operators on the field and meetings for examination of such values are held, it will be good to raise their interest in the energy conservation, and self-initiated energy conservation movements may result.

It is essential that periodic maintenance of various measuring instruments is implemented and that the operations are stabilized by automatic control, in order to upgrade the accuracy of data. These factors are also important for obtaining confidence of users through establishment of a solid quality assurance structure.

(4) Enlightenment of employees

It is essential to upgrade the capabilities of employees to uplift the general management level. This factory sends many staff members to the energy conservation conference of the iron and steel trade held once every two years, and holds factory's own seminar twice a year.

This factory also maintains close relation with the university. The factory staff join annual conferences held by the Fuel Technology Research Institute of the university and receive diagnosis and advice of professors.

The operators are also trained, and they are obliged to take an examination for qualification once every five years.

Thus, efforts are made for training of employees.

A scheme to invite proposals for improvement has also been established, and reward money is paid when a proposal is adopted. In addition, there is a scheme to pay bonus when the results of operation are improved, to motivate the employees. It is recommended that "rearrangement, readjustment and clean-up" movement is incorporated as a part of employee training because the situation of rearrangement, readjustment and clean-up of the workshop is the scale that indicates if work standards and instructions from superior officers are exhaustive or not, that is, a criterion of the management level.

(5) Management of equipment

As mentioned later, this reheating furnace is not so tightly sealed. Therefore, maintenance should always be performed after closing of these openings or modifications of doors, in order to prevent air intrusion or flame blow-out. Air leakage was observed in the exhaust gas side of the preheater, which must be also repaired at the time of furnace repair, since this will possibly lead to a decline in heat recovery rate and power loss of the exhaust fan. In addition, some thermometers presented inaccurate indications. Furnace internal temperature patterns constitute basic parameters controlling the reheating furnace. Therefore periodical calibration should be performed to obtain correct indications at every measurement.

5.5.3 Problems in the use of energy and countermeasures

5.5.3.1 Heat balance

(1) Outline of reheating furnace

Table 5.5.6 Specification of the furnace (1/3)

1	Plant name		Dunaferr Dunai Vasmü
2	Process name		Hot strip rolling
3	Furnace number		No. 2
4	Furnace type		Pusher type with 8 zones (upper: 5 zones, lower: 3 zones)
5	Charging slab	Material	Carbon steel
6		Size	240 th × 940 ~ 1,540 W × 2,900 ~ 4,250 L (2 row), × 6,900 ~ 8,500 L (1 row) [mm]
7		Weight	6,500 ~ 20,000 [kg]
8	Product		Hot plate coil
9	Manufacturer name		Stalprojekt (USSR)
10	Installation year		1974
11	Nominal capacity		170 [t/h]
12	Effective length & width		29.8 L × 9.28 W [m]
13	Nominal heating load		700 [kg/m²·h]
14	Kind of fuel & net calorific value		Coke oven gas; 19,050 [kJ/Nm³] or natural gas ; 36,006 [kJ/Nm³]

Table 5.5.6 Specification of the furnace (2/3)

15	Burner type capacity & numbers	Upper zone	Soaking	Roof type 80 [m³/h] × 26 (#5 Zone; 8, #4 Zone; 18)
16			Heating	Roof type 160 [m³/h] × 24
17			Preheating (2)	Roof type 160 [m³/h] × 24
18			Preheating (1)	Roof type 160 [m³/h] × 24
19		Lower zone	Soaking	Axial type 840 [m³/h] × 2
20			Heating	Axial type 840 [m³/h] × 5
21			Preheating	Axial type 840 [m³/h] × 5
22	Fan capacity			128 [mbar] × 100,000 [m³/h] × 500 [kW]
23	Recuperator	Type		Hanging U type
24		Heat transfer area		914 [m²] (air side)
25		Material		Cr-Mo
26	Skid pipe	Numbers		4
27		Size		140ϕ [mm]
28		Insulation		Castable insulator; 50 th[mm]
29	Cross pipe & riser	Numbers		Cross pipe; 8, Riser; 16
30		Size		140ϕ [mm]
31		Insulation		Cross pipe Castable insulator; 50 th[mm] Riser Insulating brick; 180 th[mm]
32	Improvement history			None

Table 5.5.6 Specification of the furnace (3/3)

33	Operating situation	Operating methods	3 shifts/day
34		Operating time	8 h/shift
35		Operating days	28 days/month 320 days/year
36	Furnace dimension		Shown in Figure 5.5.4
37	Instrumentation		Controller; Furnace temperature of 1 ~ 7 zone Recorder; Total gas flow rate Gas flow rate of 1 ~ 7 zone Air flow rate of 1 ~ 7 zone Cooling water flow rate Furnace temperature of 8 zones Waste gas temp. at recuperator Hot air temperature Cooling water temperature Furnace pressure, etc.,

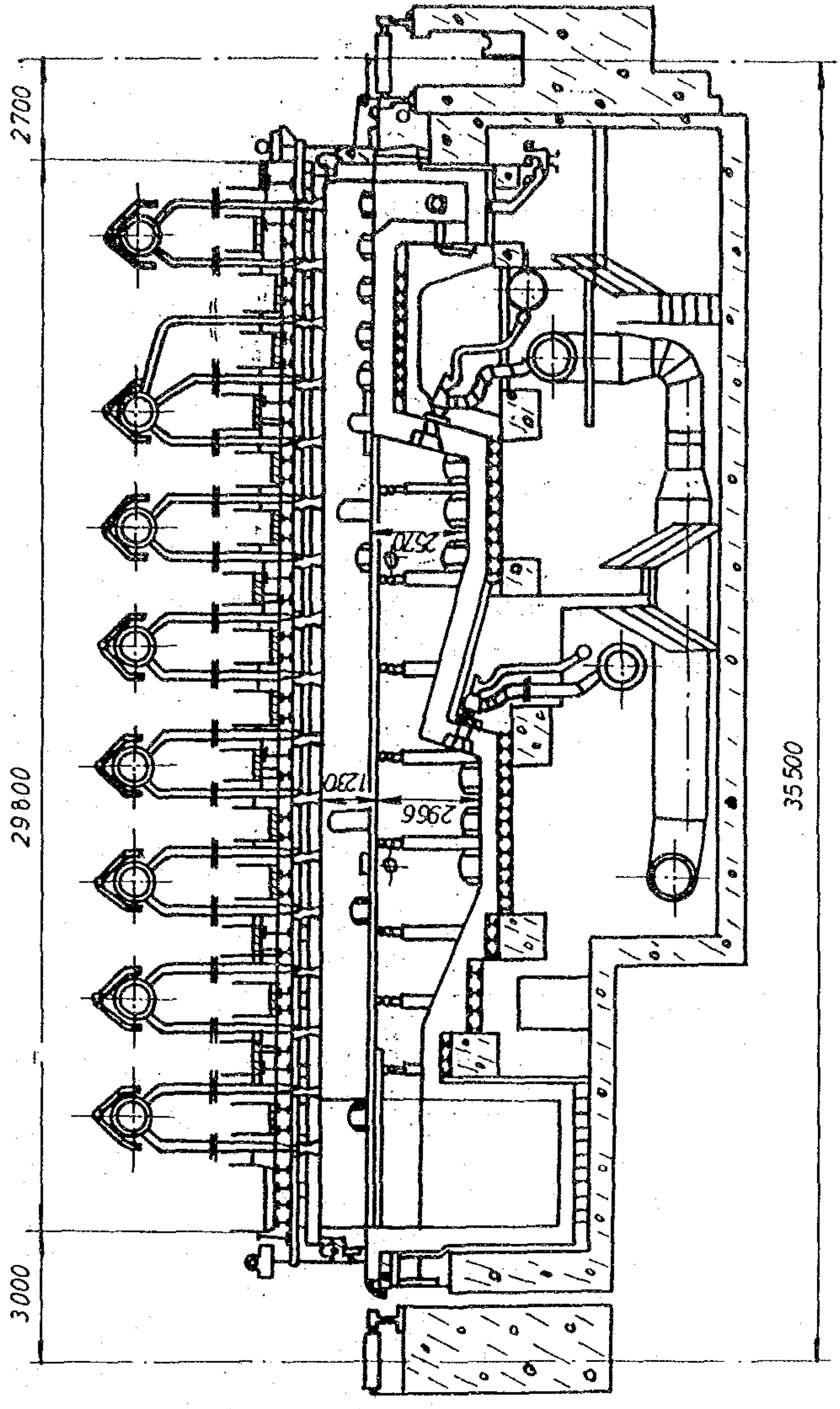


Figure 5.5.4 General view of furnace

(2) Results of measurement

The results of measurement taken with a reheating furnace including a recuperator are shown in Table 5.5.7. The values shown in ( ) are picked up from the data during operation similar to that at the measurng time because data could not be acquired due to circumstances of measuring instruments.

Table 5.5.7 Measuring data (1/3)

1	Measuring time			11 Sept. 1991, 2:15 a.m. ~ 4:35 a.m.	
2	Ambient temperature; 21 [°C]			Relative humidity; (40 [%])	
3	Fuel	Kind		Coke oven gas	
4		Flow rate & ratio	Upper zone	Soaking zone	795 [Nm³/h], 10.6[%] #5 Zone; 302 [Nm³/h] #4 Zone; 493 [Nm³/h]
5				Heating zone	219 [Nm³/h], 2.9 [%]
6				Preheating zone (2)	2,259 [Nm³/h], 30.0 [%]
7				Preheating zone (1)	0 [Nm³/h], 0 [%]
8			Lower zone	Soaking zone	487 [Nm³/h], 6.5 [%]
9				Heating zone	1,055 [Nm³/h], 14.0 [%]
10				Preheating zone	2,705 [Nm³/h], 36.0 [%]
11				Total	7,520 [Nm³/h] *2
12		Pressure		90 [mbar]	
13		Temperature		30 [°C]	
14		Composition		CO_2 2.6 [%], CO 8.2 [%], CH_4 24.7 [%], C_2H_4 2.6 [%], C_6H_6 0.6 [%], H_2 58.4 [%], O_2 0.6 [%], N_2 2.3[%]	
15		Net calorific value		19,078 [kJ/Nm³] *1	

Table 5.5.7 Measuring data (2/3)

16	2nd air	Flow rate	Upper zone	Soaking zone	4,095 [Nm³/h] #5 Zone; 1,510 [Nm³/h] #4 Zone; 2,585 [Nm³/h]
17				Heating zone	2,605 [Nm³/h]
18				Preheating zone (2)	9,680 [Nm³/h]
19				Preheating zone (1)	0 [Nm³/h]
20			Lower zone	Soaking zone	--- [Nm³/h]
21				Heating zone	6,200 [Nm³/h]
22				Preheating zone	14,355 [Nm³/h]
23		Pressure	Recuperator	Inlet	--- [mbar]
24				Outlet	--- [mbar]
25		Temperature	Recuperator	Inlet	21 [°C]
26				Outlet	(300 [°C])
27	Cooling water	Flow rate			444,010 [kg/h]
28		Temperature		Inlet	68.6 [°C]
29				Outlet	71.2 [°C]
30	Exhaust gas	Temperature		Before recuperator	892 [°C]
31				After recuperator	375 [°C]
32		Pressure		Before recuperator	(–0.15[mbar])
33				After recuperator	(–0.46[mbar])
34		Composition		Soaking zone	(O_2; 3.3[%])
35				Before recuperator	CO_2 O_2 (8.1 [%] 4.2 [%])
36				After recuperator	CO_2 O_2 4.5 [%] 11.1 [%]

Table 5.5.7 Measuring data (3/3)

37	Charged slab	Size		4.2 ~ 3.3 l[m] × 510 w[mm] x 240 th[mm]
38		Weight		7,885 ~ 13,490 [kg]
39		Total weight of charged slab		242.2 [t]
40		Temperature	Charge	21 [°C]
41			Discharge	(1,235[°C])
42		Decreased weight of slab by oxidization		--- [kg/t]
43	Furnace temp.	Upper zone	Soaking; #5. Zone	RIGHT 1,294 [°C] LEFT 1,264 [°C]
44			Soaking; #4. Zone	RIGHT 1,302 [°C] LEFT 1,274 [°C]
45			Heating;	RIGHT 1,272 [°C] LEFT 1,247 [°C]
46			Preheating (2)	RIGHT 1,197 [°C] LEFT 1,232 [°C]
47			Preheating (1)	RIGHT; 866 [°C]
48		Lower zone	Soaking	RIGHT; 1,228 [°C]
49			Heating	RIGHT 1,298 [°C] LEFT 1,302 [°C]
50			Preheating	RIGHT 1,241 [°C] LEFT 1,286 [°C]
51	Furnace pressure			0.25 [mbar]
52	Surface temperature of wall		Shown in Figure 5.5.5	

*1: This report adopts the condition of 0[°C] and 1.013[bar] as the standard state. But since the low calorific value of 18,083[kJ/m³] of the coke oven gas supplied by the Energy Limited Liability Company is 15[°C] and 1.013[bar], it was converted to the calorific value in the standard state using conversion factor k_1.

Conversion factor $k_1 = (273 + 15) / 273$
$= 1.055$

Low calorific value in standard state H [kJ/Nm³] = 18,083 × 1.055
= 19,078

*2: This value is the flow rate obtained by making correction to the gas main flow rate measured by the factory side using factor k_2 created based on the measured value (for accounting service) of the Energy Limited Liability Company and factor k_3 for conversion to the standard state.

Correction factor k_2 was obtained by an indirect method as shown below.

Period	Value measured by Energy Limited Liability Company	Integrated value on operation sheet
9/8, 22° ~ 9/9, 22°	159,000 [m³]	690
9/8, 22° ~ 9/9, 22°	123,000 [m³]	596
Total	(A) 282,000 [m³]	(B) 1,286

Period	Integrated value on operation sheet	Flow rate value measured by factory side
9/8, 22° ~ 9/9, 22°	(B') 201	(C) 39,119 [m³]

$K_2 = (A) / (B) \times (B') / (C)$
$= (282,000 / 1,286) \times (201 / 39,119)$
$= 1.127$

$K_3 = 273 / (273 + 15)$
$= 0.948$

The flow rate value measured by factory side during 2° 20' of the heat balance period was 16.432[m^3]. Therefore, fuel gas consumption after correction TV_g[Nm^3] is as follows.

$$TV_g = 16{,}432 \times 1.127 \times 0.948$$
$$= 17{,}550$$

Fuel gas consumption per hour V_g[Nm^3/h] is as follows.

$$V_g = (16{,}432 \times 1.127 \times 0.948) / 2\frac{1}{3}$$
$$= 7{,}520$$

Furthermore, since the fuel consumption in zone 8 was not measured, the difference between the consumption calculated from the flow rate record charts for other zones and V_g was determined as the consumption of zone 8.

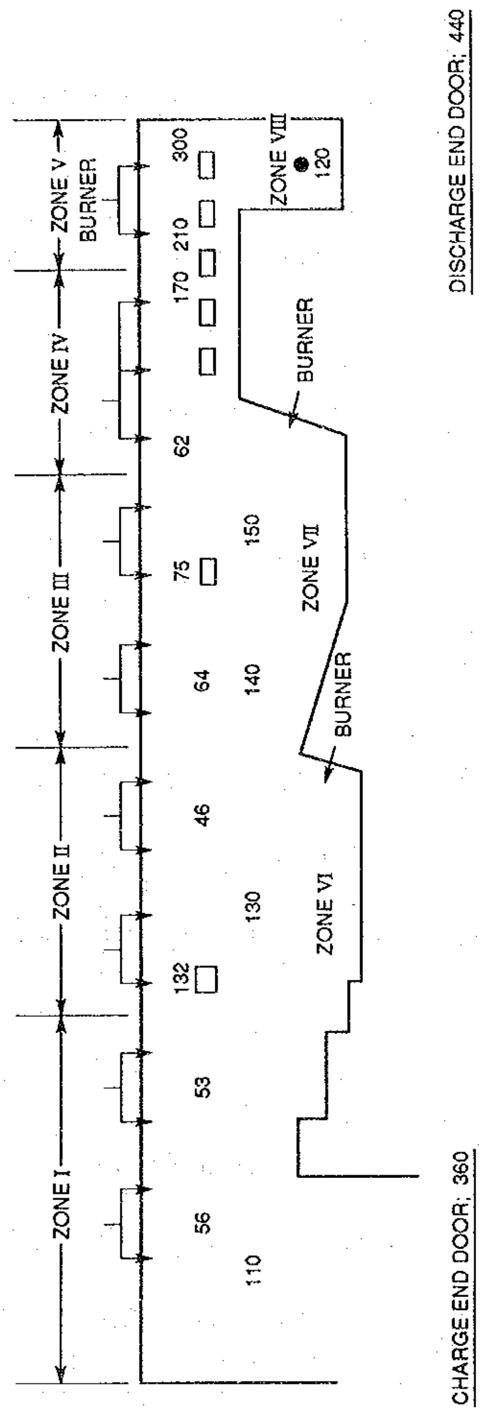


Figure 5.5.5 Surface temperature of wall

(3) Calculation of heat balance

Calculation of heat balance was made per ton of charged slab, and the ambient temperature was used as the reference temperature.

Calculation of heat balance was made for three cases, i.e., furnace proper including recuperator, furnace proper alone, and recuperator alone.

The cooling water heat exchanger and the waste heat boiler of the waste heat recovery equipment are excluded from the object of calculation of heat balance because their recovered heat is not used for the reheating furnace.

A) Advance calculation

a. Fuel consumption per ton of slab: F [Nm^3/t]

$$F = \text{Fuel consumption } [Nm^3] / \text{charged slab weight } [t] \quad (5\text{-}1)$$
$$= 17{,}550/242.2$$
$$= 72.46$$

b. Theoretical airflow: A_o [Nm^3/Nm^3 fuel]

$$A_o = 2.38 \times (H_2 + CO) - 4.76 \times O_2 + 9.52 \times CH_4 + 14.29 \times C_2H_4 + 35.80 \times C_6H_6 \quad (5\text{-}2)$$
$$= 2.38 \times (0.584 + 0.082) - 4.76 \times 0.006 + 9.52 \times 0.247 + 14.29 \times 0.026 + 35.80 \times 0.006$$
$$= 4.49$$

where;

H_2, CO, O_2, CH_4, C_2H_4, C_6H_6: Volume [Nm^3] of hydrogen, carbon monoxide, oxygene, methane, ethylene, benzene in coke oven gas of 1[Nm^3]

c. Theoretical dry exhaust gas flow rate: G [Nm^3/Nm^3 fuel]

$$G = CO_2 + N_2 + 1.88 \times H_2 + 2.88 \times CO + 8.52 \times CH_4 + 13.28 \times C_2H_4 + 34.30 \times C_6H_6 - 3.76 \times O_2 \quad (5\text{-}3)$$
$$= 0.026 + 0.023 + 1.88 \times 0.584 + 2.88 \times 0.082 + 8.52 \times 0.247 + 13.28 \times 0.026 + 34.30 \times 0.006 - 3.76 \times 0.006$$
$$= 4.02$$

d. Flow rate of water vapor produced as a result of combustion of fuel: W [Nm^3/Nm^3 fuel]

$$W = H_2 + 2 \times CH_4 + 2 \times C_2H_4 + 3 \times C_6H_6 \quad (5\text{-}4)$$
$$= 0.584 + 2 \times 0.247 + 2 \times 0.026 + 3 \times 0.006$$
$$= 1.15$$

e. Moisture content of the air: M [Nm^3/Nm^3 air]

$$M = 0.622 \times \phi \times P_s / (101.32 - \phi \times P_s) \times 29/18 \quad (5\text{-}5)$$
$$= 0.622 \times 0.4 \times 2.49 / (101.32 - 0.4 \times 2.49) \times 29/18$$
$$= 0.010$$

where;

ϕ : Relative humidity

P_s : Saturated steam pressure at atmospheric temperature [kPa]

f. Air ratio: m

① Before recuperator: m_1

$$m_1 = 1 / [1 - 3.76\{([O_2] - [O_0]) / ([N_2 \cdot D)\}] \quad (5\text{-}6)$$
$$= 1 / [1 - 3.76 \times \{(0.042 - 0) / (0.877 - 0.023 \times 0.183)\}]$$
$$= 1.22$$

where;

$[O_2]$,$[N_2]$: Oxygen and nitrogen content [Nm^3] in exhaust gas of $1Nm^3$

$[O_0]$: Theoretical oxygen flow rate [Nm^3] required for complete combustion of unburnt [CO] in exhaust gas of $1Nm^3$.
$[O_0] = 1/2[CO]$

N_2 : Nitrogen content [Nm^3] in fuel of $1Nm^3$

D : Fuel volume equivalent to exhaust gas of $1Nm^3$
$D = ([CO] + [CO_2]) / (CO + CO_2 + CH_4 + 2 \times C_2H_4 + 6 \times C_6H_6)$
$=0.183$

② After recuperator: m_2

$$m_2 = 1 / [1 - 3.76 \times \{(0.111 - 0) / (0.844 - 0.023 \times 0.102)\}$$
$$= 1.97$$

g. Dry exhaust gas volume per ton of steel [Nm^3/t]

① Before recuperator

$$F [Nm^3/t] \times \{G [Nm^3/Nm^3] + (m_1 - 1) A_0 [Nm^3/Nm^3]\} \quad (5\text{-}7)$$
$$= 72.46 \times \{4.02 + (1.22 - 1) \times 4.49\}$$
$$= 363$$

② After recuperator

$72.46 \times \{4.02 + (1.97 - 1) \times 4.49\}$
$= 607$

h. Water vapor volume in exhaust gas per ton of slab [Nm³/t]

① Before recuperator

$F[Nm^3/t] \times \{W[Nm^3/Nm^3] + m_1 \times A_0 \times M[Nm^3/Nm^3]\}$ (5-8)
$= 72.46 \times (1.15 + 1.22 \times 4.49 \times 0.010)$
$= 87$

② After recuperator

$72.46 \times (1.15 + 1.97 \times 4.49 \times 0.010)$
$= 90$

i. Cooling water volume per ton of slab [kg/t]

Cooling water flow rate [kg/h] ÷ slab charge rate [t/h] (5-9)
444,010 ÷ 103.8
= 4,278

j. Preheating air volume per ton of slab [Nm³/t]

$F\ [Nm^3/t] \times m_1 \times A_0\ [Nm^3/Nm^3]$ (5-10)
$= 72.46 \times 1.22 \times 4.49$
$= 397$

B) Calculation of heat balance

a. Calorific value of fuel

Fuel consumption per ton of slab [Nm³/t] × Calorific value [kJ/Nm³] (5-11)
= 72.46 × 19,078
= 1,382,392 [kJ/t]

b. Sensible heat of fuel

Fuel consumption per ton of slab [Nm³/t] × Mean specific heat of fuel [kJ/[Nm³·°C]
× (Fuel temperature [°C] – Ambient temperature [°C]) (5-12)
= 72.46 × 1.382 × (30 – 21)
= 901 [kJ/t]

where; Mean specific heat of fuel (coke oven gas): 1.382 [kJ/Nm³·°C]

c. Heat content of charged slab

1,000[kg] × (Heat content of slab at mean charge temperature [kJ/kg]
– Heat content of slab at ambient temperature [kJ/kg]) (5-13)
= 1,000 × (10.0 – 10.0)
= 0 [kJ/t]

where;
Heat content at charge temperature : 10.0 [kJ/kg]

Heat content at ambient temperature : 10.0 [kJ/kg]

d. Heat of formation of scale

Ignition loss Fe weight per ton of slab [kg/t] × 5,588 [kJ/kg·Fe] (5-14)
= 15 × 5,588
= 83,820 [kJ/t]

where;
Ignition loss : 15 [kg/t] (assumed)

Heat of formation of scale : 5,588 [kJ/kg·Fe]

e. Heat content of extracted slab

(1,000[kg] – Ignition loss Fe weight [kg/t]
× (Heat content of slab at mean extraction temperature [kJ/kg]
– Heat content of slab at ambient temperature [kJ/kg]) (5-15)
= (1,000 – 15) × (839.9 – 10.0)
= 817,452 [kJ/t]

where;
Heat content at extraction temperature : 839.9 [kJ/kg]

Heat content at ambient temperature : 10.0 [kJ/kg]

f. Sensible heat of scale

Ignition loss Fe weight per ton of slab [kg/t]
× 100 / T.Fe[%] × 0.900 [kJ/(kg·°C)]
× (Extraction surface temperature [°C] – Ambient temperature [°C]) (5-16)
= 15 × 100/75.5 × 0.900 × (1,235 – 21)
= 21,707 [kJ/t]

where;

Specific heat of scale: 0.900 [kJ/(kg·°C)

T.Fe of scale : 75.5 [%]

g. Sensible heat of dry exhaust gas before recuperator

Dry exhaust gas volume before recuperator per ton of slab [Nm^3/t]
× Mean specific heat of dry exhaust gas [kJ/(Nm^3·°C)]
× (Exhaust gas temperature [°C] – Ambient temperature [°C]) (5-17)
= 363 × 1.453 × (892 – 21)
= 459,339 [kJ/t]

where;

Mean specific heat of dry exhaust gas at exhaust gas temperature: 1.453 [kJ/(Nm^3·°C)]

h. Heat of water vapor in exhaust gas before recuperator

Water vapor volume in exhaust gas before recuperator per ton of slab [Nm^3/t]
× Mean specific heat of water vapor [kJ/(Nm^3·°C)]
× (Exhaust gas temperature [°C] – Ambient temperature [°C]) (5-18)
= 87 × 1.624 × (892 – 21)
= 123,062 [kJ/t]

where;

Mean specific heat of water vapor at exhaust gas temperature: 1.624 [kJ/(Nm^3·°C])

i. Heat taken away by dry exhaust gas after recuperator

Dry exhaust gas volume after recuperator per ton of slab [Nm^3/t]
× Mean specific heat of dry exhaust gas [kJ/(Nm^3·°C)]
× (Exhaust gas temperature at recuperator outlet [°C]
– Ambient temperature [°C]) (5-19)
= 607 × 1.390 × (375 – 21)
= 298,680 [kJ/t]

where;

Mean specific heat of dry exhaust gas at exhaust gas temperature: 1.390 [kJ/(Nm^3·°C]

j. Heat of water vapor in exhaust gas after recuperator

Water vapor volume in exhaust gas after recuperator per ton of slab [Nm^3/t]
× Mean specific heat of steam [$kJ/(Nm^3 \cdot °C)$]
× (Exhaust gas temperature [°C] – Ambient temperature [°C]) (5-20)
$= 90 \times 1.490 \times (375 - 21)$
= 47,471 [kJ/t]

where;
Mean specific heat of water vapor at exhaust gas temperature: 1.490 [$kJ/(Nm^3 \cdot °C)$]

k. Heat taken away by cooling water

Cooling water weight per ton of slab [kg/t] × (Temperature at outlet [°C]
– Temperature at inlet [°C]) × 4.187 [kJ/kg·°C] (5-21)
$= 4{,}278 \times (71.2 - 68.6) \times 4.187$
= 46,571 [kJ/t]

where;
Mean specific heat of water: 4.187 [kJ/kg·°C]

l. Heat recovered with recuperator (sensible heat of preheated air)

Preheated air volume per ton of slab [Nm^3/t]
× Mean specific heat of preheated air [$kJ/(Nm^3 \cdot °C)$]
× (Air temperature at recuperator outlet [°C]
– Air temperature at recuperator inlet [°C]) (5-22)
$= 397 \times 1.319 \times (300 - 21)$
= 146,096 [kJ/t]

where;
Mean specific heat of preheated air: 1.319 [$kJ/(Nm^3 \cdot °C)$]

(4) Heat balance sheet

The heat balance sheet of a reheating furnace including a recuperator is shown in Table 5.5.8. The heat balance sheet of a reheating furnace proper only is shown in Table 5.5.9, and the heat balance sheet of a recuperator only is shown in Table 5.5.10.

Table 5.5.8 Heat balance sheet of furnace with recuperator

HEAT INPUT			
Item		$\times 10^3$ kJ/t	%
1	Heat of fuel combustion	1,382.4	94.2
2	Sensible heat of fuel	0.9	0.1
3	Heat content of charged slab	0	0
4	Scale formation heat	83.8	5.7
5	Heat recovered by recuperator	(146.1)	(10.0)
Total		1,467.1	100.0
HEAT OUTPUT			
Item		$\times 10^3$ kJ/t	%
6	Heat content of extracted slab	817.4	55.7
7	Sensible heat of scale	21.7	1.5
8	Sensible heat of exhaust gas	346.2	23.6
9	Heat of cooling water	46.6	3.2
10	Heat loss from furnance wall and others	235.2	16.0
Total		1,467.1	100.0

Overall heat efficiency of furnace η_1

$$\eta_1 = [\{(6) - (3)\} / (\{(1) + (2) + (4)\}] \times 100 \quad (5\text{-}23)$$
$$= \{817.2 / (1{,}382.4 + 0.9 + 83.8)\} \times 100$$
$$= 55.7\ [\%]$$

Table 5.5.9 Heat balance sheet of furnace proper

HEAT INPUT			
Item		$\times 10^3$ kJ/t	%
1	Heat of fuel combustion	1,382.4	85.7
2	Sensible heat of fuel	0.9	trace
3	Sensible heat of air	146.1	9.0
4	Heat of content charged slab	0	0
5	Scale formation heat	83.8	5.2
Total		1,613.2	100.0
HEAT OUTPUT			
Item		$\times 10^3$ kJ/t	%
6	Heat content of extracted slab	817.4	50.7
7	Sensible heat of scale	21.7	1.3
8	Sensible heat of exhaust gas	582.5	36.1
9	Heat of cooling water	46.6	2.9
10	Heat loss from furnance wall and others	145.0	9.0
Total		1,613.2	100.0

Heat efficiency of furnace proper η_2

$$\eta_2 = [\{(6) - (4)\} / (\{(1) + (2) + (3) + (5)\}] \times 100 \quad (5\text{-}24)$$
$$= \{817.4 / (1{,}382.4 + 0.9 + 146.1 + 83.8)\} \times 100$$
$$= 50.7\ [\%]$$

Table 5.5.10 Heat balance sheet of recuperator

HEAT INPUT			
Item		$\times 10^3$ kJ/t	%
1	Sensible heat of inlet waste gas	582.5	100.0
Total		582.5	100.0
HEAT OUTPUT			
Item		$\times 10^3$ kJ/t	%
2	Sensible heat of outlet air	146.1	25.1
3	Sensible heat of outlet waste gas	346.2	59.4
4	Heat loss from body wall & others	90.2	15.5
	Total	582.5	100.0

Heat recovery by recuperator η_3

$$\eta_3 = \{(2) / (1)\} \times 100 \tag{5-25}$$
$$= (146.1 / 582.5) \times 100$$
$$= 25.1 \text{ [\%]}$$

Heat conversion efficiency of recuperator η_4

$$\eta_4 = [(2) / \{(1) - (3)\} \times 100 \tag{5-26}$$
$$= 146.1 / (582.5 - 346.2) \times 100$$
$$= 61.8 \text{ [\%]}$$

5.5.3.2 Problems, countermeasures and their effect

(1) Improvement of air ratio

The O_2 concentration of the exhaust gas before the recuperator is 4.2[%], and the air ratio calculated from the exhaust gas composition was 1.22. As the exhaust gas flow rate increases when the air ratio is large, the heat loss taken away by the exhaust gas increases naturally.

In the case of gas fuel, the optimum air ratio is 1.05 ~ 1.1 (1 ~ 1.9[%] in O_2 concentration) at the burner section and 1.1 ~ 1.15 (1.9 ~ 2.8[%] in O_2 concentration) at the furnace tail section. The following flow rate ratios are obtained when the air fuel ratio at the time when adjustment is made to air ratio 1.05 from the type and composition of the gas fuel is calculated.

Coke oven gas	Gas 1: Air 4.7
Natural gas	Gas 1: Air 9.5

The current air fuel ratio in each zone is shown in Table 5.5.11. Since all of the current values are far apart from the optimum values, it is requested that adjustment of the burner is made with the above indicated flow rate ratio as the criterion and that the result of adjustment is checked through analysis of the exhaust gas at the furnace tail.

Table 5.5.11 Measured air fuel ratio

Upper zone				Lower zone	
#5 zone	#4 zone	#3 zone	#2 zone	#7 zone	#6 zone
5	5.2	11.9	4.3	5.3	5.9

Beside drop in the exhaust gas flow rate, the exhaust temperature gas will drop because of uplift of the internal heat transfer effect as a result of rise of the flame temperature when the air ratio is improved. Therefore, the effect of reduction of the exhaust gas heat loss is large. The fuel consumption will drop by 14.6[%] when the air ratio of 1.22 observed at the time of measurement is improved to 1.05.

(2) Inspection and repair to recuperator and flue

The exhaust gas O_2 concentration before the recuperator was 4.2[%] and it was 11.1[%] at the recuperator outlet. Increase of the airflow by 25,300 [Nm^3/h] was observed between the inlet and outlet of the recuperator. Pursuit for the cause of such an increase could not be made in the stage of investigation. But that leakage of air due to damage to the heat transfer tube or entry of fresh air through the flue gaps caused by faulty sealing between the recuperator and the flue is considered responsible for this trouble.

At any rate, since it causes a drop in the exhaust gas temperature, the preheated air temperature becomes less, and it will cause a rise of fuel unit consumption. Furthermore, increase of the exhaust gas flow rate caused by mixing of the air makes the draft inferior because the pressure loss of the exhaust gas in the flue increases, and control of the internal pressure is adversely affected. It is recommended that the recuperator and the flue are inspected and faulty points are repaired urgently.

It is estimated that the preheated air temperature will rise by 53[°C] and energy saving of 2.9[%] will be attained as the effect when the air ratio of the recuperator is improved to 1.42 and the air leakage rate is reduced to 6,800 [Nm^3/h].

(3) Elimination of mixed charge of hot slabs and cold slabs

Hot slabs and cold slabs are charged as mixed because of the rolling program that attaches importance to the delivery time to users. It is one of factors that makes fuel unit consumption worse.

The slab temperature after the continuous casting process is 900 ~ 1,100[°C], and the effect to reduce the fuel unit consumption brought by hot charge that makes effective use of the sensible heat of these slabs is extremely large. But when reheating is made in the state where slabs of different temperature levels are mixed in the furnace, reheating is made with slabs of low temperature as the base, and accordingly, the merits of hot charge are gone. Therefore, efforts should be made so that cold slabs are charged gathering in as large a lot as possible and that hot slabs of similar temperature level are charged gathening in a lot or the hot slabs delivered from the continuous casting mill are directly charged.

In the case where hot slabs are placed at the slab yard temporarily under unavoidable circumstances, it is recommended that heat insulation boxes are installed to contain hot slabs to prevent temperature drop of the slabs. Heat insulation boxes are steel containers lined with a light weight heat insulator such as ceramic fibers of low thermal conductivity, and the tops are movable so as to permit bring-in/out of hot slabs.

It is also considered to be an effective method to make use of the idle soaking pit as a substitute for the heat insulation boxes.

Furthermore, it is recommended that the carriage time from the continuous casting mill to the rolling mill is shortened, and at the same time, slab temperature drop is minimized by making carriage with transport cars mounting slab boxes of heat insulation structure.

The unit consumption reduction effect obtained by hot charge is shown in Figure 5.5.6.

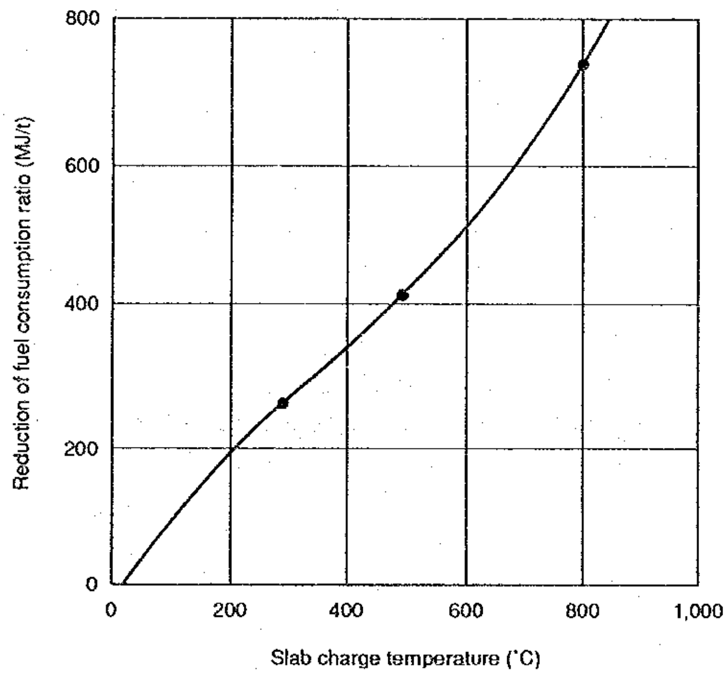


Figure 5.5.6 Effect of hot charge

(4) Repair to furnace walls and strengthening of heat insulation

Red heating of the casing of the upper heating zone was observed at a number of spots. It is due to damage to the furnace wall. There also were points in the ceiling through which the internal gas is blowing out.

Furthermore, water-cooled shielding plates (not water-cooled at the present time) are provided on the external side of a part of the heating zone and of the side wall of the preheating zone. They are extremely peculiar. They are probably provided for shielding the radiation heat from the high temperature side walls, but heat radiation from side walls occurs due to faulty insulation of the side wall structure.

It is recommended that the molten and dropped-off furnace walls are repaired at the time of furnace repair and that the furnace wall composition that effectively combines heat insulators of small thermal conductivity and thermal capacity is appleid as countermeasures against the problems stated above.

Typical calculation of heat loss and of accumulated heat at the time when various heat insulators are combined is shown in Table 5.5.12. As is apparent from this table, ceramic fibers provide superior heating time shortening and heat loss saving effect because they are of small accumulated heat besides being excellent in the heat insulation performance.

With existing furnaces, it is possible to reduce the heat loss to a major extent only by implementation of fiber veneering to adhere ceramic fibers to inside walls.

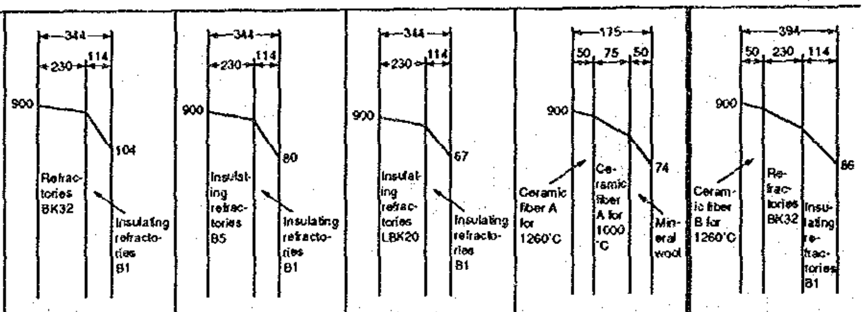
"Heat loss from furnace wall and others" shown in the heat balance sheet of furnace proper shown in Table 5.5.9 includes heat losses other than the heat loss from furnace wall and measuring errors. When it is regarded that the heat loss from furnace wall is one half of this figure and 20[%] or 1,503,900 [kJ/h] of the heat loss from furnace wall is reduced by strengthening the heat insulation, the fuel unit consumption decreases by 2.7 [%].

Table 5.5.12 Furnace wall composition and comparison of radiated heat and accumulated heat (extracted from paper of Japan Industrial Furnaces Association) (1/3)

● Furnace inside wall temperature: 900 [°C] Ambient temperature: 25°C, emissivity: 0.85

Furnace wall composition

Furnace wall thickness: 344 [mm]



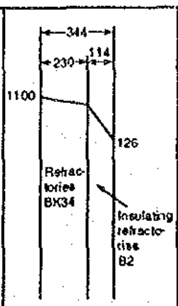
Radiated heat: Q		[kJ/m²h]	3,634	2,252	1,591	1,947	2,575
Accumulated heat:		[kJ/m²]	382,297	142,309	84,531	12,058	298,016
Continuous operation 6000 h/y	Radiated heat	[10³kJ/m²y]	21,805	13,515	9,546	11,681	15,449
	Ratio	[%]	100	61.8	56.6	63.6	72.6
* Batch operation 40 w/y	Total heat loss	[10³kJ/m²y]	31,100	15,419	10,304	8,951	23,124
	Ratio	[%]	100	53.6	44.5	29.1	88.4

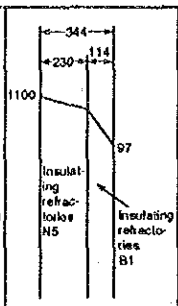
Table 5.5.12 Furnace wall composition and comparison of radiated heat and accumulated heat (extracted from paper of Japan Industrial Furnaces Association) (2/3)

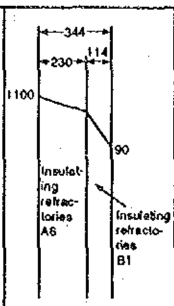
● Furnace inside wall temperature: 1100 [°C] Ambient temperature: 25°C, emissivity: 0.85

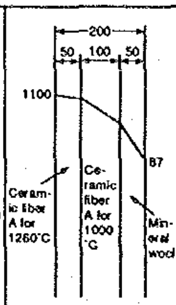
Furnace wall composition

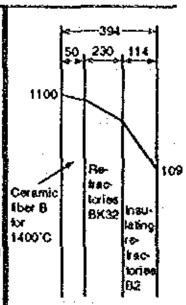
Furnace wall thickness: 344 [mm]









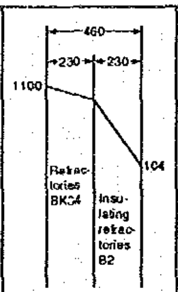


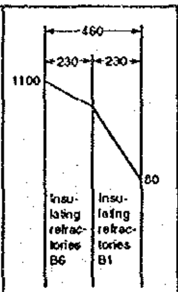
Radiated heat: Q	[kJ/m²h]	4,974	3,228	2,834	2,608	3,961
Accumulated heat:	[kJ/m²]	468,210	200,966	154,577	17,208	405,533
Continuous operation 6000 h/y	Radiated heat [10³kJ/m²y]	29,844	19,368	17,007	15,650	23,764
	Ratio [%]	100	64.9	57.0	52.4	79.6
* Batch operation 40 w/y	Total heat loss [10³kJ/m²y]	40,365	22,081	18,514	12,037	33,327
	Ratio [%]	100	54.7	45.9	29.8	82.4

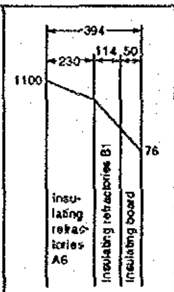
● Furnace inside wall temperature: 1100 [°C] Ambient temperature: 25°C, emissivity: 0.85

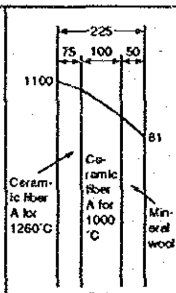
Furnace wall composition

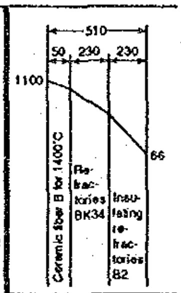
Furnace wall thickness: 460 [mm]







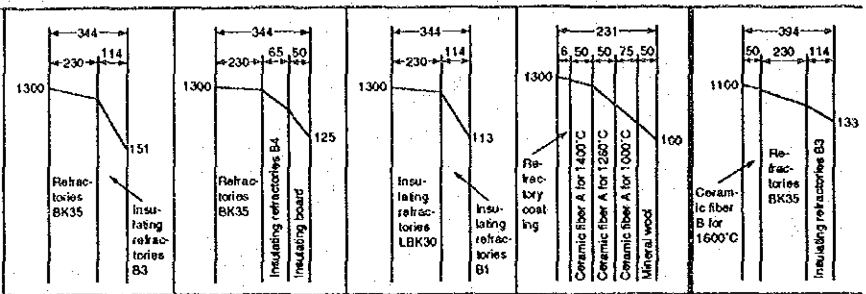




Radiated heat: Q	[kJ/m²h]	3,605	2,227	2,309	2,294	2,617
Accumulated heat:	[kJ/m²]	533,314	253,469	190,290	19,636	487,595
Continuous operation 6000 h/y	Radiated heat [10³kJ/m²y]	21,629	13,364	12,234	13,766	15,700
	Ratio [%]	100	61.8	56.6	63.6	72.6
* Batch operation 40 w/y	Total heat loss [10³kJ/m²y]	37,015	19,829	16,483	10,768	30,886
	Ratio [%]	100	53.6	41.5	29.1	83.4

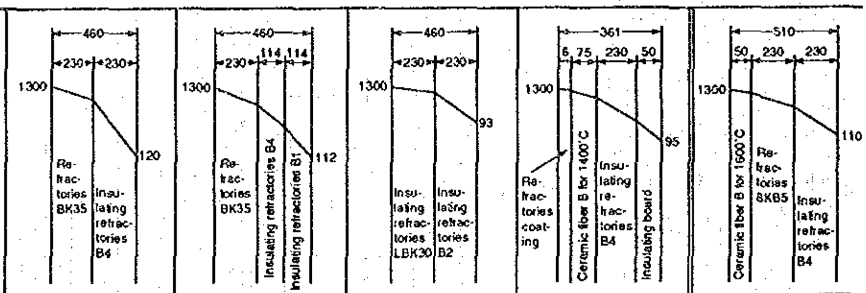
Table 5.5.12 *Furnace wall composition and comparison of radiated heat and accumulated heat (extracted from paper of Japan Industrial Furnaces Association) (3/3)*

● Furnace inside wall temperature: 1300 [°C] Ambient temperature: 25°C, emissivity: 0.85



Furnace wall composition Furnace wall thickness: 344 [mm]						
Radiated heat: Q	[kJ/m²h]	6,921	4,974	4,136	3,379	5,589
Accumulated heat:	[kJ/m²]	511,108	579,914	240,950	45,971	480,519
Continuous operation 6000 h/y	Radiated heat [10³kJ/m²y]	41,525	29,844	24,819	20,272	33,536
	Ratio [%]	100	71.9	59.8	48.8	80.8
* Batch operation 40 w/y	Total heat loss [10³kJ/m²y]	52,151	44,832	27,633	16,583	43,534
	Ratio [%]	100	86.0	53.0	31.7	83.5

● Furnace inside wall temperature: 1300 [°C] Ambient temperature: 25°C, emissivity: 0.85



Furnace wall composition Furnace wall thickness: 460 [mm]						
Radiated heat: Q	[kJ/m²h]	4,605	4,124	2,956	3,107	3,986
Accumulated heat:	[kJ/m²]	633,002	647,614	301,073	178,609	579,202
Continuous operation 6000 h/y	Radiated heat [10³kJ/m²y]	27,633	43,844	24,903	18,640	23,940
	Ratio [%]	100	89.5	64.2	67.5	86.6
* Batch operation 40 w/y	Total heat loss [10³kJ/m²y]	45,356	43,844	24,903	20,658	40,524
	Ratio [%]	100	96.7	54.9	45.5	89.4

(5) Prevention of flame blow-out through openings

Combustion gas of a considerable flow rate was blowing out of the opening for the monitor TV used for checking the locations of the slabs pushed out to zone 8. Besides, combustion gas was also blowing out of the opening for the extractor arm, charging door and side wall doors.

Such blow-out of combustion gas causes burn to furnace hardware and worsening of the workshop environment besides occurrence of heat loss.

Flames and combustion gas blow out of openings because the furnace internal pressure is higher than the atmospheric pressure. With the furnace internal pressure, the pressure at the opening bottom end level is usually kept at around 0.02 [mbar] that is slightly higher than the atmospheric pressure, in order to prevent cooling of the furnace interior by the fresh air that makes entry through the opening at the extraction end of the furnace.

In the case where the furnace internal temperature is 1,300[°C], the buoyancy produced by the combustion gas is about 0.10 [mbar] per meter of height. When the difference in height between the bottom end of the opening for the extractor arm and the furnace internal pressure detecting element is about 2 [m], therefore, the optimum furnace internal pressure is regarded as 0.22 [mbar]. The current furnace internal pressure at the top of the soaking zone side walls is 0.25 [mbar], and it is rather high. It is recommended, therefore, that the furnace internal pressure is reduced.

Blow-out of furnace internal gas is unavoidable with positive pressure operation. It is desirable, therefore, that countermeasures are taken including strengthening of sealing of side wall doors, examination of the size of the opening for the monitor TV, examination of provision of a door for the opening for the extractor arm and sealing of the gap between the charging door and the slabs.

For the opening for the extractor arm and for the charging door, the dual doors including a sub door shown in Figure 5.5.7 are effective. For the charging doors, such a simple method that iron strips of small widths or chains are suspended in a cascade form is also available, but it is considerably inferior to dual doors in the aspects of effect and service life.

The heat loss caused by blow-out of furnace internal gas from an opening can be calculated with the following equation.

$$Q = \alpha \times 44{,}670 \times \{273 / (273 + t)\}^{1/2} \times \Delta P^{1/2} \times A \times C \times (t - t_r) \quad (5.27)$$

where;

Q : Heat loss [kJ/h]

A : Area of the opening [m²]

C : Specific heat of furnace internal gas [kJ/(Nm³·°C)]

ΔP : Furnace internal pressure [mbar]

α : Coefficient by the form of the opening
0.5 when the thickness of the furnace wall is 0.5 ~ 2.5 times of the opening diameter

t : Blow-out gas temperature [°C]

t_r : Ambient temperature [°C]

When the area of 1.2 [m²] (assumed value) of the opening for the monitor TV in the soaking zone and of the opening for the extractor arm is reduced to one half and the furnace internal pressure at the measuring position is improved from 0.25 [mbar] to 0.22 [mbar], reduction of 227 [Nm³/h] in the coke oven gas and 3.0[°C] in the fuel unit consumption are achieved.

Here, the mean furnace internal pressure of an opening before and after improvement was assumed as 0.07 [mbar] and 0.11 [mbar].

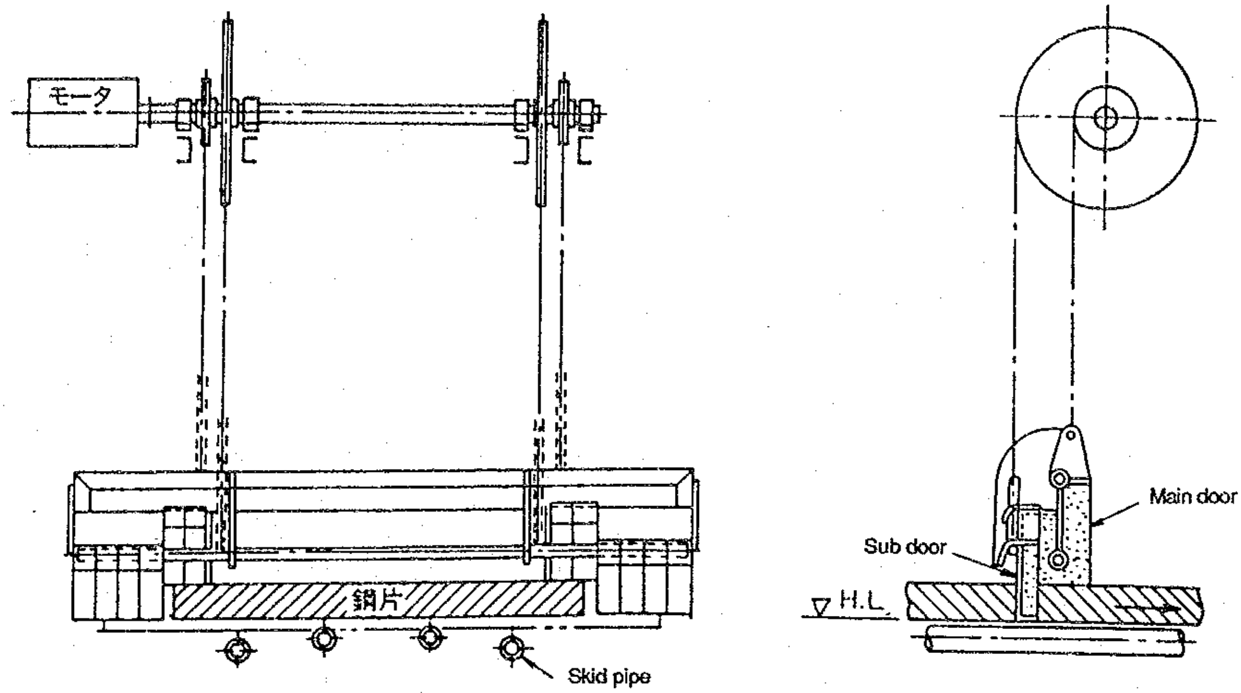


Figure 5.5.7 Furnace end door with sub-door

(6) Reduction of temperature deviation in the widthwise direction of the furnace

The furnace internal temperature is measured at two points in the widthwise direction of the furnace in each zone. But differences by 25 ~ 45[°C] were observed as shown in Figure 5.5.8. It is therefore recommended that efforts are made to eliminate differences in the temperature by readjusting the fuel flow rate distribution ratio to each individual burners.

However, temperature deviation also occurs due to deterioration of thermocouples and also when the insertion length of thermocouples into the furnace interior is different. Inspect the thermocouples before making readjustment of the burners.

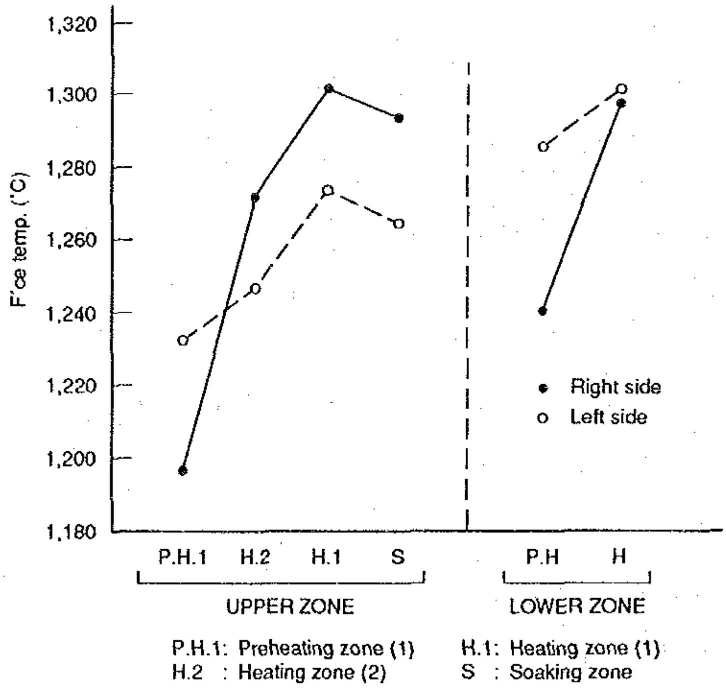


Figure 5.5.8 Furnace temp. deviation in width direction

(7) Provision of partition walls in the upper zone

The upper zone is sectioned to four zones, i.e., soaking zone, heating zone and two preheating zones. Substantially, however, it is of a box type one room structure without partitions between zones. It is therefore hard to maintain the desirable heat pattern in each zone due to the influence of the temperature in the adjacent zones.

It is recommended as a countermeasure against this problem that partition walls for making partition to three zones, i.e., soaking zone, heating zone and preheating zone, are provided at the positions which correspond to the sectioning of the lower zone.

Upkeep of the temperature in each zone will be stabilized as a result, and the desirable heat pattern can be produced. Furthermore, such a bi-effect that heat input to slabs increases is also obtained because the internal wall area, which exerts large effect over heat transfer in the furnace, increases as a result of provision of partition walls.

(8) Improvement of heat pattern

The current heat pattern and fuel distribution in each zone are shown in Figure 5.5.9. The pattern is extremely flat and fuel distribution is what lays emphasis in the preheating zone.

Such an operation is applicable to the case where high load heating of around 170 [t/h] (hearth load 700 [kg/(m^2·h)]) of design specification. In the case of light load where the mean heating rate at the time of heat balance is 103.8 [t/h] (hearth load 430 [kg/(m^2·h)]), optimum heat pattern and fuel distribution that correspond to the load should be adopted. If heating with emphasis laid on the preheating zone is made while the load is light, the gas temperature rises and the fuel unit consumption becomes inferior, and in addition, heating of slabs becomes unnecessarily quick and generation of scale is accelerated.

When the hearth load (heating rate) drops, the length of the slabs staying time in the furnace increases, and accordingly, slabs can be heated to the specified extraction temperature even if the heat input per slab surface area of 1 m^2 per hour is small. Therefore, the necessity of positive heating in the preheating zone is minor. Accordingly, as the hearth load decreases, reduction of the fuel gas flow rate in the preheating zone or review of the fuel distribution including suspension of combustion should be made. The exhaust gas temperature will drop and the heat loss will decrease as a result.

The plan for improvement of heat pattern and fuel distribution in each zone is obtained by implementing simulation of heat transfer in the furnace, heat transfer in the slab and of heat balance at each of many sections divided in the longitudinal direction of furnace based on the continuous measured data of upper surface, lower surface and internal temperature of a slab throughout the furnace. Since measurement of temperature rise with the slabs in the furnace was not conducted during the investigation of this time, the improved heat pattern is not indicated in this report, but a plan of fuel distribution in each zone that is closely related to it is shown in Table 5.5.13.

The basic line of thought for the plan for improvement of the fuel distribution in each zone is as follows.

① The total fuel flow rate to be applicable is reduced by 10[%] from the current level.

② The ratio of the total fuel flow rate used in the upper zone and the total fuel flow rate used in the lower zone is 45:55.

③ No fuel is used in the preheating zone (in either upper zone or lower zone) because heating is made with emphasis laid in the heating zone.

Furthermore, desirable optimum heat pattern accompanying changes in the heating load is shown in Figure 5.5.10.

Table 5.5.13 Improved fuel flow rate of zone

①; Present, ②; Improved

		Preheating zone		Heating zone	Soaking zone			
Upper zone		#1	#2	#3	#4	#5	Total	
		[Nm^3/h]	[Nm^3/h]	[Nm^3/h]	[Nm^3/h]	[Nm^3/h]	[Nm^3/h]	[%]
	①	0	2,259	219	493	302	3,273	43.5
	②	0	0	2,400	450	250	3,100	45.6
Lower zone		#6		#7	#8		Total	
		[Nm^3/h]		[Nm^3/h]	[Nm^3/h]		[Nm^3/h]	[%]
	①	2,705		1,055	487		4,247	56.5
	②	0		3,300	400		3,700	54.4

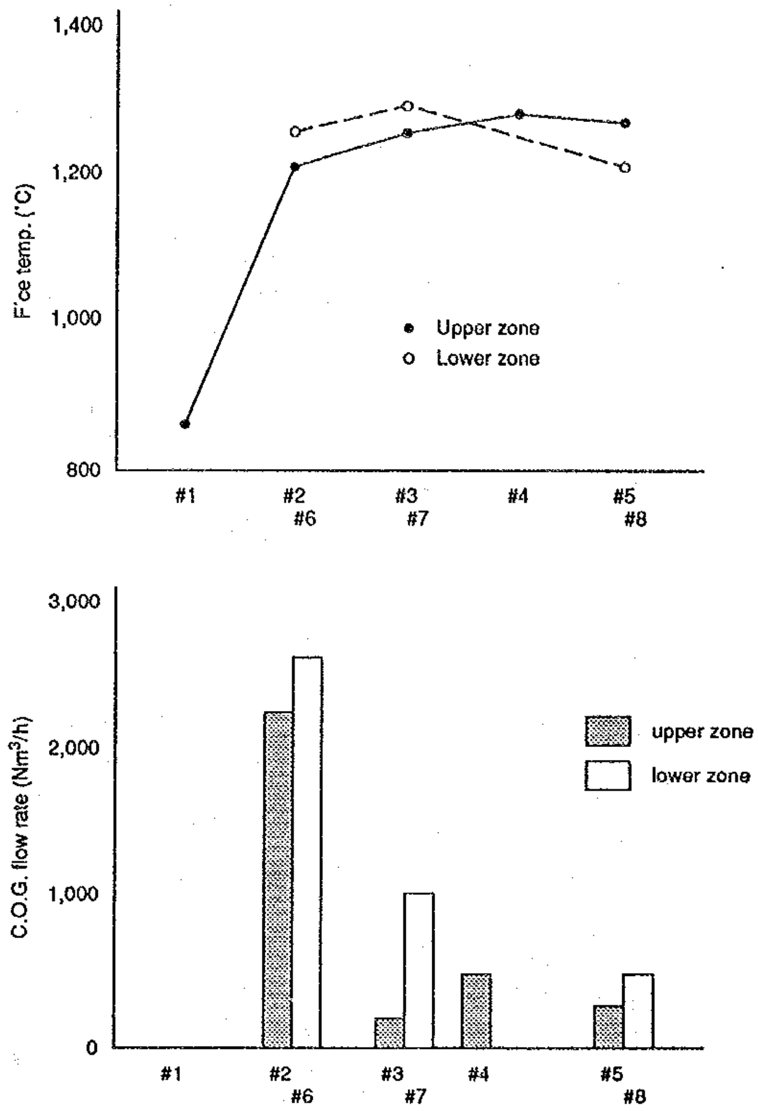
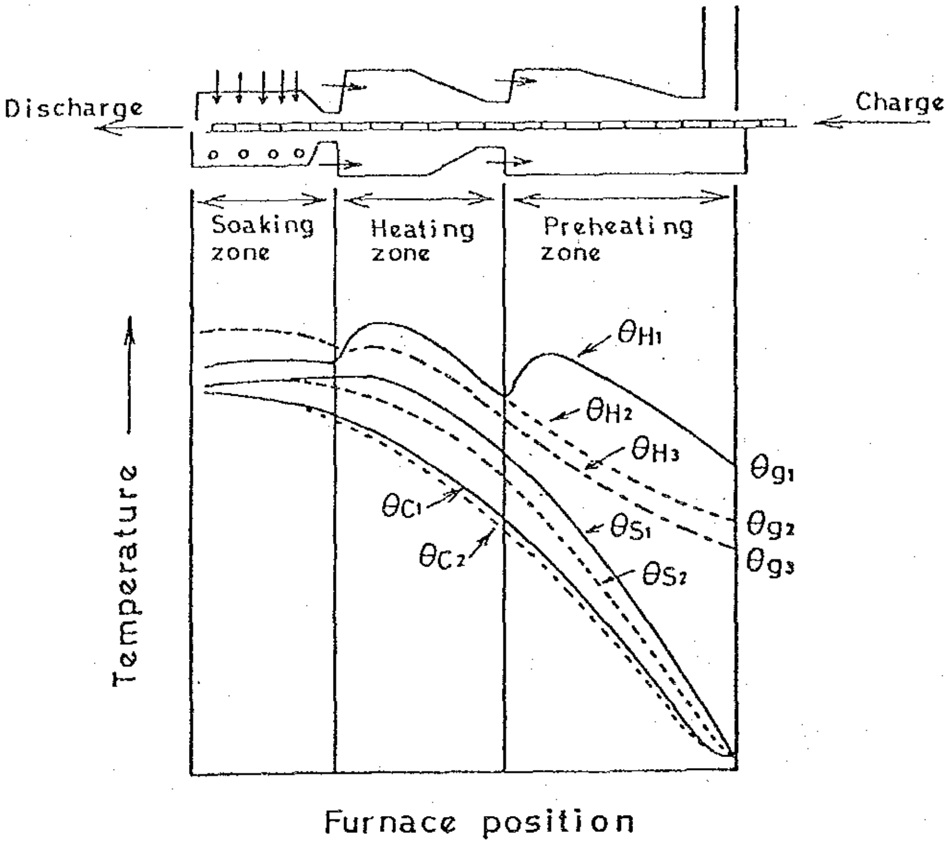


Figure 5.5.9 Actual heat pattern & present fuel rate ratio of each zone



θ_{H1} , θ_{H2} , θ_{H3} ; Heat pattern

θ_{S1} , θ_{S2} ; Slab surface temp.

θ_{C1} , θ_{C2} ; Slab center temp.

θ_{g1} , θ_{g2} , θ_{g3} ; Furnace tail waste gas temp.

1; Nominal Load

3; Light Load

Figure 5.5.10 Change in heat pattern at heating load

(9) Improvement of soaking zone

One portion (one half of zone 5 and the whole zone 8; hereinafter called extraction zone) of the soaking zone is the space for extraction of slabs with the extractor. The slab to be extracted stands by on the soaking hearth, and is extracted after being pushed out to the extraction zone. This extraction zone, therefore, is a section that is not related to slab heating. But since fuel is consumed by a considerable extent, it is recommended that an energy saving measure is examined.

The original objective of input of fuel to the extraction zone is to maintain the temperature in this space by compensating for the heat loss caused by skid cooling water, heat radiation from the furnace wall and blow-out of flames through gaps such as those of extraction door. In the extraction zone, 638 [Nm^3/h] (total of one half of 302 [Nm^3/h] consumed in zone 5 and 487 [Nm^3/h] consumed in zone 8), that is, fuel gas flow that is equivalent to about 8.5[%] of the total consumption, is consumed in this small space of 1.2 [m]. When this fuel use ratio is compared with the fact that the ratio of heat losses such as furnace cooling water and heat radiation from furnace surface is 12[%] of the fuel calorific value, it is learned that the fuel in the extraction zone is consumed to an extent that is higher than compensation for heat losses, which is the original objective. Of course a part of this heat makes contribution to soaking of the slabs on the soaking hearth, it cannot be said to be entirely wasted. But since it is against the rule to give necessary heat to the necessary point, it is requested that the excessive fuel in the extraction zone is reduced and the fuel reduced here should be used in the soaking zone.

The factory has a plan to extend the current soaking hearth to the extraction zone as Figure 5.5.11, to provide spaces of groove form at four places on the soaking hearth as spaces required for operation of the extractor arm and to install four axial flow burners in these spaces for reducing the skid mark on the bottom side of the slabs and for heating the fresh air that makes entry through the opening for the extractor arm. This plan can be highly evaluated from the aspects of effective use of the extraction zone and reduction of fuel consumption. But since it is anticipated that treatment of the scale that drops and accumulates in the narrow groove type spaces will become a problem, it is requested that sufficient examination is made in advance for solving this problem.

As an idea, let us propose a plan for improvement with minimum modification with the functions of the extraction zone remaining unchanged. The contents of the plan are, as shown in Figure 5.5.12, to provide a partition wall on the ceiling at the position that corresponds to the rear end of the soaking hearth and to reduce the space volume of zone 8. The objective of this partition wall is to facilitate control of the temperature in the extraction zone by partitioning the extraction zone from the soaking zone, to accelerate soaking of the slabs by inducing a flow of combustion gas to the slab surfaces on the exit side of the soaking zone and not to allow direct influence of the fresh air that makes entry at the time when the extraction door is opened. As for the space volume of zone 8, it is not considered that the current depth is required. It becomes possible to reduce the fuel gas flow rate when the depth is reduced to around 1 ~ 1.5 [m]. Furthermore, since current two burners 2×840 [m^3/h] are of excessive combustion capacity, better combustion can be maintained when the current burners are replaced with two burners of around 200 [m^3/h].

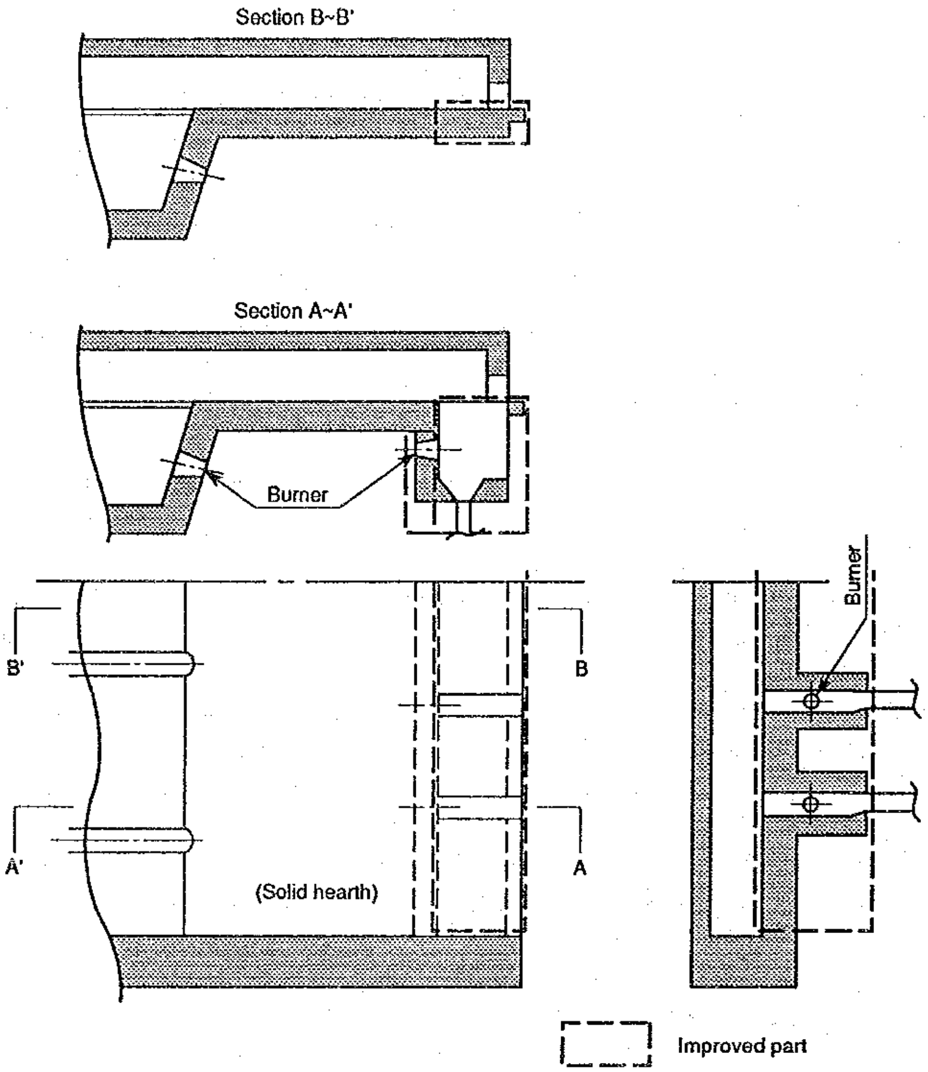


Figure 5.5.11 Improvement idea of 8-zone (factory proposal)

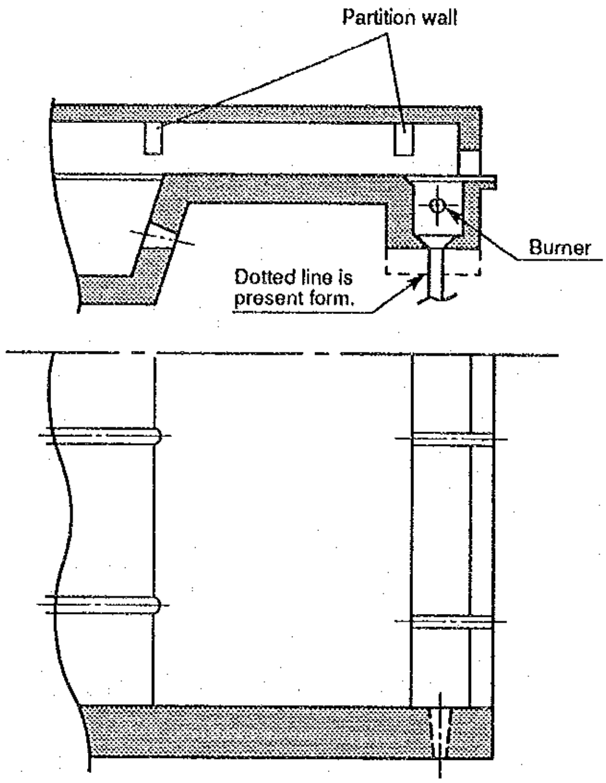


Figure 5.5.12 Improvement idea of 8-zone (study team proposal)

(10) Consolidation of instrumentation

Instruments which are considered necessary from the standpoint of operation management are provided, but controllers provided are limited to the furnace internal temperature controller using fuel gas flow rate control valve and airflow control valve as the final control elements, and no air fuel ratio control is made. In addition, it was explained that this controller is often operated manually because its control functions are inferior. It is considered to be because the size of each flow rate control valve is excessive and also because the setup of control actions (PID actions) is not suitable. It is recommended that review and examination of these points are suitably made.

It is usual that a reheating furnace of a capacity that is equivalent to the capacity of this furnace is equipped with controllers for furnace internal temperature, air fuel ratio and furnace internal pressure in order to secure the product reheating besides energy conservation, and air fuel ratio control by O_2 concentration [°C] of the combustion gas is also made. It is extremely hard to control furnace internal temperature, air fuel ratio and furnace internal pressure at the specified set values by manual operation only, and strengthening of control devices is essential.

Typical instrumentation is shown in Figure 5.5.13.

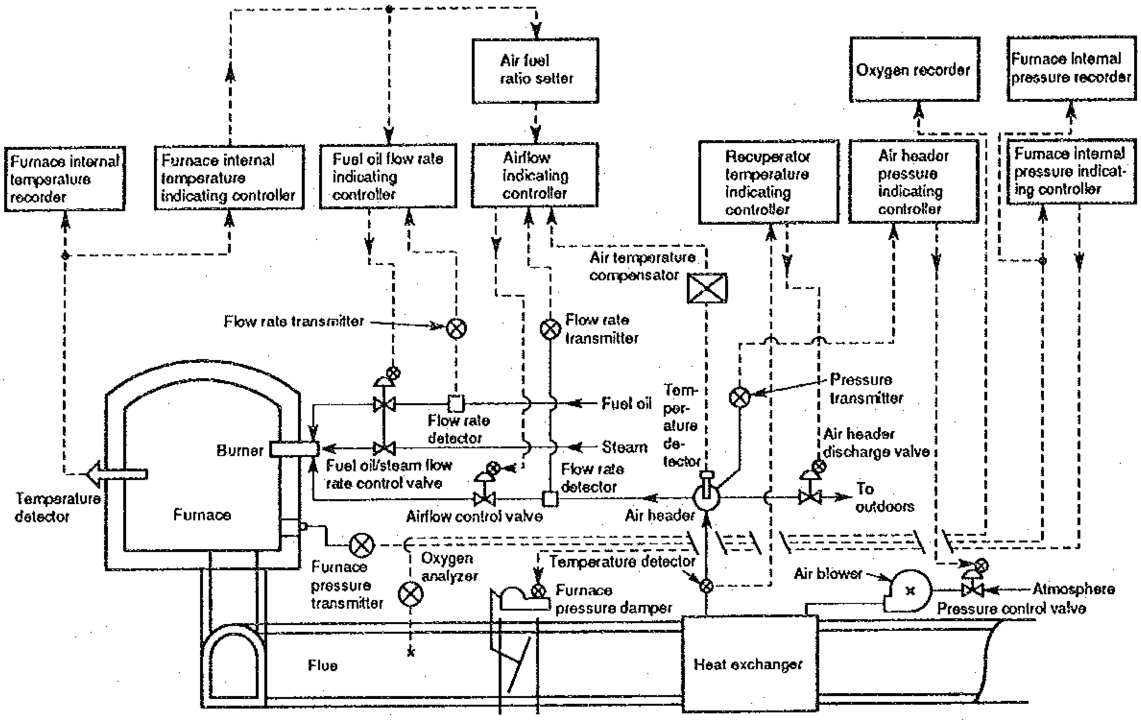


Figure 5.5.13 Typical Instrumentation of furnace

(11) Effect of improvement

A) Method for calculation of effect

A number of techniques are used for calculation of the effect at the time of implementation of energy saving measures. The outline of the technique used in this report is explained below.

a. The fuel flow rate V_F(Nm^3/h) required for heating is given by equation (5-28) from the heat balance of the furnace proper.

$$V_F = (Q_c \times W_c + L(1) + L(2)) / (H + UV_A \times T_A(3) \times C_A(3) - UV_G \times T_G(2) \times C_G(2)) \quad (5\text{-}28)$$

Q_C = (1 - Ignition loss Fe weight])
× ([Heat content of slab at extraction temperature]
– [Heat content of slab at charging temperature])
+ [Ignition loss Fe weight] × 100/75.5 × [Mean specific heat of scale]
× ([Extraction temperature] – [Charging temperature])
– [Ignition loss Fe weight] × [Scale formation heat]

$UV_A = m \times A_0$

$UV_G = G + (m - 1) \times A_0$ [Nm³/Nm³]

where;

V_F : Fuel flow rate [Nm^3/h]

Q_C : Heat input to slab [kJ/kg]

W_C : Heated slab weight [kg/h]

L(1) : Cooling water loss [kJ/h]

L(2) : Furnace heat radiation loss [kJ/h]

H : Fuel gas low calorific value [kJ/Nm^3]

UV_A : Airflow per unit fuel flow rate [Nm^3/Nm^3]

m : Air ratio

A_0 : Theoretical airflow per unit fuel flow rate [Nm^3/Nm^3]

$T_A(3)$: Before burner preheated air temperature [°C]

$C_A(3)$: Specific heat of before burner preheated air [$kJ/(Nm^3 \cdot °C)$]

UV_G : Exhaust gas flow rate per unit fuel flow rate [Nm^3/Nm^3]

G : Theoretical wet combustion gas flow rate per unit fuel flow rate [Nm^3/Nm^3]

$T_G(2)$: Furnace tail exhaust gas temperature [°C]

$C_G(2)$: Specific heat of furnace tail exhaust gas [$kJ/(Nm^3 \cdot °C)$]

b. The heat Q [kJ/h] the slabs, skid and furnace walls receive from the combustion gas in the furnace is given by equation (5-29).

The overall heat transfer coefficient from the combustion gas to the slabs, skid and furnace walls and the heat input areas of the slabs, skid and furnace walls are different. But slabs were selected as a representative for calculation to simply implement calculation of heat transfer. Therefore, ϕ is the apparent numeric value that corresponds to the representative area.

$$Q = \phi \times S(1) \times 4.88 [\{(T_GM + 273) / 100\}^4 - \{[T_CM + 273) / 100\}^4] \quad (5\text{-}29)$$
$$T_GM = \{T_G(1) + T_G(2)\} / 2$$

$$T_G(1) = \{H + UV_A \times T_A(3) \times C_A(3)\} / \{UV_G \times C_G(1)\} \quad (5\text{-}30)$$
$$T_CM = \{T_C(2) + T_C(1)\} / 2$$

where;

- Q : Heat received by slabs, skid and furnace walls from combustion gas in the furnace [kJ/h]
- ϕ : Overall heat transfer coefficient [kJ/(m²·°C·h)]
- $S(1)$: Slab surface area [m²]
- T_GM : Combustion gas mean temperature [°C]
- $T_G(1)$: High temperature combustion gas temperature [°C]; theoretical combustion gas temperature was adopted here.
- T_CM : Slab mean temperature
- $T_C(2)$: Slab extraction temperature [°C]
- $T_C(1)$: Slab charging temperature [°C]
- $C_G(1)$: Specific heat of combustion gas [kJ/(Nm³·°C)]

c. The exhaust gas temperature $T_G(3)$ [°C] at the recuperator inlet is determined by equation (5-31) that takes into account the temperature drop by air suction from the furnace charging opening and the flue heat radiation loss.

$$T_G(3) = (V_F \times UV_G \times T_G(2) \times C_G(2) + V_AL \times T_A(1) \times C_A(1) - L(3)) / ((V_F \times UV_G + V_AL) \times C_G(3)) \quad (5\text{-}31)$$

where;

- V_AL : Airflow entering through furnace charging opening [Nm³/h]
- $T_A(1)$: Ambient air temperature [°C]
- $C_A(1)$: Specific heat of fresh air [kJ/(Nm³·°C)]
- $L(3)$: Heat radiation loss between furnace tail and recuperator [kJ/h]
- $C_G(3)$: Specific heat of exhaust gas at recuperator inlet [kJ/(Nm³·°C)]

d. Also with the recuperator, the following equation establishes from heat balance and heat transfer rate.

$$V_F \times UV_G \times (T_G(3) - T_G(4)) \times C_G(3) = V_F \times UV_A \times (T_A(2) - T_A(1)) \times C_A(2) + L(4) \quad (5\text{-}32)$$

(Case of parallel flow)

$$V_F \times UV_A \times (T_A(2) - T_A(1)) \times C_A(2) = (\alpha \times S(2)) \times ((T_G(3) - T_A(1)) - (T_G(4) - T_A(2)) / LN((T_G(3) - T_A(1)) / (T_G(4) - T_A(2))) \quad (5\text{-}33)$$

(Case of counter flow)

$$V_F \times UV_A \times (T_A(2) - T_A(1)) \times C_A(2) = (\alpha \times S(2)) \times ((T_G(3) - T_A(1)) - (T_G(4) - T_A(1)) / LN((T_G(3) - T_A(2)) / (T_G(4) - T_A(1))) \quad (5\text{-}34)$$

Since the recuperator is of such a structure that fresh air enters from both ends of exhaust gas high temperature side and low temperature side of the recuperator and the preheated air makes outflows from the center, the following equation was adopted.

$$V_F \times UV_A \times (T_A(2) - T_A(1)) \times C_A(2) = (\alpha \times S(2)) \times 1/2\ ((T_G(3) + T_G(4)) - (T_A(2) + T_A(1))) \quad (5\text{-}35)$$

where;

α : Coefficient of overall heat transfer [kJ/(m²·h·°C)]

$S(2)$: Heat transfer area [m²]

$T_G(4)$: Exhaust gas temperature at recuperator outlet [°C]

$T_A(2)$: Air temperature at recuperator outlet [°C]

$C_A(2)$: Specific heat of air at recuperator outlet [kJ/(Nm³·°C)]

$L(4)$: Heat radiation loss of recuperator proper [kJ/h]

The flowchart for calculation of the anticipated effect of energy conservation measures using the equations indicated above is shown in Figure 5.5.14.

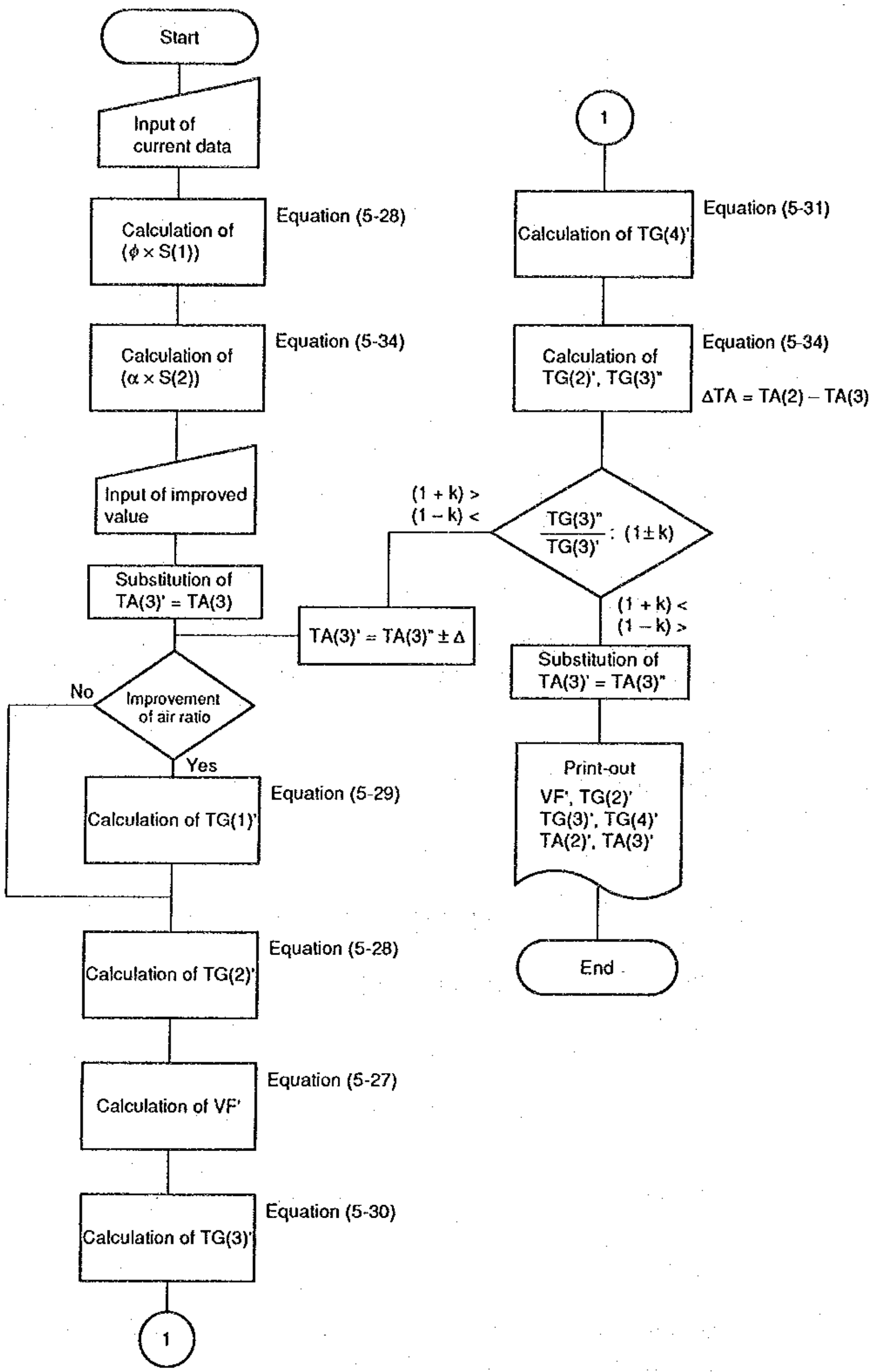


Figure 5.5.14 Flowchart of calculation

B) Estimation of energy conservation effect

The energy conservation effect of each improvement plan was stated in each item.

When all of the following measures which do not require large investment, energy conservation effect of 23.3[%] can be anticipated.

(1) Improvement of air ratio

(2) Inspection and repair of leakage to recuperator and flue

(4) Repair to furnace wall and strengthening of heat insulation of furnace wall

(5) Prevention of blow-out of flames through openings

This anticipated value is not equal to the sum of each individual value because of the multiplication effect exerted over the preheated air temperature, flame temperature and so forth.

The fuel consumption, etc. of items (1),(2),(4) and of {(1)+(2)+(4)+(5)} are shown in Table 5.5.14 as compared with current figures.

Table 5.5.14 Calculation result

Item	Present	Improve action			
		(1) Air ratio	(2) Recu.	(4) Insulate	(1)+(2) +(4)+(5)
Fuel consumption ratio [Nm^3/h]	7,520	6,419	7,302	7,318	5.769
Exhaust gas temperature before recuperator [°C]	892	654	862	868	585
Exhaust gas temperature after recuperator [°C]	375	275	600	467	367
Preheated air temperature [°C]	300	275	353	327	302
Fuel saving ratio [%]	—	14.6	2.9	2.7	23.3

(12) Electrical equipment

A) Outline of factory electrical equipment

The electric power one line diagram related to reheating furnaces drawn up based on what were told by concerned parties is shown in Figure 5.5.3. The electric power is received at 120kV and is supplied in parallel with the power generated by the private power plant of 42MW. Supply to the factory is made at 10kV. The principal electrical equipment related to reheating furnaces include combustion air forced draft fans and cooling water pumps. The electric power is supplied to the former with step-down made to 3kV and to the latter at 400V.

B) Combustion air forced draft fan for No. 2 reheating furnace

The combustion air is sucked with a fan. It flows through the cut-off damper and control damper, enters two recuperators in parallel, recovers heat from combustion exhaust gas, becomes hot air and is then supplied to each zone burner of the reheating furnaces. The specification of the fan and motor is shown in Table 5.5.15.

The results of measurement of the motor input taken in correspondence to the damper opening between September 10 and September 12, 1991 are shown in Figure 5.5.15 and Figure 5.5.16.

Table 5.5.15 Combustion Air Fan

Fan	Air Flow Pressure	100,000 1,300	Nm3 / h kp/m^2
Motor	Type Rated Power Rotation Number Voltage Frequency Pole	Squirrel-Cage Induction Motor 500 1,480 3 50 4	 kW r.p.m kV Hz
Coupling		Direct	

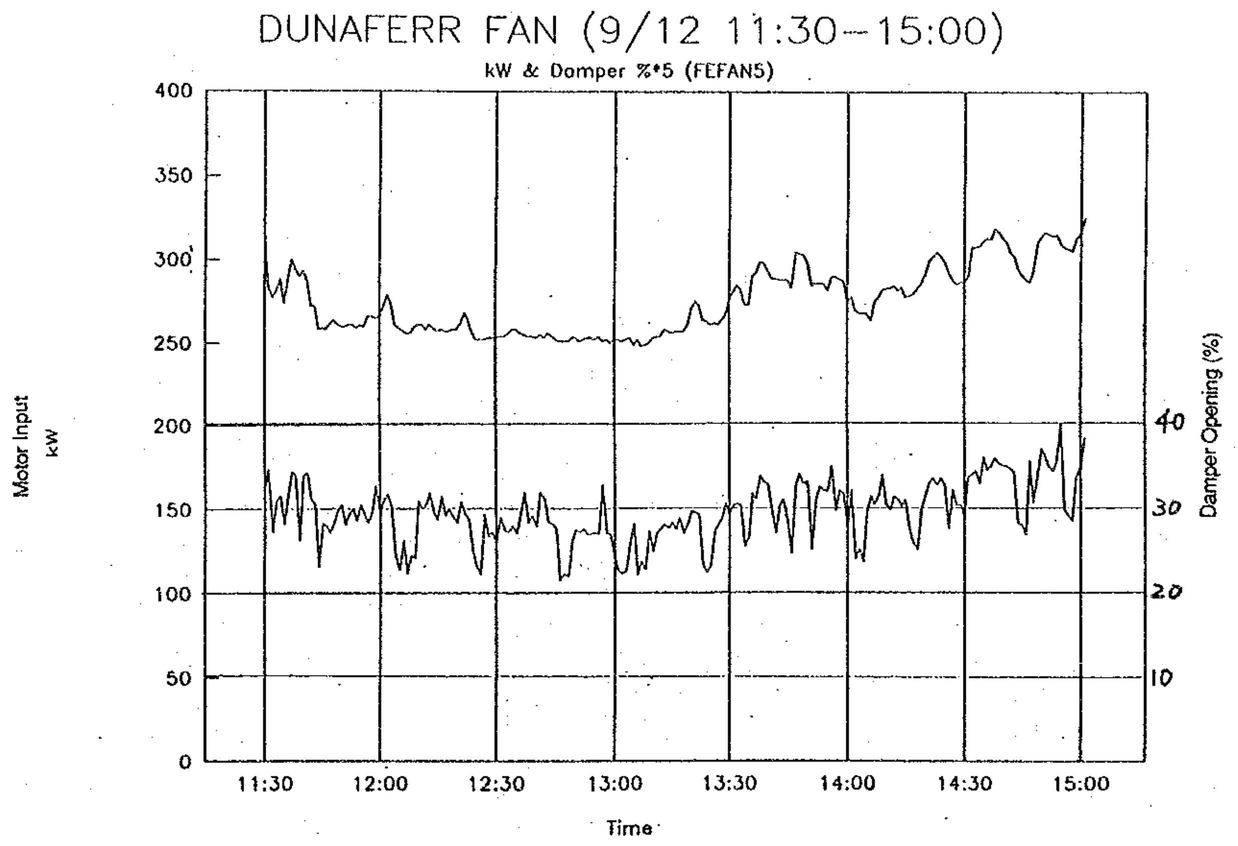


Figure 5.5.15 Air Fan Power Consumption

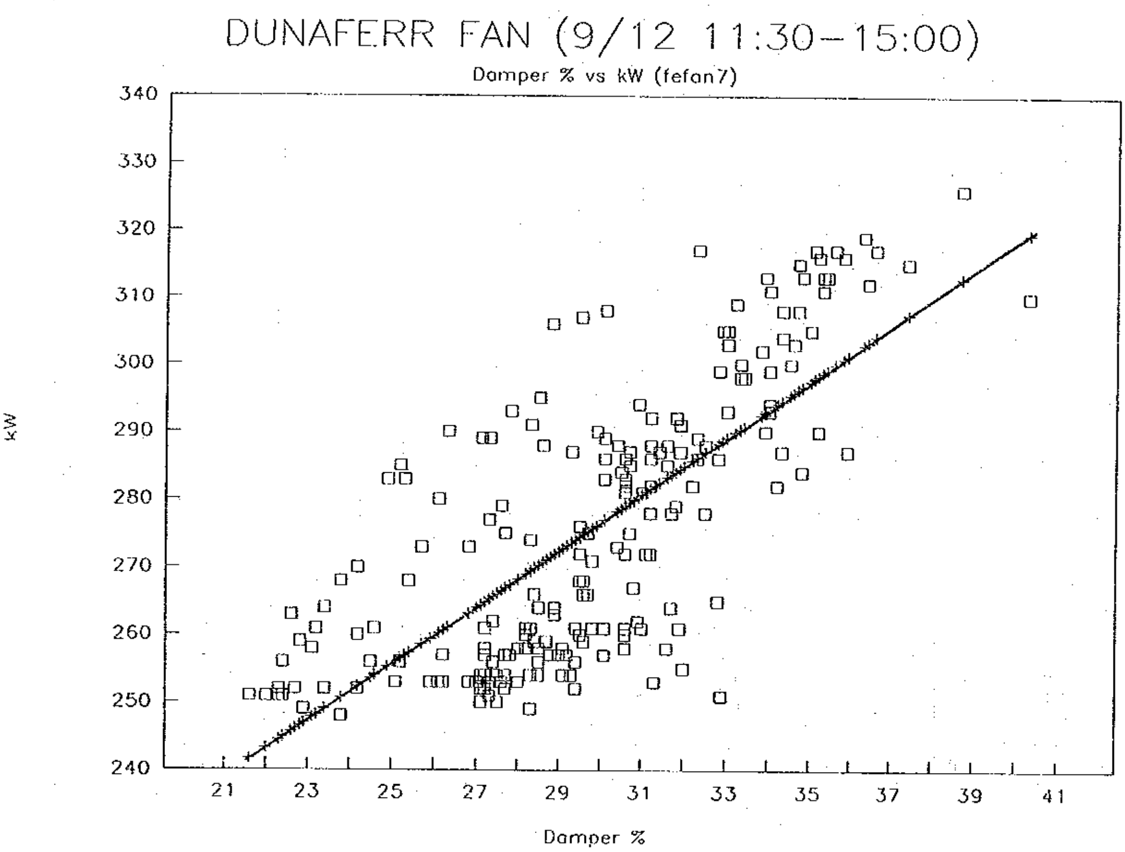


Figure 5.5.16 Motor Input vs. Damper Opening

These figures indicate that the motor input varies in the range of 320 ~ 250kW and the delivery damper opening varies in the range of 38 ~ 22%.

The regression expression of damper opening X (%) and motor input Y (kW) can be obtained as follows from what are shown in Figure 5.5.16.

$$Y = 4.17 X + 151.6 \quad (1)$$

As the rated output of this motor is 500kW, when the motor efficiency is assumed as 93%, the load factor is 69 ~ 54%.

According to the calculation of heat balance of the furnace, the airflow calculated from the furnace outlet exhaust gas analyzed value is 41,200 Nm^3/h and the airflow calculated from the after-recuperator exhaust gas analyzed value is 66,500 Nm^3/h. Since this airflow includes what is directly sucked from outside by the furnace or the recuperator, the airflow delivered by the fan is smaller than this figure.

From the results indicated above, it is learned that the fan is run at an airflow that is less than one half of its capacity and a loss caused by damper closing is occurring.

Furthermore, air is leaking at recuperator by a large rate. This leakage may be what is directly sucked from outside or what leaked from the forced draft air. But at any rate, power loss of the forced draft fan and of the exhaust gas suction fan is involved. It is first of all necessary to eliminate air leakage at recuperators.

Next, the fan should be replaced with a fan of suitable capacity and the loss caused by closing of the damper should be avoided. When variation of production rate and advancement of air leakage at recuperators, etc. are taken into account, revolution control that is capable of coping with variation of the airflow is most suitable. Revolution control is such that the airflow is regulated by changing the revolution of the motor, that is, the revolution of the fan, by changing the voltage and frequency of the inverter installed at the power supply in the state where the damper is kept fully open. The airflow of the fan is proportional to the revolution and the pressure is proportional to the square of the revolution. As the shaft power is proportional to the product of airflow and pressure, it is proportional to the cube of the revolution. Therefore, when the airflow is reduced with the revolution reduced, the power can be saved to an extent that is far larger than the case where damper opening is reduced.

The fan's characteristic curves could not be acquired during the investigation of this time and measurement of airflow and total pressure of the fan were not made. But assume that the airflow at the time when the mean electric power is 285kW is one half of the rated airflow. As the motor input at this time is 82% in the case of damper control and 15% in the case of revolution control, the electric energy saving rate and amount are as follows when change is made to revolution control.

Electric energy saving rate

$$285\ (1 - 0.15/0.82) \times 7{,}200 = 233\ \text{kW} \times 7{,}200\ \text{h/y}$$
$$= 1{,}677{,}600\ \text{kWh/y}$$

Electric energy saving amount

$$1{,}677{,}600\ \text{kWh/y} \times 3.6\ \text{Ft/kWh} = 6{,}039{,}000\ \text{Ft/y}$$

The expenses required for this modification are ¥25,000,000 (equivalent to 12,500,000 Ft) in the case of Japan, and these expenses can be recovered in about two years.

It is recommended that the total pressure and airflow of the fan as well as their relation with the motor input are measured and compared with the characteristic curves and that detail examination including forecast of load variation of reheating furnaces is made prior to implementation of countermeasures.

Attached data

List of study mission members

No	Name	Duty	Description of responsibilities
1	Mitsuo Iguchi	Leader, administration affairs	Administration, management Energy management
2	Teruo Nakagawa	Deputy-leader	Heat management technology, measurement technology Liaison and negotiation
3	Tetsuo Oshima	Energy management technology	Survey of heat management technology
4	Toshiyuki Ochi	Energy management technology	Survey of heat management technology
5	Koichi Inaba	Process control	Survey of dyeing process and heat management technology
6	Taro Ihara	Process control	Survey of tyre process and heat management technology
7	Tatehiro Tanabe	Process control	Survey of alumina process and heat management technology
8	Toshio Ohnishi	Process control	Survey of cement process and heat management technology
9	Toshio Noda	Process control	Survey of iron and steel process and heat management technology
10	Kenichi Kurita	Electricity management technology	Survey of electric power receiving and distribution and electric equipment at dyeing, tyre, alumina factories
11	Kazuo Usui	Electricity management technology	Survey of electric power receiving and distribution, and electric equipment at cement and steel plants
12	Hirokazu Hirata	Energy equipment	Survey of energy conditions and energy facilities
13	Motoo Hori	Energy conservation popularization	Survey of energy conditions and conditions of energy conservation
14	Takao Shiomi	Energy management technology	Heat management technology in general In charge of research work at home
15	Ayako Sato	Energy management technology	Heat management technology in general In charge of research work at home
16	Yukie Kawaguchi	Energy measure Energy conservation popularization	Conditions of energy measures and energy conservation In charge of research work at home
17	Masao Fuse	Energy measures Energy conservation popularization	Conditions of energy measures and energy conservation In charge of research work at home

Supplement 2

List of counterpart personnel

1. Members of AEEF

No	Name	Assignment
1	Dr. Dénes Rácz	Head of Technical Dept.
2	Mr. Sándor Komáromi	Head of Energy Planning and Information Dept.
3	Mr. Imre Gáspár	Heat of Regional Energy Management Department
4	Ms. Ildikó Szücs Fekete	Deputy Heat of Energy Planning Dept.
5	Mr. János Becz	Factory Team Leader of Hungarian side
6	Mr. Ferenc Pardavi	Electrical Engineer
7	Mr. Kornél Jonás	Mechanical Engineer
8	Mr. Endre Slenker	Electric & Measurement Engineer
9	Mr. László Szabó	Instrument Engineer
10	Mr. József Stieber	Instrument Engineer
11	Mr. Gyula Petró	Electrical Engineer

2. Members of MVMT

No	Name	Assignment
1	Mr. Lajos Ropolyi	Mechanical Engineer
2	Mr. Miklós Kenézy	Electrical Technician
3	Mr. Zoltán Dudás	Electrical Technician
4	Mr. Balács Csovics	
5.	Mr. Gábor Mohácsi	

Itineraries of on-the-spot survey teams

1) Advance team

Team members ① Teruo Nakagawa Deputy leader
② Kenichi Kurita Electricity management technology

No.	Date	Day of week	Itinerary
1	July 22, 1991	Mon	Departure from Tokyo
2	July 23	Tue	Arrival in Budapest
3	July 24	Wed	Confirmation of packing conditions of research equipment and materials
4	July 25	Thu	Unpacking of research equipment and materials
5	July 26	Fri	Unpacking of research equipment and materials
6	July 27	Sat	Preparations for research
7	July 28	Sun	Preparations for research
8	July 29	Mon	Confirmation of operationof research equipment, indicator calibration
9	July 30	Tue	Confirmation of operation of research equipment, indicator calibration
10	July 31	Wed	Confirmation of operation of research equipment, indicator calibration
11	Aug. 1	Thu	Confirmation of operation of research equipment, indicator calibration
12	Aug. 2	Fri	Confirmation of operation of research equipment, indicator calibration
13	Aug. 3	Sat	Preparations for research
14	Aug. 4	Sun	Preparations for research, join first team

2) First team

Team members

① Mitsuo Iguchi	Leader
② Teruo Nakagawa	Deputy leader (joins from advance team)
③ Toshiyuki Ochi	Energy management technology
④ Koichi Inaba	Process control (dyeing)
⑤ Taro Ihara	Process control (tyre)
⑥ Tatehiro Tanabe	Process control (alumina)
⑦ Kenichi Kurita	Electricity management technology (joins from advanceteam)

No.	Date	Day of week	Itinerary
1	Aug. 3, 1991	Sat	Departure from Tokyo
2	Aug. 4	Sun	Arrive in Budapest, join advance team
3	Aug. 5	Mon	Explanation of study method
4	Aug. 6	Tue	Explanation of study method
5	Aug. 7	Wed	Explanation of study method
6	Aug. 8	Thu	Explanation of study method
7	Aug. 9	Fri	Explanation of study method
8	Aug. 10	Sat	Preparations for study
9	Aug. 11	Sun	Preparations for study
10	Aug. 12	Mon	Survey of dyeing factory
11	Aug. 13	Tue	Survey of dyeing factory
12	Aug. 14	Wed	Survey of dyeing factory
13	Aug. 15	Thu	Survey of dyeing factory
14	Aug. 16	Fri	Survey of dyeing factory
15	Aug. 17	Sat	Preparations for study
16	Aug. 18	Sun	Preparations for study
17	Aug. 19	Mon	Preparations for study
18	Aug. 20	Tue	Preparations for study, Move from Budapest to Nyiregyhaza
19	Aug. 21	Wed	Survey of tyre factory
20	Aug. 22	Thu	Survey of tyre factory
21	Aug. 23	Fri	Survey of tyre factory
22	Aug. 24	Sat	Preparations for study, Move from Nyiregyhaza to Budapest, Team member Ihara departs from Budapest
23	Aug. 25	Sun	Preparations for study, Move from Budapest to Almasfuzito
24	Aug. 26	Mon	Survey of alumina plant, Team member Ihara arrives in Tokyo
25	Aug. 27	Tue	Survey of alumina plant
26	Aug. 28	Wed	Survey of alumina plant
27	Aug. 29	Thu	Survey of alumina plant
28	Aug. 30	Fri	Survey of alumina plant, Move from Almasfuzito to Budapest
29	Aug. 31	Sat	Survey work taken over by 2nd team, Depart from Budapest
30	Sept. 1	Sun	En route home
31	Sept. 2	Mon	Arrive in Tokyo

3) Second team

Team members ① Mitsuo Iguchi Leader (join from 1st team)
② Teruo Nakagawa Deputy leader (join from lst team)
③ Tetsuo Ohshima Energy management technology
④ Toshio Ohnishi Process control
⑤ Toshio Noda Process control
⑥ Kazuo Usui Process control
⑦ Hirokazu Hirata Energy measures
⑧ Motoo Hori Energy conservation measures

No.	Date	Day of week	Itinerary
1	Aug. 29, 1991	Thu	Depart from Tokyo
2	Aug. 30	Fri	Arrive in Budapest, Join lst team
3	Aug. 31	Sat	Take over survey work from 1st team
4	Sept. 1	Sun	Preparations for research Move from Budapest to Beremend (factory team)
5	Sept. 2	Mon	Survey of cement factory Survey of measures in Budapest (measures study team)
6	Sept. 3	Tue	Survey of cement factory Survey of measures in Budapest (measures study team)
7	Sept. 4	Wed	Survey of cement factory Survey of measures in Budapest (measures study team)
8	Sept. 5	Thu	Survey of cement factory Survey of measures in Budapest (measures study team)
9	Sept. 6	Fri	Survey of cement factory Move from Beremend to Budapest Survey of measures in Budapest (measures study team)
10	Sept. 7	Sat	Preparations for study
11	Sept. 8	Sun	Preparations for study Move from Budapest to Dunaujvaros (factory team)
12	Sept. 9	Mon	Survey of steel factory Survey of measures in Budapest (measures study team)
13	Sept. 10	Tue	Survey of steel factory Survey of measures in Budapest (measures study team)
14	Sept. 11	Wed	Survey of steel factory Survey of measures in Budapest (measures study team)
15	Sept. 12	Thu	Survey of steel factory Survey of measures in Budapest (measures study team)
16	Sept. 13	Fri	Survey of steel factory Move from Dunaujvaros to Budapest Survey of measures in Budapest (measures study team)
17	Sept. 14	Sat	Preparations for progress report
18	Sept. 15	Sun	Preparations for progress report
19	Sept. 16	Mon	Confirmation of contents of progress report
20	Sept. 17	Tue	Confirmation of contents of progress report
21	Sept. 18	Wed	Progress report signed and submitted Departs from Budapest
22	Sept. 19	Thu	En route home
23	Sept. 20	Fri	Arrive in Tokyo

SCOPE OF WORK
FOR
THE STUDY
ON
THE RATIONAL USE OF ENERGY
IN
THE REPUBLIC OF HUNGARY

AGREED UPON BETWEEN

STATE AUTHORITY FOR ENERGY
MANAGEMENT AND SAFETY
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

Budapest, August 6,1990

Dr.Árpád Bakay

Deputy Undersecretary of State

Ministry of Industry and Trade

Mr.Masayoshi Enomoto

Leader of the Preliminary
Survey Team
Japan International Cooperation
Agency

1.Introduction

In response to the request of the Government of the Republic of Hungary (hereinafter referred to as "Hungary"), the Government of Japan decided to conduct a study on the rational use of energy in industry in Hungary (hereinafter referred as "the Study") in accordance with the relevant laws and regulations in force in Japan.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA") the official agency responsible for the implementation of the technical cooperation programmes of the Government of Japan, will undertake the Study in close cooperation with the authorities concerned of the Government of Hungary.

This document sets forth the scope of work with regard to the Study.

2.Objective of the Study

The objective of the Study is to contribute to the promotion and strengthening of rational use of energy in the field of industries in Hungary by studying the technical and managemental applicability of rational use of energy and formulating the report for the promotion of rational use of energy in the representative industries stated below:

(1) Alumina manufacturing industry

(2) Textile industry

(3) Rubber industry

(4) Cement industry

(5) Iron and steel industry

3.Scope of the Study

In order to achieve the above objective, the Study will cover the following items.

(1)Literature survey on the energy situation in Hungary

① To survey the energy situation in Hungary

② To survey the situation of energy use in the field of whole industries in Hungary.

(2)Study on the promotion of rational use of energy in the industry

①To investigate current program for rational use of energy

②To study and evaluate the activities of State Authority for Energy Management and Safety

ⓐthe current activities for promotion of rational use of energy

ⓑthe achievements of past activities

ⓒthe future plan/program for promotion of rational use of energy

(3)Study on the situation of energy use in the following five(5) factories of each industry

1. Alumina Plant of Almásfüzitö
2. Budaprint Secotex Textilfesto Rt
3. Curing machine of Taurus Hungarian Rubber Works
4. Cement Factory,Bélapatfalva
5. Reheating furnace of Hot Rolling Mill in Dunaferr Dunai Vasmü

①To survey the situation of energy use in each factory

ⓐoutline of the factory

ⓑsituation of energy management

ⓒenergy flow chart

ⓓsituation of major energy consuming equipment

ⓔproblems found in each factory and countermeasures without changing the existing production process

ⓕestimated effects of the countermeasures

(4)Recommendation for the promotion of the rational use of energy in Hungary

①To recommend measures to promote rational use of energy in the field of industries

②To recommend activities of State Authority for Energy Management and Safety for rational use of energy

③ To recommend countermeasures without changing the existing production process and to estimate their effects

④ To prepare the reference of the technical guideline for the promotion of rational use of energy in industries

4.Steps and Schedule of the Study

(1)Steps

Step 1: Procurement of Equipment and carrying-vehicle in Japan

Step 2: Shipment of Equipment and carrying-vehicle

Step 3: Home office work in Japan

Step 4: Field work in Hungary

Step 5: Home office work in Japan

Step 6: Presentation of and discussion on the Draft Final Report in Hungary

Step 7: Home office work for completion of the final report in Japan

Step 8: Submission of the final report

(2)Schedule

Schedule of the Study is shown in Annex.

5.Reports

JICA shall prepare and submit the following reports written in English to the Government of Hungary within the time periods indicated below:

(1)Inception Report at the commencement of Stage Step 4 : 10 copies

(2)Progress Report at the end of Step 4 : 10 copies

(3)Draft Final Report and its summary with in 5 (five) months after the commencement of Step 4 : 15 copies

(4)Final Report and its summary within 2 (two) months after the receipt of comments on the Draft Final Report from the Government of Hungary : 30 copies

6. Undertaking of the Government of Hungary

(1) To facilitate smooth conduct of the Study, the Government of Hungary shall take necessary measures:

① To secure the safety of the Study team

② To permit the members of the Japanese study team to enter, leave and sojourn in Hungary for the duration of their assignment therein, and exempt them from alien registration requirements and consular fees.

③ To exempt the members of the Japanese study team from taxes, duties and other charges on equipment, machinery and other materials brought into Hungary for the conduct of the Study.

④ To exempt the members of the Japanese study team from income tax and charges of any kind imposed on or in connection with any emoluments or allowances paid to the members of the Japanese study team for their services in connection with the implementation of the Study.

⑤ To provide necessary facilities to the Japanese study team for remittance as well as utilization of the funds introduced into Hungary from Japan in connection with the implementation of the Study.

⑥ To secure permission for the members of the Team to enter into private properties and restricted areas for the conduct of the Study.

⑦ To secure permission for the Japanese study team to take all data and documents (including photographs and maps) related to the Study out of Hungary to Japan.

⑧ To provide medical services as needed. Its expenses will be chargeable to the members of the Japanese study team.

(2) The Government of Hungary shall bear claims, if any arises against members of the Japanese study team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or wilful misconduct on the part of the members of the Japanese study team.

(3) State Authority for Energy Management and Safety shall act as counterpart agency to the Japanese study team and also as coordinating body in relation with other governmental and non-governmental organization concerned for the smooth implementation of the Study.

(4) State Authority for Energy Management and Safety shall, at the expense of Hungarian side, provide the Japanese study team with the following, in cooperation with other organization concerned:

① Available data and information related to the Study

② Counterpart personnel

③ Suitable office space with necessary equipment in Budapest

④ Credentials or Identification cards

7. Undertaking of JICA

For the implementation of the Study, JICA shall take the following measures:

(1) To dispatch, at its own expense, the Study team to Hungary

(2) To pursue technology transfer to the Hungarian counterpart personnel in the course of the Study.

8. Consultation

JICA and State Authority for Energy Management and Safety shall consult with each other in respect of any matter that may arise from or in connection with the Study.

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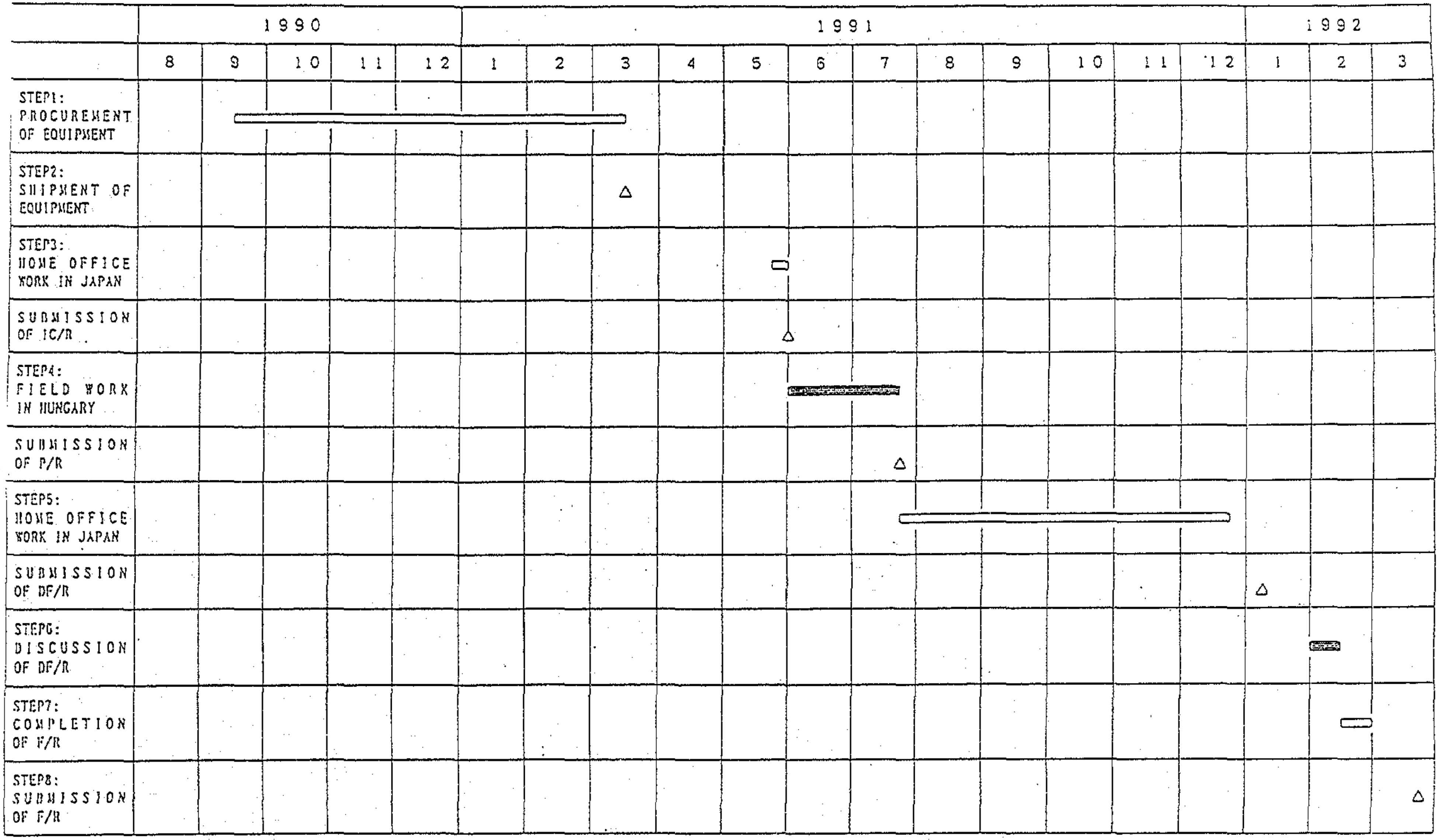
Annex

TENTATIVE SCHEDULE OF THE STUDY



IC/R : Inception Report P/R : Progress Report DF/R : Draft Final Report F/R : Final Report

MINUTES OF MEETING
ON
SCOPE OF WORK
FOR
THE STUDY
ON
THE RATIONAL USE OF ENERGY
IN
THE REPUBLIC OF HUNGARY

Budapest, August 6,1990

For the Government of the Republic of Hungary	For the Japan International Cooperation Agency
Györke Béla (signature)	(signature)
Mr. Béla Györke	Mr. Masayoshi Enomoto
Deputy Director of National Authority for Energy Economy	Leader of the Preliminary Survey Team
Ministry of Industry and Trade	Japan International Cooperation Agency

MINUTES OF MEETINGS

ON DISCUSSIONS

FOR

THE STUDY ON THE RATIONAL USE OF ENERGY

The JICA Preliminary Survey Team made a visit to Hungary from July 31 to August 7 , 1990 to discuss with the relevant Hungarian authorities concerned about the Study on The Rational Use of Energy.

Meeting were held at the Ministry of Industry and Trade from August 1 to 6, 1990 between the Hungarian officials chaired by Mr.Bela Gyorke,Deputy Director,National Authority for Energy Economy, Ministry of Industry and Trade on the Hungarian side, and the Preliminary Survey Team headed by Mr.Masayoshi Enomoto on the Japanese side (attendance as shown in the lists of Hungarian and Japanese delegations).

This Minutes of Meeting complements the Scope of Work agreed and signed by both sides and is intended for the smooth conduct in the whole course of the Study.

Following were confirmed by the Hungarian side and Japanese delegation during discussion:

1. Both sides recognized the importance of close cooperation in due course of the Study in order to make the Study fruitful, and that sufficient efforts should be made by both sides at every particular stage of the Study based on the Scope of Work.
2. The Hungarian side requested the Japanese side to provide the equipment listed in the attached paper upon the completion of the said study, and the Japanese side agreed to it.
3. The Hungarian side requested the Japanese side to bear the cost of transportation of the above equipment from Japan to Budapest, and the Japanese side agreed to it.
4. The consignee of the above equipment shall be as follows:

   Mr. Tamás Láng-Miticzky
   State Authority for Energy Management and Safety
   Állami Energetikai és Energiabiztonságtechnikai Felügyelet
   Budapest,
   Köztársaság tér 7.
   1081
   HUNGARY

5.Both sides agreed on that Hungarian side assigns counterpart engineers for Japanese study team while their field survey in Hungary for technology transfer, and numbers of hungarian counterparts are as follows:

(1)4(four) engineers (3(three) heat engineers, 1(one) electric engineer) from State Authority for Energy Management and Safety, who shall be assigned for the whole study period of Japanese team in Hungary.

(2)4(four) engineers (2(two) heat engineers, 2(two) electric engineers) from each factory, who shall be assigned for nearly one week only when Japanese team makes field survey at the factory.

6.The Japanese side requested the Hungarian side to provide a driver of the equipment carrying vehicle, and the Hungarian side agreed to it.

7.The Japanese side requested the Hungarian side to provide a working room both at State Authority for Energy Management and Safety and at each factory, and the Hungarian side agreed to it.

Equipment List

No.	Name	Set(s)
1	Equipment carrying vehicle with antishock rack and lifter	1
2	Ultrasonic flow meter for fuel oil or water	1
3	High temperature anemometer for gas	1
4	Steam condensate flow meter	1
5	Pitot type flow meter	1
6	Differential pressure transmitter for orifice	2
7	Oxygen meter for exhaust gas	1
8	Carbon dioxide and monoxide meter for exhaust gas	1
9	Pretreatment unit for sampling exhaust gas	1
10	Sampling tube for exhaust gas	10
11	Thermometer for surface	2
12	Thermocouple with compensate cable for gas (K type)	20
13	Infrared radiation thermometer (low range)	1
14	Infrared radiation thermometer (high range)	1
15	Glass thermometer	5
16	Hygrometer	5
17	Thermal video system	1
18	20 channel recorder with data memory and reader	3
19	Personal computer (desk top type) for analysis	1
20	Personal computer (book type) for field work	2
21	Water conductivity meter	1
22	Water pH meter	1
23	Water hardness meter	1
24	Pressure gauge with transmitter for furnace gas	1
25	Pressure transmitter for steam	3
26	Steam trap checker	1
27	Watt-power factor meter	5
28	Watt-hour meter	1
29	Power meter	1
30	Tachometer	1
31	Lux meter	1
32	Circuit tester	1
33	Voltage detector	5
34	Heat resisting gloves	5
35	Cobalt glass for eye protect	5
36	Camera	1
37	Power insulation gloves	5
38	Extension power cord with tools	3
39	Stop watch	2
40	Wagon desk for field work	4
41	Training unit for measurment of temperature and power	1
42	Training unit for measurment of water flow and power	1
43	Training unit for measurment of gas pressure and power	1

LIST OF ATTENDANCES

Japanese Side

Preliminary Survey Team

Mr.Masayoshi Enomoto (Leader)	Director of Industry Division JICA
Mr.Mikio Takasima (Policy for Development Cooperation)	Development Cooperation Division ECB,MFA
Mr.Shigenori Nakauchi (Administration for Rational Use of Energy)	Energy Conservation Policy Planning Office ANRE, MITI
Mr.Toshinori Isogai (Planning and Coordination)	Industry Division, JICA
Mr.Teruo Nakagawa (Energy Auditing Technology)	The Energy Conservation Center

Embassy of Japan Budapest

Mr.Motokichi Aoyama	Second Secretary

Hungarian Side

Ministry of Industry and Trade

Mr.Béla Györke	-	Deputy Director National Authority for Energy Economy
Mr.Sándor Hidas	-	Head of Section Department of External Economic Relations

State Authority for Energy Management and Safety

Mr.Dénes Rácz	-	Chief Head of Department Energy Effeciency Office

Gp.

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