7. MEASUREMENT DATA PROCESSING

7. MEASUREMENT DATA PROCESSING

7.1 Measurements and Errors

Various types of errors may occur when actually taking measurements with measuring equipment. Since it is not possible to obtain the true value by a measurement, measurement values that include a margin of error are normally used in an analysis. Thus, it is important to understand the nature of errors in order to minimize them.

7.1.1 Factors of Errors

Errors can generally be attributed to the following 4 factors.

(1) Errors due to measurement principles and methods

Errors occur because a physical principle or theory used is not appropriate for the actual object or method of the measurement.

(2) Errors due to the measuring instrument

An imperfection or trouble in the measuring equipment causes a "bias" or "dispersion" in the measurement value.

(3) Errors due to the condition and environment of measurement

An error is caused by the interaction (electrical and mechanical impedance) between the measuring instrument and an object of measurement, influence from the environment or condition of the power source, or by changes and instability that occur to the measurement object itself due to changes in the environment.

(4) Errors due to the reading method

An error may occur due to cognitive limitations or peculiarities in individual reading habits of the measuring person, or as the result of "rounding up" by the A-D converter, etc.

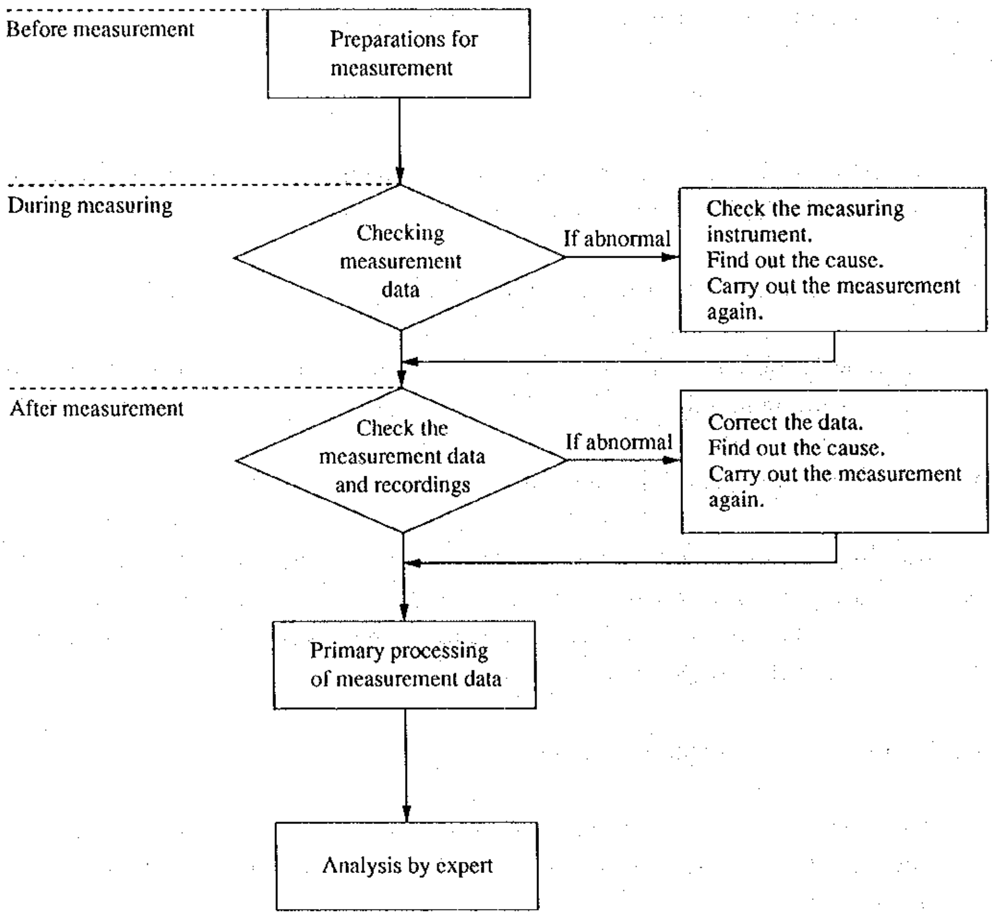
7.2 Measurement Data Collection and Data Processing Procedure

In order to conduct an analysis based on various measurement data, the data must be collected and processed correctly.

7.2.1 Data Process Flow

The process flow for measurement data is as shown in Figure 7.1.

Figure 7.1 Measurement Data Processing Flow



7.2.2 Verifications of Data Processing and Notes to be Taken

(1) Verifications and notes to be taken before starting a measurement

- Carry out maintenance work on the measuring instruments periodically.
- Calibrate the measuring instruments before starting the measurement (Zero point calibration, span calibration, etc.)
- Check whether or not the wiring and sensor installations, etc., are carried out properly.
- Make sure that the measuring instrument itself is correctly set.

(2) Verifications and notes to be taken during a measurement

- Compare the measurement value with the normal value and theoretical value, and find out whether any abnormality is present.

  If there is an abnormality, find out its cause and carry out the measurement again.
- Compare the findings with those on other existing meters. (If there is an existing meter)
- Take the measurement with a number of types of measuring instruments, and compare each measurement data.
- Compare the measurement with the values obtained from interviews with responsible personnel at the factory.
- Make sure that there is no difference depending on measurement point (location).
- In case of prolonged measurements, make sure that there is no abnormality to the measuring instrument.
- If any abnormality or change occurred to the object of measurement (facility, line, etc.), record its details and time.
- Prohibit all non-authorized personnel from operating the measuring instrument.

(3) Verifications and notes to be taken after the measurement

Plot the measured data on a spreadsheet and graph, and verify whether or not any abnormality exists. If an abnormality occurs, find out its cause, and then consult an expert, and either correct the data or carry out the measurement again.

- When analyzing recorded data, display it on a table or graph so that it can be viewed easily. In doing so, indicate the date, factory name, measurement object, and other particular remarks.

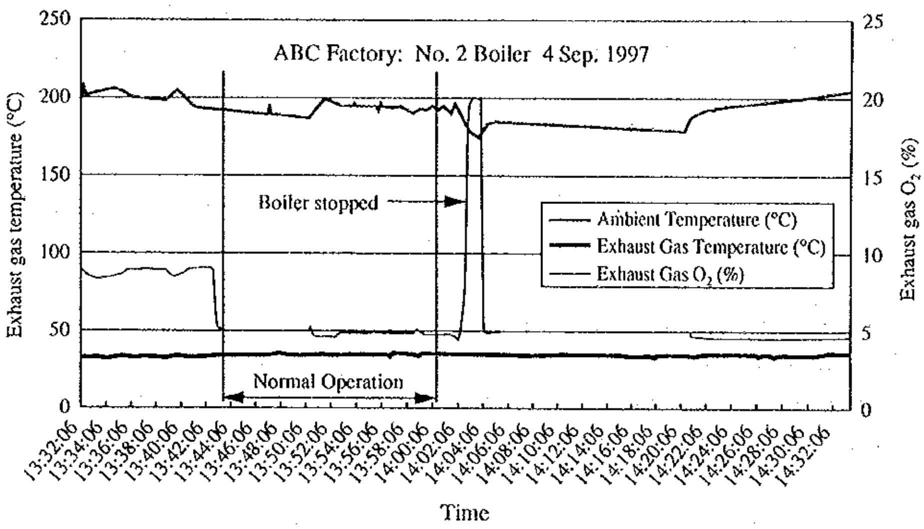
- If the measurement object (facility, line, etc.) was subject to a temporary halt due to an incident, such as an accident, immediately before the start of operation or immediately after the end of operation, there will be a large fluctuation in the measurement data. In such a case, carry out steps that will enhance ease of analysis such as removing the affected part of the data, or consult with an expert.

An example of a primary processing of measurement data is shown in Table 7-1 and Figure 7.2.

Table 7.1 Example of Data Processing

Date/Time : 09-04-1997 12:12:12				
Factory : ABC Factory				
Facility : No.2 Boiler O_2, Gas Temperature & Ambient Temperature				
Date	Time	Data 1 Ambient Temperature (DEGC)	Data 2 Gas Temperature (DEGC)	Data 3 Gas O_2 (%)
97/09/04	13:26:42	29.8	197.4	19.72
97/09/04	13:26:44	29.9	197.2	19.74
97/09/04	13:26:46	29.9	197.8	19.77
97/09/04	13:26:48	29.9	197.3	19.86
97/09/04	13:26:50	29.8	197.0	20.01
97/09/04	13:26:52	31.0	196.6	20.09
97/09/04	13:26:54	29.6	197.3	20.15
97/09/04	13:26:56	29.9	197.0	20.19
97/09/04	13:26:58	29.9	196.8	20.22
97/09/04	13:27:00	29.2	197.0	20.25
97/09/04	13:27:02	30.0	197.2	20.26
97/09/04	13:27:04	29.9	197.3	20.28
97/09/04	13:27:06	30.0	197.2	20.29
.	.	.	.	.
.	.	.	.	.

Figure 7.2 Example of Measurement Data Processing (represented in graph)



7.3 Measurement Data Processing

While some measuring instruments are used for spot measurements, others have main bodies that come with memory functions, and yet other types are capable of outputting signals to recorder.

(1) Instruments used for spot measurements

In order to prevent omissions in measurements, record the measurement data on a dedicated recording form or by other means devised for such purpose.

- Pressure gauge (bourdon tube) (P-1 to P-4)
- Glass thermometer (T-1)
- Termo-hygrometer (T-2)
- Surface thermometer (T-8)
- SC meter (W-1)
- PH meter (W-2)
- Oxygen analyzer (spot) (G-3)
- Low voltage detector (E-1)
- Tester (E-2)
- Clip-on AC power meter (E-4)
- Tachometer (TM-1)
- Lux meter (L-1)

(2) Instruments with main bodies that have memory functions

If the instrument has a built-in floppy disk unit, use a dedicated analysis software to analyze its data, and if it has a memory function, call up the data and then organize it.

- Radiation pyrometer (T-9, T10)

  Number of memory points: 100

- Infrared thermovideo (T-12)

  Number of memory points: 30 images/1 disk (3.5 inch FD 2HD)

  Use its dedicated analysis software to analyze.

- Steam trap checker (S-1)

  Number of memory points: 800

  After transmitting the data to a personal computer using an RS232C, analyze it with a dedicated software.

- Clamp-on power meter (E-3)

Analyze the recorded data after reading it in from the main body's accessory FDD Unit as numerical data using Microsoft EXCEL.

(3) Instruments that output analog signals

Measurement data from each measuring instrument is output in analog signals, and then stored on the floppy disk of a recorder that comes with built-in memory. Data in the floppy disk is converted to a table and graph by reading it in with a spreadsheet software (Microsoft EXCEL).

• Digital low pressure indicator (P-5)	output: 1 - 5 VDC	to Hybrid Recorder
• Steam pressure transmitter (P-6)	output: 4 - 20 mADC	
• Sheathed thermocouple (T-3 to T-7)		
• Suction pyrometer (T-11)	output: 1 - 5 VDC	
• Ultrasonic flow meter (F-1)	output: 1 - 5 VDC	
• Vortex flowmeter (F-2)	output: 4 - 20 mADC	
• Hot wire anemometer (F-3)	output: 0 - 1 VDC	
• Oxygen analyzer (Continuous) (G-2)	output: 0 - 1 VDC	
• Transducer (E-5 to E-9)	output: DC 0 - 1, 0 - 1.1 mA	
• CO, CO_2 meter (EC-1)	output: 0 - 1 VDC	
• Pitot type flowmeter (EC-2)	output: 1 - 5 VDC	

8. EXPLANATION ON HEAT CALCULATION WORKSHEET

8. EXPLANATION ON HEAT CALCULATION WORKSHEET

This document describes the content of the heat calculation worksheet provided by The Energy Conservation Center, Japan and how to use it. It is prepared on the assumption that the user will read this explanation with the worksheet opened on a desktop PC. Full understanding of the worksheet content will expand the extent of its applications.

(1) Compatibility

This heat calculation worksheet consists of several files, which were initially developed in Japanese on Japanese-version Lotus 123/DOS. Some of the files to be provided are converted into English or Excel. Therefore, the macro is of Lotus 123/DOS, which can be directly read and executed by Excel.

(2) Copyright

The Energy Conservation Center, Japan reserves the copyright to the heat calculation sheet software. Users cannot distribute this calculation sheet software to a third party. The Energy Conservation Center, Japan will not be responsible for any trouble whatsoever that might be encountered while using this calculation sheet software.

(3) Structure

The calculation sheet software includes the following files:

H_BL_GAS.xls:	Gas fuel combustion calculation and boiler heat balance
H_BL_OIL.xls:	Oil fuel combustion calculation and boiler heat balance
HBFC_GAS.xls:	Gas fuel combustion calculation and heat balance of steel product continuous reheating furnace
SHIFTAVG.xls:	Rearrangement of boiler continuous measuring data
SHIFTABG.wk1:	Rearrangement of boiler continuous measuring data, Lotus 123/DOS
Eco_INSU.xls:	Calculation of economical thickness of heat insulation
Mlt_INSU.xls:	Calculation of heat release and temperature of multi-layer heat insulation
EMISSION.xls:	Calculation of heat emission amount from surface for numerous cases
STEAM_14.xls:	Approximation and application of steam table

Since these calculation worksheets were initially created by using Lotus 123/DOS, ruled lines are not always reproduced in Excel. As a result, it may be hard to distinguish input cells from other numerical expression cells.

8.1 Combustion Calculation and Heat Balance of Boiler (or Reheating Furnace)

Files: H_BL_GAS: Gas fuel combustion calculation and boiler heat balance
H_BL_OIL: Oil fuel combustion calculation and boiler heat balance
HBFC_GAS: Gas fuel combustion calculation and heat balance of steel continuous reheating furnace

Combustion calculation forms the basis of heat calculation, as well as the calculations of heat transfer and heat insulation. The concept of this calculation is based on material balance and heat balance. Since the calculation involves only a simple equation and the four basic operations, the calculation can be performed even without a PC. It will be certainly more efficient and practical, however, to use the PC for the calculation. Using this software, the calculation sheet for each type of fuel (gaseous fuel, liquid fuel) and coal combustion is prepared and then the heat balance of the air preheater and that of the boiler are added.

8.1.1 Basic Calculation

The basic calculation is performed by setting the fuel composition, air conditions, and oxygen and carbon monoxide content in the exhaust gas. The cells in which you need to enter the setting values are displayed with frames to make it easier to identify these cells.

The fuel composition can be entered manually as well as by selecting it from a menu. The base temperature, ambient temperature, ambient humidity, air temperature (can be assumed as burner air temperature), and percentage of oxygen in the air are set for the air conditions. The ambient humidity is used for calculating the moisture content in combustion air. You can select the setting between relative humidity and wet bulb temperature. (The previous setting value will be retained even if you switch the setting, i.e it will remain effective.) This switching is performed by exchanging the formula using macro instructions, and the approximation formula of the steam table is used [Cell: v101..ae120].

Note: The information in square brackets ([ ]) indicates the relevant cell address.

The O_2 content and CO content contained in exhaust gas are set for the exhaust gas conditions. The settings of these exhaust gas compositions can be switched between wet base and dry base measured values in accordance with the analyzer characteristics. The previous setting value will be retained even if the setting is switched. However, you cannot select both wet base and dry base simultaneously. For example, you cannot select the wet base for measuring CO and dry base for measuring O_2. This switching is performed by exchanging the exhaust gas components and exhaust gas volume formulas using macro instructions [Cell: ap61..ax80]. The setting values that existed before you switched the wet base to dry base or vice versa are displayed as the new setting values after the values are converted into the new setting unit by macro instructions.

As a result of the calculation, the calorific value (net, gross) of fuel is displayed. Also, the wet base and dry base values of air volume, exhaust gas volume (for each component), and percentage of exhaust gas composition are displayed in the theoretical combustion column. The wet base and dry base values of each component of exhaust gas and its volume and exhaust gas volume are displayed in the actual combustion column. The air volume and air ratio are also displayed. Screen 8.1, Screen 8.2 and Screen 8.3 show examples of the calculation sheets [Cell: a21..i40].

Screen 8.1 Gaseous Fuel Combustion Calculation

Gas Combustion			<Dry>	Ostrowiec		Base temperature	28	Air O_2%
Gas composition	Wet volume		Exhaust gas	Composition /Wet	Exhaust volume	Composition/Dry		21.0%
CO	0.00%		CO_2	6.2%	0.99	7.3%	Adiabatic temperature:	
CO_2	0.09%		N_2	72.7%	11.59	84.7%	(\D)	1459
H_2	0.00%		O_2	6.9%	1.09	8.0%	Exhaust temperature	240.0
CH_4	97.85%		H_2O	14.2%	2.26	-	Exhaust O_2(re)	4.00%
C_2H_4	0.00%		CO	0.0%	0.00	0.0%	AR(Re)	1.211
C_2H_6	0.42%		Total	100.0%	15.94	100.0%	AR Effect	2.89%
C_3H_8	0.13%				Wet	Dry	Exhaust gas temperature	
C_4H_{10}	0.09%			Excess air	5.31	5.21	after AH(calculated)	240
N_2	1.42%			Air total	14.94	14.66	Exhaust volume(re)	12.66
O_2	0.01%			Air ratio	1.55	1.55	Air volume(re)	11.66
H_2O	0.00%		Invasion air ratio		0.0%		Exhaust gas loss	10.43%
Fuel temperature	28	Theoretical combustion		Wet	Dry	Exhaust gas loss	Burner air	Exhaust weight
Air temperature	28.0	Oxygen	Gas volume	10.63	8.47	13.02%	14.94	19.82
Ambient temperature	28	1.98	CO_2	9.4%	11.7%	Exhaust carbon dioxide(C base)		
Wet Bulb	50.0%	Air_Wet	N_2	70.3%	88.3%	kg/fuel-m^3_N		0.533
Fuel weight	0.73	9.62	O_2	0.0%	0.0%	kg/fuel-10^3kcal-Hl		0.0628
Net heat Hl	8,487	Air_Dry	H_2O	20.3%	-	Unit:kg,m^3_N,°C,kcal fuel:\F		
Net heat Hh	9,416	9.45	Unit:m^3_N,°C,kcal,kg			Insulation Calculation	10.Sep	2002.9.10 17:15

Screen 8.2 Liquid Fuel Combustion Calculation

	Oil Combustion		<Dry>	A_fuel		Base temperature	28	Air O_2%
Oil composition	Wt. %		Exhaust gas	Composition/wet	Exhaust volume	Composition/dry		21.0%
C	84.6%		CO_2	8.8%	1.58	9.8%	Adiabatic temperature:	
H	11.8%		N_2	74.4%	13.28	82.2%	(\D)	1552
O	0.7%	HV adjust	O_2	7.2%	1.29	8.0%	Exhaust gas temperature	250.0
N	0.5%	\U	H_2O	9.5%	1.70		Exhaust gas O_2(re)	4.0%
S	0.3%		CO	0.0%	0.00	0.0%	AR(re)	1.221
H_2O	0.3%		SO_2	0.0118%	0.002	0.0130%	AR Effect	2.96%
Fuel temperature	28	Atomizing steam	Total	100.0%	17.86	100.0%	Exhaust gas temperature	
Air temperature	28	kg/kg	0		Wet	Dry	after AH(calculated)	250
Ambient temperature	28	Pressure ata	8	Excess air	6.30	6.15	Exhaust volume(re)	13.97
Relative Humidity	60.0%	Invasion air ratio		Air total	17.19	16.81	Air volume(re)	13.30
15/4dens	0.86		0.0%	Air ratio	1.58	1.58	Exhaust gas loss	10.05%
Wt/Volume	0.85155	Theoretical combustion		Wet	Dry	Exhaust gas loss	Burner air	Exhaust weight
Heat value/kg		Oxygen	Gas volume	11.57	10.00	12.71%	17.19	22.92
Hl	10262	2.24	CO_2	13.7%	15.8%	CO_2 emission(C_eq)		
Hh	10879	Air Wet	N_2	72.8%	84.2%	kg/fuel-kg		0.846
Heat value/lit(Ref.)		10.90	O_2	0.0%	0.0%	kg/fuel-th.kcal-Hl		0.0968
Hl	8738	Air Dry	H_2O	13.5%	-	Unit:kg,m^3_N,°C,kcal Fuel:\F		
Hh	9264	10.65	SO_2	0.0182%	0.0210%	Adiabatic Calculation	10.Sep	18:28:32

Screen 8.3 Coal Combustion

Coal Combustion				<Dry>	STAR		Base temperature	28.0	Air O_2%
Composition(DAF)	Wt. %			Exhaust gas	Composition/Wet	Exhaust volume	Composition/Dry		21.0%
C	81.49%			CO_2	7.4%	1.11	7.8%	Adiabatic temperature:	
H	4.92%			N_2	75.6%	11.30	79.7%	(AD)	958
O	11.42%			O_2	11.4%	1.70	12.0%	Residue(including Soot)	
N	1.30%	Exhaust gas temperature		H_2O	5.2%	0.77		Generation kg/kg	0.10
S	0.78%		250	CO	0.5%	0.07	0.5%	Carbon %	3.27%
H_2O	6.00%	Exhaust gas O_2(Re)		SO_2	0.0%	0.00	0.0%	Heat kcal/kg	26.42
Fuel temperature	23.0		8.0%	Total	100.0%	14.95	100.0%	Exhaust gas temperature	500
Air temperature	28.0	AR(Re)	1.57		94.8%	Wet	Dry	Specific heat	0.20
Ambient temperature	28.0	AR improve effect	8.8%		Excess air	8.09	7.94	Exhaust volume(re)	10.57
Relative Humidity	50.0%	after AH(count)	250		Air total	14.56	14.29	Air volume(re)	10.19
Ash	16.21%	Invasion air ratio	0.0%		Air ratio	2.25	2.25	Exhaust gas loss	18.15%
Hh(DAF)	6302	Theoretical combustion			Wet	Dry	Exhaust gas loss	Burner air	Exhaust weight
Heat value/kg-wet		O_2		Gas volume	6.83	6.21	25.36%	14.56	19.45
Hl	5148		1.33	CO_2	17.2%	19.0%	Exhaust carbon dioxide(C base)		
Hh	5386	Air Wet		N_2	73.6%	81.0%	kg/fuel-kg		0.631
Heat value/kg-wet coal heat value			6.48	O_2	0.0%	0.0%	kg/fuel-10^3kcal-Hl		0.123
Hl	5889	Air Dry		H_2O	9.1%	-	Unit:kg,m^3_N,°C,kcal fuel:\F		
Hh	6066		6.36	SO_2	0.1%	0.1%	Insulation Calculation	02.09.10	18:43:37

The calculation sheets have been designed and developed to meet general purpose applications as far as possible. For example, the base temperature is a setting value and is not always fixed at 0 °C. Moreover, if you change the setting of the oxygen content in air, the calculation sheet can be used for oxygen enrichment combustion. Also, you can set the intruding air into the furnace as the volume ratio to the theoretical air, and the volume excluding this setting amount is treated as the burner air ratio. The combustion air and exhaust gas calculations are performed by handling the air volume required by fuel components and generated exhaust gas volume in a matrix array instead of by approximation calculation. Furthermore, the moisture content in combustion air is included in the calculation.

8.1.2 Adiabatic Temperature of Combustion

The adiabatic temperature of combustion is calculated by macro instructions based on the setting conditions (including the fuel, air, and exhaust gas conditions). This method is used because the specific heat of the combustion gas is expressed by a cubic equation of the gas temperature, and the relationship between the temperature and specific heat cannot be solved by a simple process. Therefore, repeated calculations have to be performed for convergence to obtain a closer result. However, the thermal decomposition of combustion generated gas at high temperature is not taken into consideration (needless to say that complete adiabatic combustion cannot exist in reality). This adiabatic combustion temperature therefore should be considered to be a reference value. The convergence method is simple and is done in the following manner. The postulated value is corrected and calculations are repeated over and over until the combustion temperature, which was obtained from the calculation based on a certain assumed temperature, becomes close to the postulated value [Cell: p81..s100]. You can set a convergence limit value for ending the repeated calculations.

8.1.3 Fuel Selection

The composition of each kind of fuel selectable in the menu is already provided in the worksheet [Cell:a125..n142]. When the code of fuel selected in the menu is entered, the fuel composition is quoted to the extent of the selected fuel [am63:an76] by the index function and copied into the basic setup screen for combustion calculation. The reason why the index cell is provided separately is that manual setting is disabled if the index expression is written in the basic setup screen a21:i40. For the oil combustion worksheet, the fuel is selected from the menu. You can select your desired fuel composition from the menu, and by changing the composition already written, you can obtain the desired fuel composition. It is troublesome, however, to change the component instead of the fuel compositions. In other words, it is necessary to add components not listed in the fuel selection table, set the volume of oxygen required and components of generated gas, and also set specific heat.

The coal combustion worksheet [file:H_BL_Coal.xls] handles the fuel as described below.

<Coal handling>

For setting of fuel components, percentages of components including water and ash are set. These set values are adjusted in the worksheet so that the total including water and ash will be 100%. Setting of composition of elements is necessary because this calculation worksheet calculates the combustion gas based on the composition. In combustion calculation, the required air volume and combustion exhaust gas are calculated by removing the residue from the components converted into 100 %.

For the heat value, a lower heat value is set. This set value is used in the calculation worksheet but the calculated heat value from element analysis is not used.

For the combustion residue (hereinafter referred to as the residue), the volume of residue generated, discharge temperature, etc. are set on the basic setting screen. These items are used not only for calculation of air ratio improvement and air heating but also boiler heat balance.

8.1.4 Exhaust Gas Oxygen and Various Properties

The changes in the various calculation results when the oxygen concentration in the exhaust gas is changed in calculations such as the above can be immediately obtained by entering the new numeric value in the oxygen cell. However, supposing you want to know the exhaust gas volume for several oxygen settings, it would be convenient if this result could be displayed in a summary table. The spread sheet is provided with a function to create such a table (called "What-if table"). Thus, this calculation sheet can calculate and display changes in the calculation results in accordance with various oxygen concentration levels as shown in Screen 8.4 [Cell: a41..i60]. Since this calculation is performed by several key operations instead of automatic execution, a macro instruction is used. The calculation is performed by CTRL+I (press and hold down the CTRL key and press the I key) after setting the assumed value. (At this time, "¥I" will appear next to the title at the top of the table.) After the calculation is completed, the time is written at the bottom of the screen under the table to prevent you from forgetting to perform the calculation.

The macro instruction may be executed by Alt+I on some systems (PC) or software. Also, the backslash "\" is displayed for the yen sign in the English version.

Screen 8.4 What-if Table for Combustion Calculation

What-if Study(\I) <Dry> Ostrowiec

Tbl.1 Burner air etc.

O_2 dry	Air ratio	Air/Wet	Exhaust/Wet	CO_2	Exhaust weight
0.0%	1.00	9.6	10.63	9.4%	13.03
4.0%	1.21	11.7	12.66	7.9%	15.63
8.0%	1.55	14.9	15.94	6.2%	19.82
12.0%	2.20	21.1	22.14	4.5%	27.74
16.0%	3.87	37.2	38.25	2.6%	48.33
(CO dry	0.00%)			10.Sep	17:16:00

Tbl.4 Adiabatic temperature(\T)

O_2 dry	CO 0.0%	0.5%
0.0%	2039	2028
4.0%	1764	1753
8.0%	1459	1447
12.0%	1108	1095
16.0%	690	675
	10.Sep	17:15:38

Tbl.2 Exhaust gas loss (to HI)

O_2 dry	Exhaust gas temperature 300	400	500	600
0.0%	11.4%	15.8%	20.3%	24.9%
4.0%	13.5%	18.6%	23.9%	29.4%
8.0%	16.8%	23.3%	29.8%	36.6%
12.0%	23.1%	31.9%	41.0%	50.2%
16.0%	39.5%	54.5%	69.9%	85.6%
			10.Sep	17:16:01

Tbl.3 Burner air heat (to HI)

O_2 dry	Air temperature 200	350	500
0.0%	6.1%	11.6%	17.2%
4.0%	7.4%	14.1%	20.9%
8.0%	9.5%	18.0%	26.8%
12.0%	13.4%	25.5%	37.9%
16.0%	23.7%	44.9%	66.7%
		10.Sep	17:16:02

Excel provides the "Table" function that allows automatic calculation without necessity of the macro for What-if calculation as described above. This worksheet uses the Table function to simply view a case of the air ratio improvement effect and air heating effect. However, if the Table function is frequently used, the worksheet re-calculation speed may drop.

The following study has been prepared as the What-if table besides the above.

8.1.5 Fuel Economy Ratio by Air Ratio Adjustment

This table is used for reading the fuel economy ratio from the percentages of O_2 before and after adjustment for each exhaust gas temperature indicated in the exhaust gas dissipation coefficient table in Screen 8.4 above (ratio for the fuel volume before adjustment is performed). The heat amount excluding the exhaust gas dissipation is calculated as the required heat amount (no change of volume even if the air ratio is adjusted) [Cell: k21..u40]. Since the calculation for this table is executed using the macro instruction I after the calculation of Screen 8.4 above, there is no need for a separate calculation. Screen 8.5 shows an example of this table.

Screen 8.5 Air Ratio Adjustment

Tbl.5 Fuel economy by air ratio adjust(\G)(to before adjust fuel) — Ostrowiec

Invasion air ratio 0.0%

2.89%	Exhaust temperature=			300
Before adjust	O_2 dry after adjust			
O_2 dry	0.0%	4.0%	8.0%	12.0%
0.0%	0.0%	-	-	-
4.0%	2.3%	0.0%	-	-
8.0%	6.1%	3.9%	0.0%	-
12.0%	13.2%	11.1%	7.6%	0.0%
16.0%	31.7%	30.1%	27.3%	21.3%

2.89%	Exhaust temperature=			400
Before adjust	O_2 dry after adjust			
O_2 dry	0.0%	4.0%	8.0%	12.0%
0.0%	0.0%	-	-	-
4.0%	3.4%	0.0%	-	-
8.0%	8.8%	5.7%	0.0%	-
12.0%	19.2%	16.3%	11.3%	0.0%
16.0%	46.0%	44.1%	40.8%	33.2%

2.89%	Exhaust temperature=			500
Before adjust	O_2 dry after adjust			
O_2 dry	0.0%	4.0%	8.0%	12.0%
0.0%	0.0%	-	-	-
4.0%	4.6%	0.0%	-	-
8.0%	12.0%	7.7%	0.0%	-
12.0%	25.9%	22.4%	15.9%	0.0%
16.0%	62.2%	60.4%	57.1%	49.0%

2.89%	Exhaust temperature=			600
Before adjust	O_2 dry after adjust			
O_2 dry	0.0%	4.0%	8.0%	12.0%
0.0%	0.0%	-	-	-
4.0%	5.9%	0.0%	-	-
8.0%	15.5%	10.2%	0.0%	-
12.0%	33.7%	29.5%	21.5%	0.0%
16.0%	80.8%	79.6%	77.3%	71.1%

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For example, if the percentage of O_2 before adjustment in the exhaust gas temperature of 250 °C is 10 %, and if it is adjusted to O_2 5 %, the fuel economy will be 8.0 % in terms of the heat balance.

In the calculation, the heat amount excluding the exhaust gas dissipation is calculated first as the required heat amount for each case. Then, the fuel economy volume is calculated based on this calculated heat amount value.

8.1.6 Fuel Economy Ratio by Air Preheating

In the same manner as in the previous section, the fuel economy ratio by air preheating is also calculated using the macro instruction ¥I as shown in Screen 8.6 [Cell: w 21..ae40]. The cells with a dash (-) in the table indicate cases which cannot exist since the air preheating temperature set is higher than the exhaust gas temperature. For example, if the air is preheated to 150 °C in conditions where the exhaust gas temperature is 250 °C and the exhaust gas oxygen is 5 %, the fuel is cut down to 5.6 % in terms of heat balance.

Screen 8.6 Air Preheating with Exhaust Gas Heat

Tbl.6 Fuel economy by air preheat(\J)(to before preheat)

Ostrowiec	
Air invasion=	0.0%

Exhaust temperature before preheat= 300

O_2 dry	Preheat temperature 200	350	500
0.0%	6.5%	-	-
4.0%	7.9%	-	-
8.0%	10.3%	-	-
12.0%	14.9%	-	-
16.0%	28.1%	-	-

Exhaust temperature before preheat= 400

O_2 dry	Preheat temperature 200	350	500
0.0%	6.8%	12.1%	-
4.0%	8.4%	14.7%	-
8.0%	11.0%	19.0%	-
12.0%	16.5%	27.2%	-
16.0%	34.3%	49.7%	-

Exhaust temperature before preheat= 500

O_2 dry	Preheat temperature 200	350	500
0.0%	7.1%	12.7%	-
4.0%	8.9%	15.6%	-
8.0%	11.9%	20.4%	-
12.0%	18.6%	30.2%	-
16.0%	44.1%	59.9%	-

Exhaust temperature before preheat= 600

O_2 dry	Preheat temperature 200	350	500
0.0%	7.5%	13.4%	18.7%
4.0%	9.5%	16.6%	22.8%
8.0%	13.0%	22.1%	29.7%
12.0%	21.3%	33.8%	43.2%
16.0%	62.2%	75.7%	82.2%

09.10 17:16

This calculation sheet is used to calculate the gas temperature of the air preheater outlet from the heat balance of the air preheater using the macro instruction ¥E [Cell: ag21..an40]. Use of the macro instruction ¥I for What-if Table allows this calculation (macro ¥E) to further continue. You can use this temperature as a reference for studying low-temperature corrosion of the air preheater. The calculation sheet also displays the exchanged heat amount [Cell: w41..ae60] and logarithmic average temperature difference [Cell: ag101..ao120]. In these calculations, the heat emission from the surface of the air preheater can be set as the ratio to the holding heat amount of exhaust gas at the air preheater inlet (the heat balance is calculated by excluding this heat emission volume from the exhaust gas heat amount at the air preheater inlet [Cell: ai22]).

Also, the air leakage in the air preheater (assuming that preheated air has entered the exhaust gas side from the air side at the gas side inlet of the air preheater) can be set by the ratio to the theoretical combustion air [Cell: al22]. (Be sure to enter these setting values before performing the calculation using the macro instruction ¥I.) When these setting values are set to zero, the calculations are made by assuming that there is no heat emission and no air leakage.

Additionally, the following spreadsheets are provided:

- Air preheater logarithmic average temperature difference (Cell ag101:ao120)
- Air preheater temperature efficiency (Cell ag121:ao140)
- Air preheater inlet exhaust gas temperature (after mixing the leak air) (Cell aq101:ay120)
- Exchange heat value in the air preheater (Cell aq121:at130)

On the Cell a21 basic setting screen, effects of air ratio improvement and air preheating can be calculated on a trial basis. The set values (prerequisite) are as follows:

- Exhaust gas temperature (If the air temperature in basic setting is higher than the atmospheric temperature, the exhaust gas temperature to be set herein is treated as the air preheater inlet exhaust gas temperature.)
- Oxygen in the exhaust gas after improvement (This set value is treated as the Dry/Wet selection value for exhaust gas analysis currently selected.)
- Preheated air temperature

Under such prerequisite, items automatically calculated and displayed by the Table function, etc. are as follows:

- Air ratio (after improvement of oxygen in the exhaust gas)
- Fuel saving percentage as a result of air ratio improvement
- Exhaust gas temperature after the air preheater

(If the air temperature in basic setting is higher than the atmospheric temperature, it is understood that the air preheater is installed. Therefore, the exhaust gas temperature after the air preheater is calculated from the heat balance of the air preheater.)

- Exhaust gas volume (after air ratio improvement)
- Air volume (after air ratio improvement)
- Exhaust gas loss rate (after air ratio improvement)
- Fuel saving percentage by air preheating (Percentage against the air temperature in basic setting. If the air temperature and preheated air temperature are equivalent in basic setting, the air preheating effect is indicated as "zero".)

8.1.7 Boiler Heat Balance

The heat balance of the steam boiler is included in the combustion calculation worksheet. This calculation sheet allows you to calculate the boiler heat balance by setting the fuel volume, volume of feed water, exhaust gas temperature, and steam conditions according to the JIS land boiler heat balance (JIS B 8222), and to display the result of the calculation [Cell: az21..bh40]. (Be sure to complete combustion calculations such as fuel selection before calculating the boiler heat balance) [Cell: bi21..bq40]. The approximation formula of the steam table is used for calculating the steam enthalpy and compressed water enthalpy [Cell: az61..bg110]. You can select either of the following methods for the radiation heat from the furnace wall: (a) setting method by the ratio from the boiler capacity as indicated in JIS; (b) calculation method based on the furnace wall temperature. Screen 8.7 shows the basic numeric data for the boiler heat balance calculation and Screen 8.8 shows an example of the boiler heat balance table.

Screen 8.7 Assumptions for Boiler Heat Balance

Data for Boiler Heat Balance Calculation (combustion calculation to be completed) Ostrowiec

Time	Begin	1100	(set in four	Emission option	c
Time	Close	1200	digits)	d:JIS formal	1.28%
Time	hr	1		c:Calculation	0.28%
Boiler capacity t/h		12	(Rated)	m:Manually	1.4%
Base temperature		28		Adopted	0.28%

Item	Unit	Amount	/hour	Pressure abs	Temperature	Unit heat	Others
Fuel latent heat	m^3_N	1400.0	1400.0	-	-	8487	
Fuel sensible heat	kcal	1400	1400.0	-	28	0.00	
Burner air	m^3_N wet	20912	20912	-	844	0.00	
Invasion air	m^3_N wet	0	0	-	28	0.00	
Exhaust gas	m^3_N wet	22318	22318	-	240.0	69.31	
CO loss	m^3_N wet	0	0	-	-	3018	
Eco inlet feed	kg	-	-		14.5	14.8	
Boiler-in feed	kg	15000	15000		80	80.2	
Drum blow	kg	0	0	8.033	-	171.5	
Outlet steam	kg	15000	15000	12.00		654.8	
	Dryness%	98%	Wet steam				

Screen 8.8 Boiler Heat Balance Table

Boiler Heat Balance (net heat value based)

Ostrowicc

Heat-in

	kcal/m^3_N	kcal/h	%
Fuel caloric	8,487	11,881,806	100.0%
Fuel sensible heat	0.0	0.0	0.0%
Air sensible heat	0.0	0.0	0.0%
			0.0%
Total	8,487	11,881,806	100.0%

Heat-out

	kcal/m^3_N	kcal/h	%
Steam generated	6,858	9,600,876	80.8%
Exhaust gas loss	1,105	1,546,845	13.0%
CO loss	0.0	0.0	0.0%
Emission loss	24	32,903	0.3%
Sub total	7,986	11,180,624	94.1%
Miscellaneous	501	701,182	5.9%
Total	8,487	11,881,806	100.0%

Boiler efficiency

In/out method	80.8%
Heat loss method	86.7%

Utilized heat detail

	kcal/m^3_N	kcal/h	%
Main body of boiler	6157	8619727	72.5%
Economizer	701	981149	8.3%
Superheater	0	-	0.0%
Total	6858	9600876	80.8%

If the setting value of the steam temperature in the setting of steam conditions is lower than the saturation temperature of the setting pressure, it is treated as the saturated steam equivalent to the pressure. If the setting temperature exceeds the saturation temperature, it is treated as the super heat steam, and the setting value for dryness is ignored.

8.1.8 Successive Heat Balance Calculation for Boiler

When the measurement value to be applied as the assumption of heat balance such as the exhaust gas components is obtained by a time-oriented numeric data string (for example, when the values measured for each minute is obtained by a recording card of the continuous measuring instrument), this calculation sheet allows you to calculate the boiler heat balance successively by loading this numeric data group into the combustion calculation. In this manner, you can understand the operating characteristics such as boiler efficiency in the time series.

The combustion calculation sheet is provided with macro instructions which can input measured values from other Lotus 123 files, put these values successively into the setting values of the boiler heat balance in a chronological order, calculate the heat balance, and display the result [Cell: cal..cs14]. The measured values must be stored in the designated array in order to achieve this calculation. Moreover, the name of the file must be "Shiftavg" (Uppercase and lower case characters are not distinguished). The array of the measured values are stored in the data file Shiftavg.

From the Excel worksheet, part of a Lotus 123/DOS worksheet cannot be read with an area name by using a macro of Lotus 123/DOS. (Reading with a cell address is allowed but an area is specified with an area name in Shiftavg.) Therefore, the Shiftavg file should be read into Excel and then the data area should be transferred to the combustion calculation file by using the Excel's Copy/Paste function. In this case, the area to be copied is the numerically correct data in Shiftavg and the area name "adjusted" is assigned.

8.1.9 Measurement Data File

File: Shiftavg

The successive heat balance calculation macro loads the measured values from the file Shiftavg [Cell: ca21..ci21 and cells below] and uses this numeric data group to perform the successive heat balance calculation [Cell: cj21..cu21 and cells below]. Screen 8.9 shows a part of the result table of the heat balance calculation.

Screen 8.9 Successive Heat Balance Calculation

Time	HI	Fuel sensible heat	Air sensible heat	Total	Steam generated	Exhaust gas loss	CO loss	Emission loss	Miscellaneous	In-out method	H loss method
14:19:59	8,487.0	0.0	0.0	8,487.0	7,431.9	699.7	4.7	46.7	304.0	87.6%	91.2%
14:21:01	8,487.0	0.0	0.0	8,487.0	7,392.2	703.3	4.9	46.2	340.3	87.1%	91.1%
14:22:01	8,487.0	0.0	0.0	8,487.0	7,396.5	695.4	5.0	46.0	344.1	87.2%	91.2%
14:23:01	8,487.0	0.0	0.0	8,487.0	7,350.9	691.7	5.2	46.6	392.7	86.6%	91.2%
14:24:01	8,487.0	0.0	0.0	8,487.0	7,146.5	695.4	5.4	46.1	593.6	84.2%	91.2%
14:25:01	8,487.0	0.0	0.0	8,487.0	7,143.6	698.6	5.2	45.9	593.7	84.2%	91.2%
14:26:01	8,487.0	0.0	0.0	8,487.0	7,192.5	699.3	5.1	46.1	544.0	84.7%	91.2%
14:27:01	8,487.0	0.0	0.0	8,487.0	7,224.6	702.9	5.1	46.7	507.7	85.1%	91.1%
14:28:01	8,487.0	0.0	0.0	8,487.0	7,219.4	705.6	5.9	46.5	509.6	85.1%	91.1%
14:29:01	8,487.0	0.0	0.0	8,487.0	7,257.0	704.5	5.7	46.4	473.3	85.5%	91.1%
14:30:01	8,487.0	0.0	0.0	8,487.0	7,091.2	695.3	5.5	45.8	649.2	83.6%	91.2%
14:31:01	8,487.0	0.0	0.0	8,487.0	7,059.5	698.9	5.7	45.8	677.1	83.2%	91.2%
14:32:01	8,487.0	0.0	0.0	8,487.0	7,185.8	680.6	6.1	46.6	567.9	84.7%	91.4%
14:33:01	8,487.0	0.0	0.0	8,487.0	7,256.7	679.2	6.2	46.9	498.1	85.5%	91.4%

You can get the moving average for the measured values on the calculation sheet of the file Shiftavg. You can set the desired number of data for calculating the average once and the desired number of lines to be skipped for the moving average [Cell: r2..t3].

Example:

Calculate the average of successive 30 numeric values.
Next, move 15 lines down.
Calculate the average of successive 30 numeric values from this point.
Repeat the above.

Moving averages such as mentioned above are enabled. In the above example, the number of data for calculating the average is set to 30 and the number of lines to be moved is set to 15.

Furthermore, adjustment of the measured values is performed on the file Shiftavg. The adjustment of the measured values, for example, is performed on the assumption of temperature and pressure compensation for the flow rate measured values and conversion of the gauge pressure into absolute pressure. Compensation is performed for all measured items and the compensation formula is expressed by a simple equation [Cell: al4..i20]. Therefore, if compensation is not required, set the constant item of the equation of the first degree to 0 and set the coefficient of the simple equation to 1. Compensation is performed for all records in the same manner. In other words, you cannot change the coefficient of compensation for each record. The macro for compensation calculation automatically assigns the range name, adjusted, to the compensated data area upon completion of calculation.

Since the file Shiftavg has no function for loading the measured values, it is necessary to copy the measured data manually to this file.

8.1.10 Heat Balance Calculation of Reheating Furnace

File: HBFC_GAS

This file provides the heat balance calculation function of the continuous reheating furnace for the steel product in addition to the gas combustion calculation sheet. This, however, copes with gas combustion alone, but not the oil combustion. Since the amount of materials charged and the discharged weight cannot be expressed by the continuous measured values for the continuous reheating furnace, the successive heat balance calculation function such as for boiler example is not attached. Only the static heat balance calculation is performed.

The heat content of a steel product is given by the approximation formula [Cell: az61..bkl15]. The heat content changes according to the temperature, and it changes irregularly near the transition temperature. Therefore, the approximation formulas are provided each for the zone near the transition point, and for the temperature zones before and after this transition zone, thus connecting these three formulas. The heat amount content varies depending on the steel type. Therefore, formulas such as these are prepared for each steel type, and the necessary numeric value is selected using the Lookup function with the selection code of the steel type as a key [Cell: bd23]. You can select from 11 types of steel including rimmed steel and stainless steel.

An air preheater is, in many cases, installed in a reheating furnace. The air leakage rate in the air preheater can be calculated by measuring the oxygen in the exhaust gas at the inlet and outlet of the air preheater. Air leakage here means leakage of air to the exhaust gas side from the air side in the air preheater. The exhaust gas conditions (oxygen, temperature) in the basic setting screen (Cell a21:i40) are treated as the values for the exhaust gas at the outlet of the air preheater in the reheating furnace heat balance page. The exhaust gas conditions at the furnace body or air preheater inlet are set in Cell az41:bh49. Thus, entry of outer air into the exhaust gas between the furnace body and air preheater inlet or outlet can be obtained. Screen 8.10 shows the setting screen for heat balancing for a reheating furnace.

Screen 8.10 Setting for Rereating Furnace Heat Balance

Basic Data for Reheating Furnace Heat Balance (Including AH) — Ostrowiec

Time, begin	0	Steel 1-11	
Time, close	1400	1	
Time, hour	14.00 (digit)	Rimmed	

Heat emmission rate
Calculated 0.07%

Item	Unit	Amount	/hour	Temperature	/t-S	kcal/unit	kcal/t-charged	kJ/t
Fuel latent heat	m^3_N	81,540	5,824	-	52.88	8,487	448,787	1,878,624
Fuel sensible heat	kcal	-	-	28	-	0	0	0
Burner air	m^3_N	1,544,371	110,312	28	1002	0	0	0
Invasion air	m^3_N	0	0.0	28	0	0	0	0
Exhaust gas	m^3_N	1,626,352	116,168	426.0	1055	132	138,997	581,842
CO loss	m^3_N	0	0.0		0	3,018	0	0
Steel,charged	t	1,542	110.1	40	1.00	1,349	1,349	5,648
Steel,discharged	t	1511.16	107.9	1200	0.98	191,114	187,292	784,003
Scale loss	t	30.84	2.2	1160	0.020	1,334,926	26,699	111,760
Scale heat,sensible	t	-	-	-	-	330,335	6,607	36,630
TFe/scale		75.5%	-	-	-	-	-	-
In,cooling water	m^3	12600	900	32	8.171	-	-	-
Out,cooling water	m^3	-	-	40	-	8,000	65,370	273,637

Heat balance for a reheating furnace may be obtained for the system including the air preheater or for the system excluding the air preheater. Two heat balance tables are available for these two cases. Screen 8.11 shows an example of the heat balance table for reheating furnace [Cell:bi21..bq47].

Screen 8.11 Heat Balance Table for Reheating Furnace

Heat Balance of Continuous Reheating Furnace (includes AH)

Heat-in	(10^3 kcal/t)		Heat-out	(10^3 kcal/t)	
Fuel latent heat	448.8	94.1%	Slab discharged	187.3	39.3%
Fuel sensible heat	0.0	0.0%	Scale sensible heat	6.6	1.4%
Slab heat content	1.3	0.3%	Exhaust gas sensible heat	139.0	29.1%
Scale generation	26.7	5.6%	Cooling water	65.4	13.7%
Total	476.8	100.0%	Emission and miscellaneous	78.6	16.5%
Recovered in AH	111.1	23.3%	Total	476.8	100.0%

Heat balance of continuous reheating furnace (furnace only)

Heat-in	(10^3 kcal/t)		Heat-out	(10^3 kcal/t)	
Fuel latent heat	448.8	76.3%	Slab discharged	187.3	31.9%
Fuel sensible heat	0.0	0.0%	Scale sensible heat	6.6	1.1%
Air sensible heat	111.1	18.9%	Exhaust gas sensible heat	218.5	37.2%
Slab heat content	1.3	0.2%	Cooling water	65.4	11.1%
Scale generation	26.7	4.5%	Emission and miscellaneous	110.2	18.7%
Total	588.0	100.0%	Total	588.0	100.0%

8.1.11 Heat Value Adjustment of Liquid Fuel

File: H_BL_OIL

In the case of liquid combustion, the calorific value may sometimes be given as a precondition in addition to the fuel composition values. In this calculation sheet, however, the calorific value is calculated from the fuel composition values. Therefore, this calculated result does not always match with the given calorific value. In this calculation sheet, the unit calorific values of carbon and hydrogen among all fuel compositions are changed in proportion in order to provide a choice so that the given fuel calorific value is obtained (¥U) [Cell: a85..g100]. When this heat amount adjustment is performed, it is displayed on the screen [Cell: c22..e24]. Also, the adjusted value can be returned again to the original value using the same macro instruction.

8.2 Multi-Layer Heat Insulation

File: Mlt_INSU

For the heat insulation calculation, the heat conductivity coefficient of a heat insulation material changes depending on the temperature of the material. It is expressed by a quadratic equation of material temperature by JIS [Cell: cb1..eo40]. The heat transfer coefficient, which is a coefficient of heat loss from the outside surface of the heat insulation, is also given by the function of a surface temperature, making the heat insulation calculation become complex. Therefore, it is necessary to perform convergence by repeating the calculation. When you only wish to obtain an approximated result, it is accepted even if the heat conductivity coefficient and heat transfer coefficient do not rely on temperature. This calculation sheet can be used in these both cases.

8.2.1 Setting the Conditions

This calculation sheet allows you to calculate the surface temperature and heat emission volume when 2-layer or 3-layer heat insulation is provided for pipes, towers, and tanks. The inside and outside fluid temperature, the heat transfer coefficient of inside surface, and thickness of each layer must be set first as a precondition [Cell: a21..h40, i21..p40]. Then the heat insulation materials of each layer, outside surface heat transfer formula, wind velocity (only when there is forced convection), and emissivity of outside surface must either be selected or set from the menu of ¥A. The coefficient of the heat conductivity formula and heat transfer coefficient formula of the material is selected using a Lookup function by selecting the specific heat insulation material and heat transfer coefficient formula. There are no restrictions regarding the order of these selections and settings. Therefore, if you want to change the selection or setting you made, simply select or set the item again. You can also exit or return from/to the menu anytime, and need not to bother about setting omissions.

The heat insulation material must be selected for each layer. If, however, there is no target layer (for example, a 3rd layer when the heat insulation is performed for only 2 layers), you can simply set the thickness of the layer to zero. (In this case, even if the material of this layer is not selected, it will not affect the calculation results.) Normally, the materials (metal) of pipes, towers, and tanks are selected for the 1st layer. Since the heat conductivity coefficient of metal is large, you can ignore this and may start from the 1st layer of heat insulation. In this case, you will be able to calculate the heat insulation for up to 3rd layer.

For flat plate calculation, ceramic fiber and refractory brick are listed for material selection. By selecting one, heat insulation attained by the furnace wall in the reheating furnace can be calculated and the passing calories and temperature distribution in the furnace wall can be known.

8.2.2 Executing the Calculation

After completing the above settings and selections, you can perform the convergence calculation using the set conditions and formulas by selecting the calculation execution from the menu. Since the conditions (setting values and formulas) used for the previous calculation is retained, it is not necessary to set conditions when the same conditions are used next time. For example, this applies when you want to change the heat insulation material thickness and use other conditions same as the previous time.

The calculation sheet consists of the pipe and plane heat insulation pages, including the calculations for five cases. Therefore, you can see on the same display the calculation of a different portion or a trial calculation by changing the heat insulation material thickness and material. There are no mutual relationships between these five cases, and each case is independent. You can copy the setting conditions of another case to the currently selected case using the duplicate function in the menu. You can use the menu for selecting the pipe/plane and the case used for calculation. Screen 8.12 shows the setting page of the pipe case [Cell: a21..h40].

Screen 8.12 Multi-layer Insulation, Settings

Multi-layer heat insulation -- pipe				In frame :	<= Setting	Selected =>	2
Case No.			1	2	3	4	5
Pipe line name							
I/O temperature	Fluid, inside		250	180	180	180	180
	Ambient		20	20	20	20	20
H transfer	Inside		10000	10000	10000	10000	10000
coefficient	Outside	Convection	2.459	2.641	2.659	2.659	2.659
		Radiation	2.616	2.575	2.569	2.569	2.569
1st layer	Material		Steel 0.5C	Steel 0.5C	Steel 0.5C	Steel 0.5C	Steel 0.5C
	H transfer coefficient		46.0000	46.0000	46.0000	46.0000	46.0000
	Outside diameter		0.3185	0.1398	0.1143	0.1143	0.1143
	Thickness		0.006	0.006	0.006	0.006	0.006
2nd layer	Material		R.W.felt	R.W.felt	R.W.felt	R.W.felt	R.W.felt
	H transfer coefficient		0.0618	0.0518	0.0516	0.0516	0.0516
	Thickness		0.12	0.075	0.075	0.075	0.075
3rd layer	Material		G.W.cylinder	G.W.cylinder	G.W.cylinder	G.W.cylinder	G.W.cylinder
	H transfer coefficient		0.0342	0.0332	0.0330	0.0330	0.0330
	Thickness		0.025	0.025	0.025	0.025	0.025
H transfered	Per length (kcal/m)		118.07	50.28	44.29	44.29	44.29
Temperature	Outside surface		32.17	29.03	28.58	28.58	28.58

8.3 Economical Thickness of Heat Insulation

File: Eco_INSU

For the wall surface of steam pipes, heating tanks, and other portions, when the thickness of the heat insulation layer increases, the heat emission volume decreases, resulting in energy conservation and reduction of the fuel cost. However, the thick heat insulation requires a corresponding construction cost. JIS-9501 (1995) defines as "Economical thickness of heat insulation" the heat insulation thickness which can achieve minimum annual expense (sum of enery cost and the equipment/facility charge such as depreciation) by maintaining a balance between fuel cost reduction through heat insulation and equipment/facility cost (heat insulation construction cost), and provides the concept of this formula and specific calculated examples.

A number of factors (pipe diameter and thickness, heat transfer coefficient of the outside surface, thermal conductivity coefficient of the material, heat price, heat insulation construction cost, interest rate, and the payback period) are involved in the calculation of the economical thickness of heat insulation. Thus, it is quite difficult to calculate this manually. Moreover, the calculation examples given in JIS assume the specific conditions for these factors. Therefore, if the conditions are changed, you need to make calculations again.

This calculation worksheet accommodates such necessity.

In this worksheet, calculation for tubes and flat plates is also available. For set values, the inner/outer surface temperature, interest rate, etc. are treated as common setting conditions for both tubes and flat plates but the heat insulating material and tube diameter are individually selected for each of tubes and flat plates.

8.3.1 Setting the Conditions

In this calculation sheet, you have to set or select various preconditions such as temperature of each portion, economical conditions, and material selection. Then, the economical thickness, annual expense, and heat emission volume are calculated by executing the calculation using macro instructions. The macro instructions ¥R and ¥S are used for calculation of pipes and plane respectively. The setting cells for the setting values common for a pipe and plane are displayed on the left side portion of the screen, and the setting cells for the individual setting values are displayed on the right. Screen 8.13 shows the settings and calculation result [Cell: a21..h40].

Screen 8.13 Economical Thickness of Heat Insulation

Economical insulation			Conventional (kcal unit)		Currency	\unit
			<Pipe> (\R:calc)		09.09	22:34
<Premises---Pipe/Surface>			**Economical thickness**	Xp	0.083	m
Inside temperature	th.0	180.0	Outer diameter of insulation	do	0.281	m
Room temperature	th.r	20	Inner diameter of insulation	di	0.1143	
Heat transfer *	alpha	10.32	Annual expense	Fp	4876	\/year
Heat price *	b	5.81	Heat loss / hour *	Qp	59.9	kcal/m/h
Annual interest	n	5.00%	Surface temperature	th.pc	26.6	℃
Insulation life, year	m	15	Heat conductivity (avg)*	ramda.p	0.0558	
Working hour	hr	8,000	Insulation work price	ap	420	th.\/m³
Annual depreciation	dep	9.6%	Insulation material		Rockwool	
*: careful on unit			Bare tube heat loss		592.9	kcal/m/h
Work price coefficient	I	12	**<Plane surface> (\S:calc)**		07.28	21:51
Artificial fiber	La	200	**Economical thickness**	Xs	0.134	m
Inorganic porous	Lb	300	Annual expense	Fs	6415	\/year
Exchange rate	\/$	100	Heat loss / hour *	Qs	57.5	kcal/m²/h
Macros:	\U:Unit option		Surface temperature	th.sc	25.6	℃
\A:Menu	\P:Print		Heat conductivity (avg)*	ramda.s	0.0499	
\G:Call graph	\X:Boxes		Insulation work price	as	290	th.\/m³
\L:Cell protect	Free		Insulation material		R.W.board-1	

You can switch the unit of heat amount between kcal and Wh in this sheet (because the unit Wh is used in JIS), and the currency unit can be switched between yen (¥) and dollar ($) [Cell: rl..z16]. It should be, however, noted that the units of length m and ft are not switched even if you change the currency unit. Therefore, it is necessary to be careful about the unit when you check heat conductivity coefficient, and heat emission volume value. When the unit is switched, the values set before the switching takes place are retained as the converted value.

8.3.2 Calculation

The heat conductivity coefficient of the heat insulation material is given by function of a temperature. The coefficient of the heat conductivity formula is selected in the related calculated cells by a Lookup function in accordance with the material selection. The construction cost of heat insulation is set by a formula and the different coefficient is selected by a Lookup function depending on the category of the material [Cell: i32..I40, r32..s40].

In this calculation sheet, a differential value is calculated by differentiating the above-mentioned formula representing the annual expense with respect to the value for the insulation thickness. The convergence calculation macro repeats this calculation to find out the thickness so that the differential value will become zero [Cell: i21..o30, r21..x30]. The convergence limit is the setting value.

Also, "Pipe size/heat price vs economical thickness," "Heat insulation thickness and heat emission loss/equipment charge," and "Change of construction unit price and economical thickness" are provided as the What-if tables. The data in these tables is calculated using the macros indicated on each page of the table [Cell: r41..z120]. Screen 8.14 and Screen 8.15 show some of the examples of the tables.

Screen 8.14 Insulation Thickness & Annual Expense

Table.2 Economical thickness vs Annual expense (Pipe) (\J) 09.10 21:01

Insulation thickness to economical thickness	mm	Surface temperature	Loss heat	Loss expense	Fixed cost	Annual expense	Insulation work price
70%	0.058	30.0	74.8	3480	1626	5106	533.5
80%	0.067	28.6	68.7	3196	1772	4968	485.3
90%	0.075	27.5	63.8	2970	1927	4897	448.5
100%	0.083	26.6	59.9	2784	2092	4876	419.7
110%	0.092	25.9	56.5	2628	2266	4894	396.5
120%	0.100	25.3	53.7	2496	2448	4945	377.5
130%	0.108	24.8	51.2	2383	2640	5022	361.6

Screen 8.15 Heat Price & Economical Thickness

Table.1 Pipe size / Heat price vs Economical thickness (\H) 09.10 21:09

Heat price	25A	50A	100A	150A	200A	250A	300A	Plane
4	0.048	0.059	0.071	0.077	0.082	0.085	0.088	0.110
6	0.058	0.071	0.084	0.092	0.098	0.102	0.106	0.136
8	0.067	0.080	0.095	0.104	0.111	0.116	0.120	0.158
10	0.074	0.088	0.105	0.115	0.122	0.128	0.132	0.177
12	0.080	0.095	0.113	0.124	0.132	0.138	0.143	0.194
14	0.086	0.102	0.121	0.132	0.141	0.148	0.153	0.210

If you manually enter another value in the "economical thickness" cells [Cell: g23.g34] after calculating the economical thickness using the macro in this calculation sheet, the annual expense and heat emission volume are automatically calculated. In this case, the heat conductivity of the heat insulation material is calculated using the economical thickness (i.e., the thermal conductivity value under the heat insulation temperature in terms of the economical thickness). When the surface temperature changes are small, this would be a sufficient approximation (the What-if table is created in this manner).

8.4 Surface Heat Emission Calculation

File: EMISSION

For a pipe and plane, when the heat emission volume is calculated by setting the surface temperature, the heat transfer coefficient value of the surface directly affects the heat emission volume. On the convection heat transfer coefficient from the surface, several formulas have been suggested as functions of the surface temperature and ambient temperature based on the orientation of the surface (vertical orientation, horizontal orientation, etc.) and wind velocity. Using this calculation sheet, you will set the relevant preconditions of the calculation such as surface temperature, ambient temperature, emissivity, wind velocity, and surface area or pipe length; select the relevant formula for multiple surfaces (multiple calculation cases); and calculate the heat emission from the surface using macros. You can select the formula by setting the code (numeric value) associated with the formula [Cell: a3..o9]. This worksheet sets conditions for many cases and then performs calculation at once by using a macro. The calculation macro writes the result of calculation with each heat transfer expression to the list. Screen 8.16 shows an example of calculation.

Screen 8.16 Heat Emission Calculation

Heat Emission from Surface (execute calculation with macro C after complete settings)

Factory name:

Code:

111 Surf-Nat-Up-JIS	117 Surf-Nat-Up-Hirata	211 Pipe-Nat-Horizontal-Takamura
112 Surf-Nat-Down-JIS	118 Surf-Nat-Down-Hirata	212 Pipe-Nat-Horizontal-Hirata
113 Surf-Nat-Vert-JIS	119 Surf-Nat-Vertical-Hirata	213 Pipe-Nat-Vertical-Hirata
114 Surf-Nat-Up-Takamura	121 Surf-Forced-Smooth-JIS	221 Pipe-Forced-Takamura
115 Surf-Nat-Down-Takamura	122 Surf-Forced-Rough-JIS	
116 Surf-Nat-Vertcal-Takamura	123 Surf-Forced-Takamura	

Unit: m, deg C, hr, kcal

11-Jun-02 21:57

No.	Ambient temperature ℃	Surface temperature ℃	Formula Code	Wind velocity m/s	Emi-ssivity	S_typical length m	P_typical length m	Pipe diameter m	Area or Length m² or m	Heat transfer Convection kcal/m²/h/deg	Heat transfer Radiation kcal/m²/h/deg	Unit heat kcal/h /m² or m	Total heat kcal/h
1	20	120	113	6	0.6	6	0.5	0.1652	1	6.96	4.83	1,179	1,179
2	20	120	114	6	0.6	6	0.5	0.1652	1	6.28	4.83	1,111	1,111
3	20	120	115	6	0.6	6	0.5	0.1652	1	1.19	4.83	603	603
4	20	120	116	6	0.6	6	0.5	0.1652	1	5.83	4.83	1,066	1,066
5	20	120	117	6	0.6	6	0.5	0.1652	1	7.72	4.83	1,255	1,255
6	20	120	118	6	0.6	6	0.5	0.1652	1	0.87	4.83	570	570

When you calculate the heat emission volume from the inside based on the condition where the heat is emitted from the heat insulated surface, the heat resistance of the heat insulation material acts as a dominant factor in the heat transfer. Therefore, the heat transfer coefficient of the surface does not directly affect the heat emission volume, which may not be taken into much consideration. On the other hand, when the heat emission is calculated based on the surface temperature as it is in this calculation sheet, the heat transfer coefficient of the surface directly affects the heat emission volume. In an actual situation, the heat transfer coefficient is always changing due to wind velocity and sunlight, and the heat emission volume varies even depending on the selection of the formula used for calculation. Due to these reasons, the calculation result should not be regarded as absolute.

8.5 Approximation of Steam Table [Cell: a21..j140]

File: STEAM_14

For example, to find the pressure loss of a steam pipe, it is necessary at first to find the specific volume of the steam equivalent to the applied pressure and temperature on the steam table. Since the steam table is a list of numeric data and not formulas, you need to refer to the steam table every time the pressure and/or temperature changes. Also, an interpolation may be sometimes required depending on the pressure and temperature from the data obtained from the steam table.

The approximation formula of the steam table immediately gives the characteristic value when the steam conditions are set. Using this feature, you can easily perform simulations of various steam application problems on the work sheet. In this sheet, a formula is independent for each recorded item, and a macro is not used for the approximation itself. Therefore, you can utilize the portion you need by copying it to another sheet.

8.5.1 Pressure-Based Saturated Steam and Super Heat State Steam Table

There is one variable for the saturation steam table, one variable for pressure and one variable for temperature of super heat steam in the steam table. When there is one variable in this approximation formula, approximation is performed by polynomial expression. When there are two variables, the approximation is performed in the following manner. For example, the enthalpy under specific pressure is approximated by the polynomial expression of temperature, and this approximation is calculated for several levels of pressure beforehand. The enthalpy equivalent to the temperature under the pressures, which are before and after the level of the applied pressure, is calculated from the polynomial expression of temperature. The enthalpy under the applied conditions is then obtained by an interpolation based on the pressure.

The relative accuracy of the approximation formula for the enthalpy calculated using the above method is 0.1 % or less. Supposing that a pressure of 42 kg/cm^2 abs and a temperature of 480 °C are applied, the approximation result H = 811.5 is obtained by the interpolation (linear interpolation) based on the pressure using the following expression of temperature: 40 kg/cm^2 abs/480 °C, H = 812.04 (equation of the 5th degree of temperature) and 50 kg/cm^2/480, H = 809.21. The value displayed in the steam table is 811.6. Since the accuracy of approximation tends to be poorer near the lower limit of the applicable range, the steam characteristics for a pressure of 2 ata or less is calculated using another formula. Screen 8.17 shows an example of the steam table screen [Cell: a21..i40].

Screen 8.17 Pressure Based Steam Table

	(Pressure base) Saturated & Superheated Steam		Box	:Set value
Applied: Pr 1.5 - 140 abs under			\U:Pressure unit conversion	
	Temperature upto 500 °C		Current unit:	kg/cm² abs
Pressure kg/cm² abs	130.00			
Pressure kg/cm² gauge	128.97		When set temperature is less than saturation temperature,	
Pressure MPa	12.75		calculation is on saturated steam.	
Temperature °C	340			

<Saturated steam, pressure base>	(kcal)	(kJ)	<Super heat steam>	(kcal)	(kJ)
Saturation temperature	329.3		Super heat degree	10.7	
Saturated water volume	0.001538		Volume m³/kg	0.0142	
Saturated steam volume	0.013		SH steam enthalpy	655.7	2745
Saturated water enthalpy	363.7	1522	SH heat amount	17.7	74.0
Saturated steam enthalpy	638.0	2671	Average specific heat	1.652	6.914
Latent heat	274.3	1148	SH steam entropy	1.331	73.99
Saturated water entropy	0.847	3.546			
Saturated steam entropy	1.303	5.452			

The applicable range of this sheet is up to a pressure of 140kg/cm² and temperature of 500 °C. Since the approximation formula approximates the physical characteristic value of steam without any connection to the physical properties, it is not recommendable to perform extrapolation exceeding the applicable range.

This file contains the following approximation formula in addition to the above screen.

8.5.2 Temperature-Based Saturated Steam Table [Cell: k21..r60]

Setting value: Temperature

Approximated values: Saturation pressure (kg/cm² abs, kg/cm² gauge, MPa), Saturated water specific volume, Saturated steam specific volume, Saturated water enthalpy, Saturated steam enthalpy, Saturated steam latent heat, Saturated water entropy, Saturated steam entropy

8.5.3 Low-Pressure Saturated Steam Table (0.01 to 2.0 kg/cm^2) [Cell: u21..aa80]

Setting value: Pressure

Approximated values: Saturation temperature, Steam specific volume, Saturated water enthalpy, Steam enthalpy, Saturated water entropy, Steam entropy

This file also contains a table which calculates the saturation pressure from the setting values of the temperature, enthalpy, and entropy besides the above.

8.5.4 Compressed Water (0.1 ≤ P) [Cell: a21..aa8]

Setting value: Pressure, temperature

Approximated values: Enthalpy, Entropy

8.5.5 Mutual Approximation of Quantity of Steam State [Cell: bo21..bw140]

The following approximation formulas on pressure P, temperature T, entropy H, and enthalpy S are provided for super heat steam:

P.H to T, P,S to T, P,S to H, and P,H to S

On saturated steam: S to H
On saturated water: S to H

The following examples are provided in the same file as the application examples of the approximation formulas.

8.5.6 Steam Accumulator Calculation [Cell: ad21..ah40]

In this calculation, the initial pressure and final pressure of the steam accumulator and the hot water capacity in the vessel are set to calculate the steam volume generated between these two pressures. Generally, the steam volume of the accumulator is given by a graph using these data as parameters. If you use this approximation, the steam volume of the accumulator is given as numeric value on the worksheet. Therefore, it is easy to perform the simulation using the initial pressure and/or final pressure as parameters. Screen 8.18 shows an example of the calculation.

Screen 8.18 Steam Accumulator

Steam Accumulator & Self Evaporation of Hot Water			Box :set value
	Applicable: 1.5 - 140 kg/cm² abs under		
	Initial	Final	
Pressure kg/cm² abs	120.00	10.00	
Pressure kg/cm² gauge	118.97	8.97	
Pressure MPa	11.77	0.98	
Saturation temperature	323	179	deg C
Saturated water enthalpy	354.3	181.3	kcal/kg
Saturated water volume	0.00150	0.00112	m³/kg
Latent heat	288.5	481.6	kcal/kg
Saturated steam enthalpy	642.8	662.8	kcal/kg
Saturated steam volume	0.0146	0.1979	m³/kg
Unit evaporation		0.2	kg/m³-initial w.volume
Saturated water amount	80.0	51.2	ton
Saturated water ttl volume	120.0	57.6	m³
Evaporation	0	28.7	ton
Steam volume	0.00	5687	m³

8.5.7 Pressure Loss of Steam Pipe [Cell: ax21..bd100]

Since the specific volume of steam is represented by the approximation formula, you can easily calculate the pressure loss of the pipeline. In this calculation, the inside diameter of the pipe is read by entering the pipe code (such as Sch40, Sch60, Sch80) and nominal size A value (for example, "150" by the unit of mm). The flow velocity is calculated from the specific volume by setting the steam pressure, temperature, flow rate, and the pipe length, and then the pressure loss is calculated. The formula specified in the latest version of "How to Utilize Steam, Application edition" (issued by the Energy Conservation Center, Japan, in 1984) is used for the calculations. However, the gradual decline of pressure in the direction of pipe length due to pressure loss and the changes of specific volume are not taken into consideration. If such considerations are necessary, you can perform the calculation by dividing the length of entire pipe into some portions lengthwise.

At the same time, the heat expansion of the pipe and the steam volume required for heating up the pipe at the initial stage are calculated. (This calculation is made by assuming that the heat amount required for increasing the temperature of pipe material is supplied by the latent heat of the steam equivalent to the pressure, and does not include the heat emission.) The calculations are made for steel, copper, and aluminum as pipe materials. Screen 8.19 shows an example of the calculation.

Screen 8.19 Pressure Drop & Heat Up Steam in Steam Pipe

Pressure loss, heat expansion & heat up steam of steam pipe [Box] :set value

Applicable: 1.5 - 140 abs under

(Set nominal size A, then check nominal size B)

<Setting>

JIS pipe code		[2]
1:SGP 2:Sch40 3:Sch80		
Nominal size A (mm)		[200]
Nominal size B (inch)		8
Inside diameter:Di	m	0.1999
Pipe weight	kg/m	42.1
Steam flow:G	t/h	[20]
Pressure abs	kg/cm²	[15]
Temperature	°C	[230]
Latent heat	kcal/kg	465
Unit volume:v	m³/kg	0.1467
Saturation temperature	°C	197
Pipe length:L	m	[200]
Initial temperature	°C	[20]

<Calculated>

Flow velocity		m/s	26.0
Pressure loss		kg/cm²	0.483
Heat expansion		m	
	Carbon steel		0.400
	SUS 18-8		0.547
	Aluminum		0.806
	Copper		0.560
Heating steam		kg	356.4
(as saturated steam / steel pipe)			

If set temperature is less than saturation temperature of steam, the sheet assumes it as sat steam.

Pressure loss formula: $10.5/10^8*v*G^2/((Di/1000)^5*(@PI/4)^2)/3.6^2*L$

(Quoted from "Intelligent steam use"(ECC) p.72

Equivalent length on right

8.5.8 Steam Turbine Calculation [Cell: by21..cg180]

In this calculation sheet, the enthalpy difference in the steam turbine is calculated by a simple method by using a square and ruler on the i-s chart attached to the steam table. If you, however, use the approximation formula of the steam table and the mutual approximation of the steam characteristic value, you can perform the steam turbine simulation on the worksheet. On this worksheet, for the simple extraction condensing turbine (without re-heating), the output of high & low pressure parts and overall efficiency are calculated by setting data such as the steam conditions of inlet steam and extraction steam, expansion efficiency, and condenser vacuum (switchable between vacuum and saturation temperature). (The extraction steam is set by the ratio to the inlet steam flow). The overall efficiency is calculated by assuming that all heat amount which the extraction steam is retaining is effective. Screen 8.20 shows an example of the steam turbine calculation.

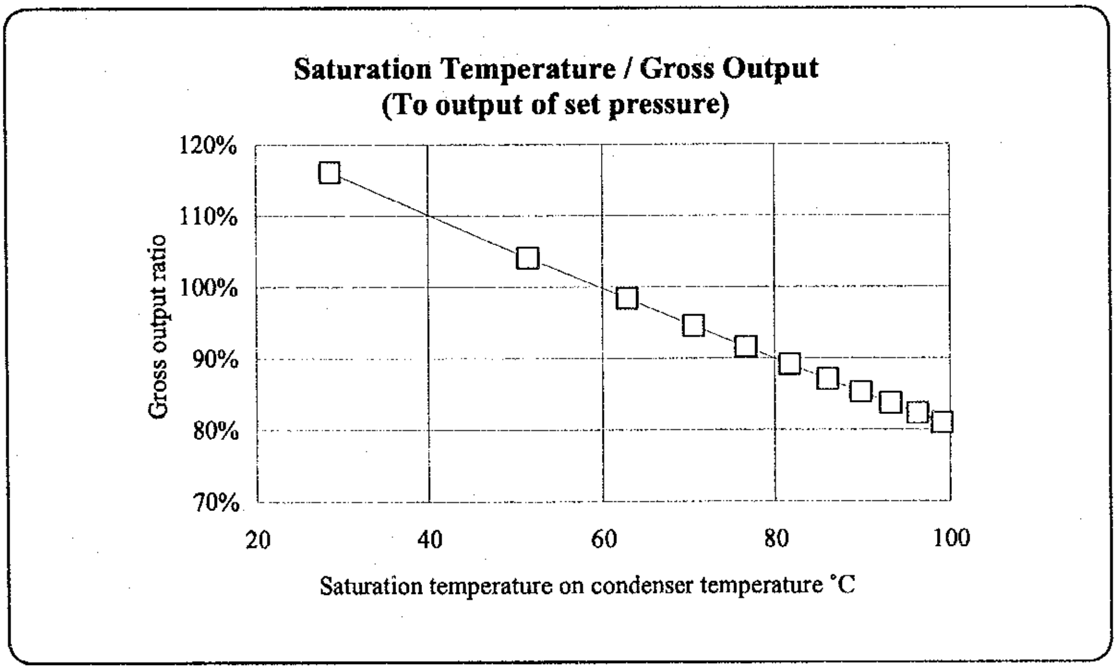
Screen 8.20 Steam Turbine Simulation

Steam Turbine — Box :set value

<H-P turbine>		<L-P turbine>		<Condenser>	
(Back-pressure turbine)		(Condensing turbine)			
Pressure	40	Extraction pressure	20	Pressure	0.20
Temperature	275	Temperature	211.4 Wet	Vacuum Hg	612.9
Enthalpy	689.6	Enthalpy	661.6	Saturation temperature	59.66
Entropy	1.488	Entropy	1.502	Dryness	81.5%
Expansion efficiency	80.0%	Expansion efficiency	85.0%	Enthalpy	518.9
Power out	0.0326	Power out	0.1659	Entropy	1.577
(kWh/kg-stm)		(kWh/kg-stm)			
Steam kg	1	Extraction kg	0.4	Condense kg	0.6
		Extraction ratio	40.0%	Overall efficiency	54.9%
				(Overall efficiency)	
Output(kWh)	0.0326 (kWh)	Output(kWh)	0.0996 (kWh)	Total out	0.1321 (kWh)

You can easily simulate the effect (sensitivity) of all presumed values for the turbine output using this calculation sheet. The study using extraction steam pressure and condenser vacuum as parameters is displayed in a graph as an example on the sheet. Screen 8.21 shows the saturation temperature equivalent to condenser vacuum and turbine output.

Screen 8.21 Sensibility of Condenser Saturation Temperature on Turbine Output



If you set the efficiency to zero, this sheet can be used for the calculation of simple pressure reduction (adiabatic expansion of enthalpy constant).

8.5.9 Pressure and Temperature Reducing Device [Cell: ci21..cn85]

When the back-pressure turbine is used for generating electric power and supplying the process steam, a pressure and temperature reducing device by water injection for high-pressure super heat steam is sometimes installed as the turbine bypass to cope with turbine shutdown time and load fluctuation. In this calculation, you will set the primary side and secondary side steam conditions and water injection conditions to calculate the necessary water injection volume. Screen 8.22 shows an example of this calculation.

Screen 8.22 Pressure & Temperature Reduction

Temperature, Pressure reducing device (by water injection) [Box] :set value

			Primary	Secondary
Steam				
	Pressure	kg/cm^2 abs	60	16
	Temperature	°C	300	230
	Enthalpy	kcal/kg	689.7	685.4
	Amount	t/h	25	25.19
Water				
	Pressure	kg/cm^2 abs	69	
	Temperature	°C	120	
	Enthalpy	kcal/kg	121.4	
	Injection	t/h	0.191	

8.6 Using the Calculation Disk

(The information in this section is given based on Lotus 123/DOS. The spread sheet on Windows may be slightly different in the display format and selection method.)

8.6.1 Menu

These worksheets developed on Lotus 123/DOS are provided in the Book format of Exel97. When you boot up your existing Excel97 on your PC and load the necessary files from this disk, the private menu will appear on the screen in most cases. When you use the cursor key to move the cursor on this menu, the outline of each menu will be displayed on the message line above the menu line. To enter data in the setting value cell, you need to exit this menu using Exit. However, we recommend you to use this menu to look through the pages of the sheet screens before exiting the menu. (Press the Return key at the desired menu item to jump to the relevant page.) Since the private menu can hold only 8 items, sometimes a sub-menu is provided under the specific item. A selection is provided so that you can return to the original menu after moving to the sub-menu and you can also quit the menu.

The screen display area is fixed on the DOS version. On the other hand, the screen display area can be adjusted for the Windows version, and thus the operation of moving between screens using macros may not be effective in some cases. It will not affect the calculation, however. Since the layout on the worksheet is displayed as a table in most of the files, you can grasp most of the worksheet structure by moving to the "Location map on the menu". If you make a print-out of this map page, you can keep it with you for reference whenever you need to. Screen 8.23 shows a location map of the gas combustion sheet.

Screen 8.23 Location Map on Combustion Calculation Sheet

Location Map

(H_BL_GAS.xls)

	A	J	V	AF	AP	AZ	BI
1	Instruction	What-if remarks	W/D option remarks	Air Heat remarks	Map	Heat balance remarks	Macro list
21	Setting Basic calculation	AR adjust effect	Air heating effect	AH outgas temperature	Cp arrange (Heat balance)	Heat balance setting	H_balance table
41	What-if table	Utilized heat Saturated water	AH calc	AH outgas macro	AH heat balance	Surface emission	AR.AH effect
61	Fuel composition	Heat value Air required	Combustion calculation	Fuel selection	O/CO W/D option	Sm_Hs approximation	H_balance English
81	Gas Cp coefficients	Adiabatic temperature calculation	Cp arrange	AR W-ifs macro	Adiabatic W-if macro	FW_Hw approximation	H_balance JIS style
101	Menu macros	Control macros	Humidity option RH/WB	AH logarithmic mean temperature difference	AH inlet gas temperature	Hw/T approximation	-
121	-	-	Humidity option to AE180	AH temperature efficiency	AH exchanged heat	AH effect	-

ca1.. Heat balance macro   cj1.. Heat balance macro
ca21.. Heat balance data   caj1.. Heat balance data

You can enter this private menu anytime using macro instruction ¥A from normal input status (Press and hold down Ctrl (or Alt) key and press the A key).

8.6.2 Input and Calculation

When you enter a value in a cell on the spread sheet, the calculation is automatically performed and the displayed values of the related cells will change. For numeric input to the cell indicated with %, a % value should be directly entered in Excel. For example, to set 24% in fuel gas composition, enter 24, instead of 0.24. The cells that you can set are enclosed in a thick frame (the frame line type may not be distinguishable or the frame line may not be displayed on some PC and/or some software types).

If you accidentally enter data in the cell in which a formula is written, the formula may be destroyed and you could be obtaining a wrong calculation result if you did not notice this mistake. Even if you notice such a mistake, it is difficult to recover many of the formulas after the file has been saved and has replaced the original file. If you lock the cell using macro instruction ¥L (cell protect/free), you can avoid the destruction of formulas by accidental inputs. It is best, however, to make a backup copy of the disk (files) in the beginning to prevent these troubles.

8.6.3 Macro

A part of the calculations (such as a calculation to be repeatedly performed for convergence) and What-if table must be recalculated by executing macros. In such cases, indications such as ¥C is displayed on the relevant calculation pages. You simply need to execute this indicated macro (press and hold down the Ctrl (or Alt) key while pressing the C key in the same manner as mentioned earlier). Lotus 123/Windows or Excel/Windows can read the macros as they are and execute them without rewriting the macros of Lotus 123/DOS.

For macros commonly set for files, there are ¥X (hide/display ruler—does not work on Excel) and ¥A (initial menu) in addition to ¥L described above. ¥L and ¥X are so-called toggle switches. Each time you press the switch, the operation is reversed. For example, after setting the cell protect by pressing ¥L, press ¥L again to cancel the protect status and enable input in the cell.

The print macro ¥P does not work on Excel. Printing should be performed by using the Windows' feature.

A macro consists of a series of written procedures to be performed by keyboard input on Lotus 123 as they are according to an input sequence along with the indications of the dedicated macro instructions. Since the types and use methods of the dedicated macro command can be displayed by the Help of Lotus 123/DOS (you can read this information from the worksheet any time using Help key), you can easily understand the dedicated macro command (used for a branch of operation according to the conditional judgment and menu screen display control in many cases) used in this sheet and change them according to your needs. To execute a macro, simply hold down the Ctrl key (or Alt key for some PC) and press the relevant alphabet key. Lotus 123 starts reading and executing the procedures one after another from the cell in which the macro was indicated to the lower cells, and the operation is stopped (ended) if there is a blank cell. Therefore, the cell immediately below the macro end cell must either be left blank, or "{quit}" must be indicated in the last of the macro instructions (this is more secure) to declare the end. Moreover, if you assign the name "¥0" (zero) to the macro, this macro is executed immediately after reading the file. The macros of the private menu of this calculation sheet are processed in this manner.

8.6.4 Operation Table

The What-if table is also called the operation table. It is used for checking how the calculated numeric values change when 1 or 2 setting values are changed in the process of a series of calculations. This table is one of the convenient functions of the spread sheet. You can create an operation table by selecting the desired variables and calculated result values. However, some procedures (key operations using Lotus menus) are necessary. In this calculation sheet, several What-if tables are provided on the screen and the macros for calculation key operations have been prepared. Therefore, you can look at the simulation result by simply executing the macro name (such as ¥T) indicated at the title portion of each operation table, and also check the calculation result of some tables in a graph.

Excel has a feature that creates the What-if table as if it was made through calculation with a function, without need of each calculation. This worksheet uses this "Table" feature for part of the combustion calculation worksheet. It should be noted that this "Table" feature will be lost if this worksheet is saved in the Spreadsheet format other than Excel.

8.7 Japanese Version Enecalc.wj2

The following calculation sheets have been developed for the Japanese version, in addition to the calculation sheets explained above.

Combustion calculation of solid fuel

Heat calculation A, B — Heat transfer formulas, heat exchange, and heat transfer coefficient examples

Various gas specific heat, evaporation out of hot water surface, air invasion from furnace openings, and ambient diffusion formulas

Pressure loss of gas and liquid tree structure pipes

Pressure loss of gas and liquid loop structure pipes

Economical study of the co-generation system

Among the English version calculation sheets we have offered this time, the successive heat balance of boiler, heat balance of reheating furnace, Shiftavg, and EMISSION functions and/or files are not included in the Japanese version.

9. INDUSTRY SPECIFIC MEASUREMENT PLANS

9. INDUSTRY SPECIFIC MEASUREMENT PLANS

9.1 Iron and Steel Industry

9.1.1 Iron and Steel Industry (Ostrowice)

(1) Electric Arc Furnace

a. Purpose of measurement

The purpose is to grasp the current state of operation in order to assess the input energy and amount of heat loss at an electric arc furnace, and calculate the potential for energy conservation.

b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Cooler inlet exhaust gas CO vol%	4 charges	CO, CO_2 meter	to Recorder
② Cooler inlet exhaust gas CO_2 vol%	4 charges	CO, CO_2 meter	to Recorder
③ Cooler inlet exhaust gas O_2 vol%	4 charges	O_2 meter	to Recorder
④ Cooler inlet exhaust gas temperature	4 charges	Thermocouple	to Recorder
⑤ Cooler inlet exhaust gas pressure	4 charges	Digital low pressure indicator	to Recorder
⑥ Cooler inlet exhaust gas flow rate	4 charges	Hot wire anemometer or Pitot tube	to Recorder
⑦ Cooling water flow rate	4 charges	Ultrasonic flowmeter	to Recorder
⑧ Cooling water pressure (inlet)	4 charges	Pressure gauge	to Recorder
⑨ Cooling water pressure (outlet)	4 charges	Pressure gauge	to Recorder
⑩ Cooling water temperature (inlet)	4 charges	Thermocouple	to Recorder
⑪ Cooling water temperature (outlet)	4 charges	Thermocouple	to Recorder
⑫ Molten steel temperature	4 charges	Meters for operation	to Recorder
⑬ Combustion O_2 flow rate	4 charges	Meters for operation	to Recorder
⑭ Fuel flow rate	4 charges	Meters for operation	to Recorder
⑮ Power consumption and power factor of EAF	4 charges	Meters for operation	to Recorder
⑯ Power consumption for cooling water pump	4 charges	Clamp meter	to FDD
⑰ Power consumption for IDF	4 charges	Clamp meter	to FDD
⑱ Furnace surface temperature	spot	Radiation pyrometer	Memo
⑲ Carbon input	4 charges	Operation record	Memo

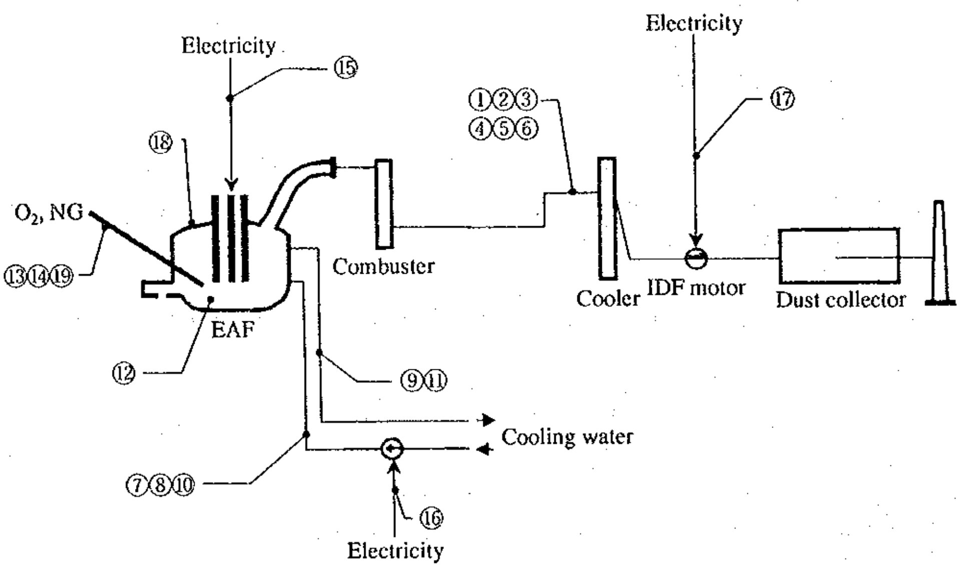
Notes 1: Items ① through ⑥ should be measured at the cooler's outlet if they cannot be measured at its inlet.

2: The following operation data, in addition to the items shown above, are also necessary to grasp the current state of operation. (Amount of tapped steel, amount of slag, amount of scrap, amount of pig iron, amount of electrodes consumed, hot heel, amount of dust, composition of dust, composition of slag, scrap temperature, etc.)

c. Measurement points

The measurement points for an electric arc furnace are shown in Figure 9.1.1.

Figure 9.1.1 Measuring Points of Electric Arc Furnace



(2) Rolling Mill and Reheating Furnace

a. Purpose of measuement

The purpose is to grasp the present operation status of a rolling mill in order to obtain the electricity intensity of the rolling mill and perform heat balancing of a reheating furnace.

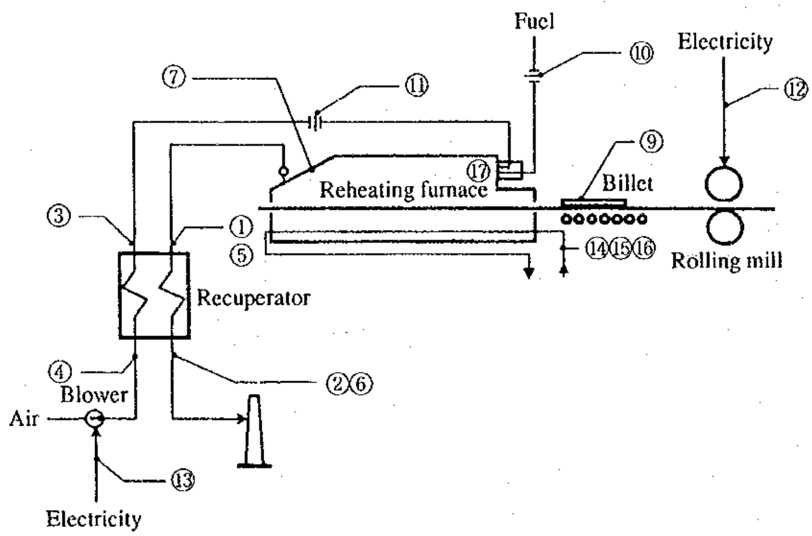
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Exhaust gas temperature at recuperator inlet	24 h	Thermocouple	to Recorder
② Exhaust gas temperature at recuperator outlet	24 h	Thermocouple	to Recorder
③ Combustion air tempearture at recuperator outlet	24 h	Thermocouple	to Recorder
④ Combuston air temperature at recuperator inlet	24 h	Thermocouple	to Recorder
⑤ Exhaust gas O_2 % at recuperator inlet	24 h	O_2 meter	to Recorder
⑥ Exhaust gas O_2 % at recuperator outlet	24 h	O_2 meter	to Recorder
⑦ Reheating furnace wall temperature	spot	Radiation pyrometer	Memo
⑧ Area of the opening	spot		Memo
⑨ Billet delivery amount	24 h	Operation record	Memo
⑩ Fuel flow rate	24 h	Operation record	Memo
⑪ Combustion air flow rate	24 h	Operation record	Memo
⑫ Power consumption for rolling mill	24 h	Meters for operation	to Recorder
⑬ Current, power consumption and power factor of reheating furnace blower	24 h	Clamp meter	to FDD
⑭ Amount of cooling water	1 heat	Ultrasonic flowmeter	to Recorder
⑮ Cooling water temperature at inlet/outlet	1 heat	Thermocouple	to Recorder
⑯ Pressure of cooling water	1 heat	Pressure gauge	to Recorder
⑰ O_2 % in the furnace	spot	O_2 meter	Memo

c. Measuring points

Figure 9.1.2 shows the measuring points of a rolling mill and a reheating furnace.

Figure 9.1.2 Measuring Points of a Rolling Mill and a Reheating Furance



(3) Heating Furnace for Forging

a. Purpose of measurement

The purpose is to grasp the current operating status of a heating furnace for forging in order to perform its heat balance.

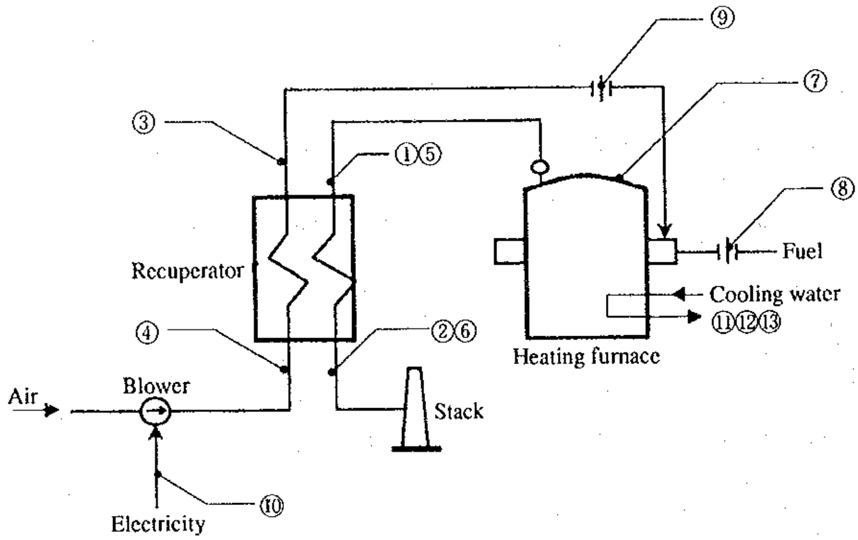
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Exhaust gas temperature at recuperator inlet	1 heat	Thermocouple	to Recorder
② Exhaust gas temperature at recuperator outlet	1 heat	Thermocouple	to Recorder
③ Combustion air tempearture at recuperator outlet	1 heat	Thermocouple	to Recorder
④ Combuston air temperature at recuperator inlet	1 heat	Thermocouple	to Recorder
⑤ Exhaust gas O_2 % at recuperator inlet	1 heat	O_2 meter	to Recorder
⑥ Exhaust gas O_2 % at recuperator outlet	1 heat	O_2 meter	to Recorder
⑦ Reheating furnace wall temperature	spot	Radiation pyrometer	Memo
⑧ Fuel amount	1 heat	Operation record	Memo
⑨ Combustion air flow rate	1 heat	Operation record	Memo
⑩ Current, electric power and power factor of blower	1 heat	Clamp meter	to FDD
⑪ Amount of cooling water	1 heat	Ultrasonic flowmeter	to Recorder
⑫ Cooling water pressure	1 heat	Pressure gauge	to Recorder
⑬ Cooling water temperature	1 heat	Thermocouple	to Recorder

c. Measuring points

The measurement points for a heating furnace for forging are shown in Figure 9.1.3.

Figure 9.1.3 Measuring Points of a Heating Furnace for Forging



(4) Energy Utilization Facilities

Equipment	Targeted equipment or location	Measurement time
Electricity management	Electric arc furnace	24 h
Fan/blower	Electric arc furnace	24 h
Electric motor	Electric arc furnace	24 h
Air compressor		24 h
Pump	Electric arc furnace cooling water Central pump	24 h 24 h
Lighting	Various locations in the factory	spot
Boiler	Boiler room	24 h
Steam pipe	Various locations in the factory	spot

For the measuring method and measuring points, see "10. ENERGY UTILIZATION FACILITIES".

HUTA OSTROWIEC CHECK LIST

1. Factory out-line
   (1) Factory name — Huta "Ostrowiec" SA
   (2) Adress — 27-400 Ostrowiec ue. Samsonwicze 2
   (3) No.of employee — 4,151
   (4) Main products — Deformed bars,plain bars and wire rod
   Forged product
   (5) Production capacity — Bar and wire rod : 60,000t/M
   Forged products : 10,000t/M
   (6) Process outline

   (7) History
   · foundation 1913
   · history of expansion and revamping
   Metallugical line
   - EAF :
   - CC : In CC was installed for the first time in poland. Now they have a plan to renew it.
   - Mill : Instrumentation was renewed in

   Processing line
   - EAF :
   - Forging shop :
   - Mechanical working shop

   · Shear of products in poland

   · Evaluation on products quality……… see pamphlet
   (recognized by LLOYD's etc)

   · Feature of process

   (8) Plant layout

   (9) Electricity one line diagram

   (10) Eergy price
   Electricity
   Natural gas
   Oil
   light oil

2. Production and energy consumption

(1) Trend of production

	Unit	1992	1993	1994	1995	1996
Bar and wire						
Forged product						

(Metallurical line)

Molten steel	t		437,832	586,682	658,020
Bar	t		388,839	441,138	485,759

(2) Trend of energy consumption

	Unit	1992	1993	1994	1995	1996
Fuel oil	t		42,674	38,424	0	
Diesel oil						
Kerosene						
Natural gas	$10^3 Nm^3$		50,257	41,133	84,063	
Coal						
Other fuels						
Electricity	Mwh		503,774	410,653	634,620	
Raw water(river)	m^3		780,800	381,995	210,400	
Steam and hot water						
Oxygen(L-O_2)						

(3) Trend of energy intensity

	Unit	1992	1993	1994	1995	1996
Fuel oil						
Diesel oil						
Kerosene						
Natural gas						
Coal						
Other fuels						
Electricity						
Raw water						
Steam and hot water						
Oxygen						

(4) Rate of energy cost vs product cost : about %

3. Energy conservation activity

(1) Energy conservation strategy and target

(2) How do you follow about it ?

(3) Problems on promotion of energy conservation .... list attached

(4) Energy conservation items in the past or future .... list attached
- Operation improvement
- Process modification

(5) Energy conservation promotion organization

(6) Activity of energy conservation committee

(7) Do you have the group that execute mainly energy conservation activity, and how they do it ?

(8) Personal evaluation for energy conservation activities such as promotion and award

4. Energy management

(1) Data of energy consumption by process

(2) Cost sheet of main product

(3) Monthly report of production and energy consumption showing comparison between planning and actual data.

(4) Energy supply flow diagram showing flow meter location

(5) Commendation or award system for man and group in energy conservation activity （表彰制度）

5. Metallurgical Line

(1) Main specifications

Equipment	Specification	
EAF (2set)	Type	Electric arc furnace with EBT
	Nominal capacity	140 ton/charge
	Fabricator	
	Installation	
	Trans former capacity	Nominal MVA
	Voltage 1st/2nd	110 KV/
	Ampere (2nd)	A
	Type of dust collecter	
	Capacity of fan	KW
	Oil burner capacity	l/h× set
Ladle furnace (set)	Type	
	Capacity	ton/ch
	Fabricator	
	Installation	
	Trans former capacity	Nominal MVA
	Voltage 1st/2nd	KV/ V
	Function	
	Heating	
	Decarburization	
	Degassing	
	Alloying	

Equipment	Specification	
Continuous caster (2set)	Type	
	Strand	4 /set
	Capacity	t/h
	Fabricator	Demag
	Installation	
	Casting speed	m/min
	Product	Bloom 220mm × 220mm
		mm × mm
Reheating furnace (1 set)	Type	Pusher type
	Capacity	t/h
	Fabricator	
	Installation	
	Furnace dimention	width ×effective length
	Charged materials	Bloom 220mm × 220mm
	Kind of fuel	Natural gas
	Burner capacity	max Mcal/h
	Target of furnace temperature	Heating zone ℃ Soaking zone ℃
Rolling mill (1 set)	Type Capacity Product Max. rolling speed Motor capacity	 t/h Bar and wire rod m/s (rougher sub-total) MW (intermediate sub-total) MW (finisher sub-total) MW

Equipment	Specification	
Reheating furnace after rougher (1 set)	Type	Pusher type, side charge, side discharge
	Capacity	t/h
	Fabricator	
	Installation	
	Furnace dimention	width ×effective length
	Charged materials	Bar
	Kind of fuel	
	Burner capacity	max Mcal/h
	Target of furnace temperature	℃ ℃

(2) Design and operational information

Process	Item	Design	Actual
EAF	Production	t/ch	t/ch
	Productivity	t/h	t/h
	Tap-to-tap	90 ? min	135 min
	Scrap ratio	%	%
	Molten steel temp.	℃	℃
	Electricity consumption	kwh/t	EFonly 500 kwh/t
	Electrode consumption	kg/t	kg/t
	Cooling surface rate of wall	%	%
	O_2 injection	Nm^3/t	Nm^3/t
	Oil injection	l/t	l/t
	Cabon injection	kg/t	kg/t
	Scrap pre-heating temp.	scrap ℃	scrap ℃
		exhaust gas ℃	exhaust gas ℃
	Other fuel consumption	Nm^3/t	Nm^3/t

Process	Item	Desing	Actual
Ladle furnace	Treatment rate		
	Treatment time (net)		
	Electricity consumption		
	Fule consumption		
	Other energy consumption		
Continuous caster	Productivity	t/h	t/h
	Casting speed	m/min	m/min
	Ave. continuous c. rate		
	Electricity consumption	kwh/t	kwh/t
	Fuel consumption	Nm^3/t	Nm^3/t
Reheating furnace	Productivity	t/h	t/h
	Fuel consumption	Mcal/t	$60Nm^3/t$. (Mcal/t)
	Yield in furnace	%	%
	Kind of fuel	oil	Natural gas
	Burner capacity		
	Preheating zone upper	N m^3/hx set	N m^3/hx set
	lower		
	Heating zone upper		
	lower		
	Soaking zone upper		
	lower		
	Heat insulation material		
	Electricity consumption	kwh/t	kwh/t
	Disccharge temp of billet	℃	℃
	O_2 content of exhaust gas	%	%
Rolling mill	Productivity	t/h	t/h
	Electricity consumption	kwh/t	kwh/t
	Yield		
	Max. rolling speed	m/s	m/s
	Cooling water rate	t/h	t/h

Item		Design	Actual
Reheating furnace after rougher	Productivity	t/h	t/h
	Fuel consumption	Mcal/t	Mcal/t
	Yield in furnace	%	%
	Kind of fuel		
	Heat insulation material		
	Disccharge temp of billet	℃	℃
	O_2 content of exhaust gas	%	%

(3) Energy balance date .... Preformance test or design or during operation

1) Energy balance of EAF
mesuring date

Heat input (Mcal/t)	Heat output (Mcal/t)
Electricity (kwh/t) :	Heat content of molten steel :
Electrode (kgl/t) :	Sensible heat of exhaust gas :
Oxidation heat :	Heat of cooling water :
Oil injection (l //kg):	Sensible heat of slag :
Slag formation heat :	Heat loss :
Heat content of scrap :	Heat recoverd by scrap preheating :( )
Heat recoverd by scrap preheating :( )	
Total	Total

2) Heat balance date of reheating furnace

- Mesurement
- Charged billet temperature : ℃
- Productivity : t/h

Heat Input	Mcal/t	Heat Output	Mcal/t
Combustion heat of fuel		Heat content of extracted billet	
Sensible heat of fuel		Sensible heat of scale	
Heat content of charged billet		Sensible heat of exhaust gas	
Scale formation heat		Heat of cooling water	
		Heat loss	
Heat recovered by recuperator ( )		Heat recovered by recuperator ( )	
Total		Total	

3) Heat balance date of reheating furnace after rougher

- Mesurement
- Charged billet temperature : ℃
- Productivity : t/h

Heat Input	Mcal/t	Heat Output	Mcal/t
Combustion heat of fuel		Heat content of extracted billet	
Sensible heat of fuel		Sensible heat of scale	
Heat content of charged bar		Sensible heat of exhaust gas	
Scale formation heat		Heat of cooling water	
		Heat loss	
Heat recovered by recuperator ( )		Heat recovered by recuperator ( )	
Total		Total	

6. Processing Line

(1) Main specification

Equipment	Specification	
EAF (1 set)	Type Capacity Fabricator Installation Transformer Voltage (1st/2nd) Ampere (2nd) Dust collecter type Capacity of fan Oil burner	Electric arc furnace with EBT 70 T/ch Nominal MVA kv/ kv KA kw l/h× set
Ladle furnace (1 set)	Type Capacity Fabricator Installation Transformer Voltage (1st/2nd)	 Nominal MVA kv/ kv
Ingot casting	Type Ingot weight	Botton pouring 50 ton , 200 ton
Ingot car (1 set)	Type Capacity Vaccum	 ton mmHg
Forge heating furnace (1 set)	Type Capacity Fabricator Installation	
Forging press (5 set)	Type Capacity Fabricator Fluid pressure	Hydraulic press 800, 1250, 2000, 3200 and 8000 ton kg/ cm^2
Preliminary heat treating furnace (1 set)	Type Capacity Heating temp Buner capacity	
Final heat treating furnace (1 set)	Type Capacity Heating temp Buner capacity	Pit type and bogie type Mcal/h
Quenching tank	Capacity Coolant	
Mechanical working shop	Type Max.weight	

(2) Design and operation information

Process	Item	Design	Actual
EAF	Productivity	t/h	t/h
	Tap-to-tap	min	min
	Scrap ratio	%	%
	Electricity consumption	kwh/t	kwh/t
	Electrode consumption	kg/t	kg/t
	O_2 〃	Nm^3/t	Nm^3/t
	Oil 〃	l /t	l /t
	aux. fuel 〃		
	Moten steel temp.	℃	℃
	Cooling water flow rate ×Δt		
Forge heating furnace	Productivity	t/h	t/h
	Fuel consumption	Mcal/t	Mcal/t
	Heat insulation material		
	Charged material temp	℃	℃
	Discharged material temp	℃	℃
Preliminary heat treatimg furnace	Productivity	t/h	t/h
	Fuel consumption	Mcal/t	Mcal/t
	Heat insulation material		
	Product temp	℃	℃
Final heat treatimg furnace	Productivity	t/h	t/h
	Fuel consumption	Mcal/t	Mcal/t
	Heat insulation material		
	Product temp	℃	℃

Process	Item	Design	Actual
Plant total	Electricity consumption	kwh/t	kwh/t
	Fuel 〃	Mcal/t	Mcal/t
	O_2 〃	Nm^3/t	Nm^3/t
	Argon 〃	Nm^3/t	Nm^3/t
	Cooling water	m^3/t	m^3/t

7. Energy supply equipment

(1) Main specification

Equipment	Specification	
Power receiving Station	Voltage Main franformer	110 kv to steel-making 2 ×63 MVA (110kv) to rolling mill and others 3×75MVA (v) to forge arc furnace 2×25 MVA (30kv)
Emergency generator (set)	Type Capacity	 kw
Boiler (set)	Type Capacity Kind of fuel Comment	 t/h kg/ cm^2 ℃ Steam and hot water are supllied from the city
Waste heat boiler (set)	Type Capacity Location	 t/h kg/ cm^2
Oxygen plant (2 set)	Type Capacity Feed air compressor	 O_2 gas gene. 1200Nm^3/h Liquid O_2 gene. t/h N_2 gas gene. Nm^3/h Nm^3/h× kg/ cm^2× KW
Air compressor (7 set)	Type Capacity	Turbo, reciprocating, 10,000 Nm^3/h× kg/ cm^2× KW×2set 6,000 Nm^3/h× kg/ cm^2× KW×3set 720 Nm^3/h× kg/ cm^2× KW×3set
Tank and Holder	Oxygen Oil	
Water supply system	reference :electricity check list	

(2) Design and operation information

Equipment	Item	Design	Actual
Power receiving Station	Contract demand	MW	155 MW
	Power factor		0.42
	Maximum demand	MW	145 MW
	Average power supply	MW	MW
Boiler	Average steem supply	t/h	t/h
	Average fuel comsumption	Mcal/t	Mcal/t
Waste heat boiler	Average heat recovery	Mcal/tp	Mcal/tp
Oxygen plant	Average O_2 comsumption	Nm^3/h	Nm^3/h
	Average power omsumption	kwh/N m^3O_2	kwh/N m^3O_2
	Average O_2 generation	Nm^3/h	Nm^3/h
	Average power omsumption	kwh/h	kwh/h
	Average feed air supply	Nm^3/h	Nm^3/h
	Average feed air supply (press.)	kg/ cm^2	kg/ cm^2
Air compressor	Average air supply volume	Nm^3/h	Nm^3/h
	Average power omsumption	kwh/h	kwh/h
	Average air supply presse	kg/ cm^2	kg/ cm^2
Water supply system	refer to electricity check list		

8. Energy consumption in 1996 (HUTA OSTROWIEC)

Process	Production		Electricity	Natural G.	Oil	Compressed air	Oxygen	Argon	Hot water	Steam	Recircu. water
	Product	Ton	10^3 kwh	10^3 Nm^3	l	10^3 Nm^3	10^3 Nm^3	10^3 Nm^3	ton	ton	10^3 m^3
[Generated energy]											
[Consumed energy]											
Metallurgical Line											
EAF and LF	Molten S.										
Continuous C/	Billet										
Rolling mill	Bar and wire										
(Sub-total)											
Processing Line											
Steel melting shop	Ingot										
Forging shop	Forged P.										
(Sub-total)											
Energy Supply											
Air separation	Oxygen										
Air compressor	Air										
Recircu.water	Recircu.w.										
Others											
(Sub-total)											
Others											
Consumption total											
Purchased energy total											
Demand max.											

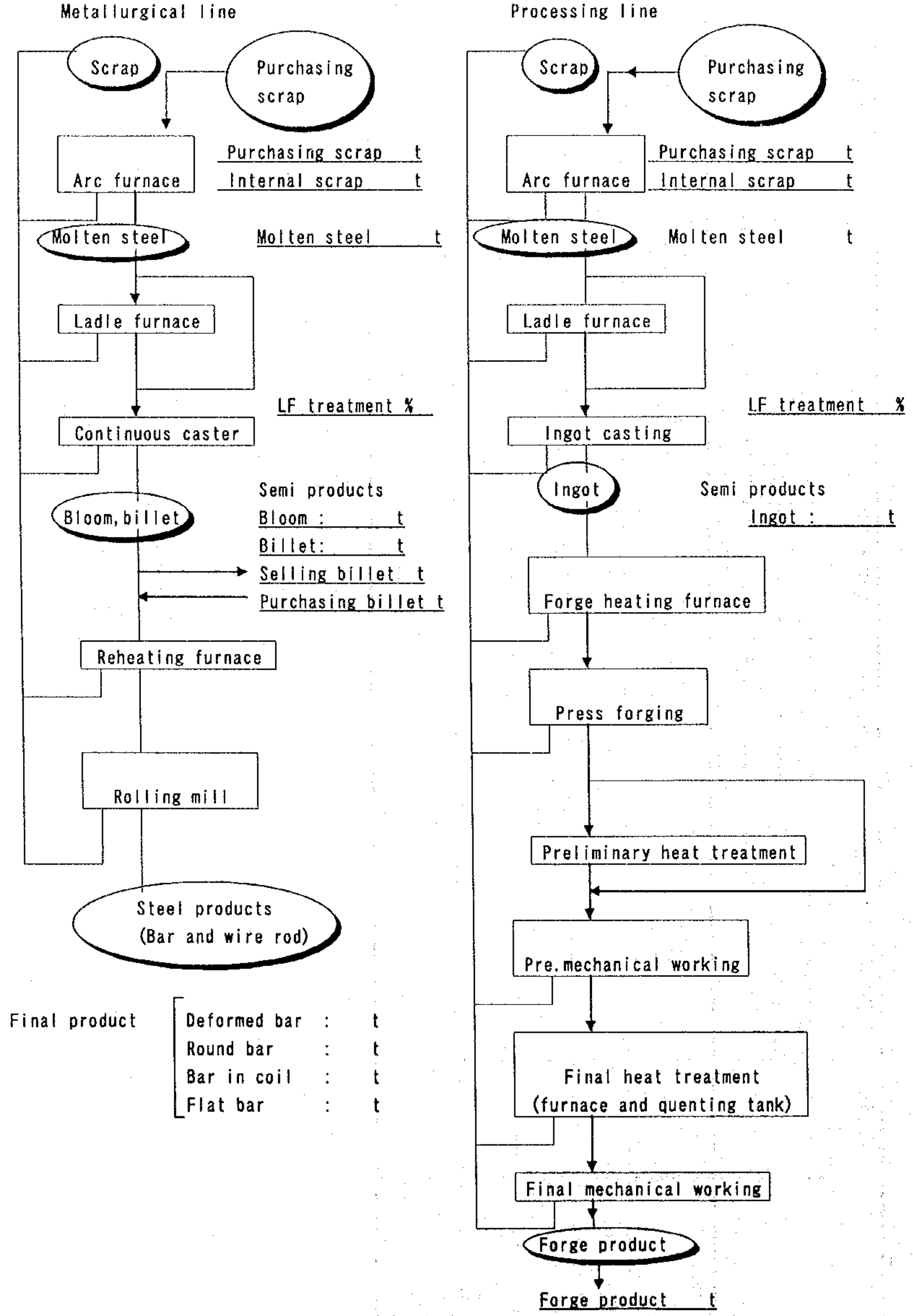
(Note) In case that each process has own air compresser and it electricity is supplied from each, it is not necessary to put it's data in "compressed air"

9. Main equipment working rate

unit (hour)

	(暦時間) 【A】 Calendar hour	(予定修理) 【B】 Programmed Maintenance	(稼働可能時間) 【 C=A-B 】 Available time for operation	Non-operating time (非稼働時間) 【D】 Equipment trouble (Down time)	【E】 Inspection or survey	【F】 Operational maintenance (ex. roll change)	【G】 Others	【H】 Sub-total D+E+F+G	(作業率) 【I】 Operating rate (C-H)÷C	(稼働率) 【J】 Working rate I × C / A
Metallurgical Line EAF										
CC										
Reheating furnace										
Rolling mill										
Processing Line EAF										
Reheating furnace										
Forge press										

10. Material flow in 1996. Ostrowiec



11. Site survey plan

1. General observation of operation and equipment
- operation
- maintenace of equipment
- energy conservation equipment
- energy conservation potentiality
- data collecing for analisis
  - main equipments
  - pumps
  - blowers
  - compressors

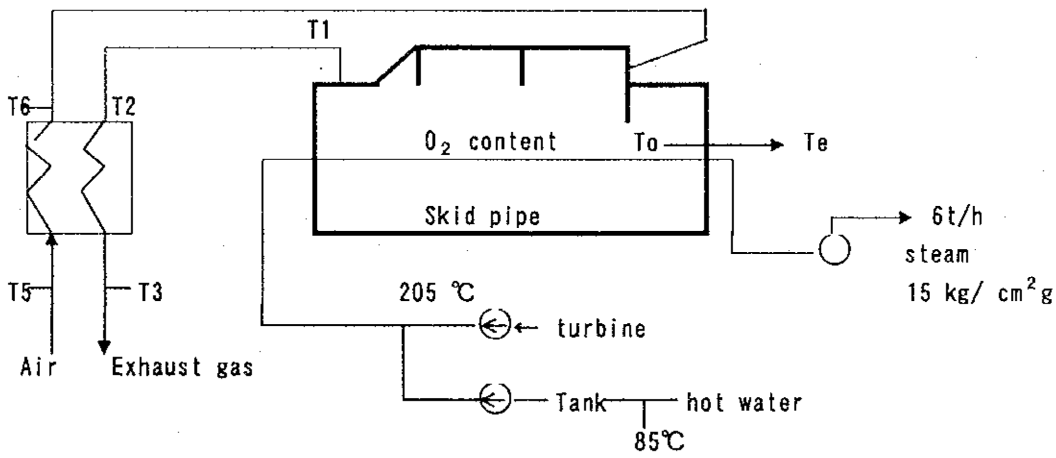
2. Actual operation data

1) EAF and Ladle furnace

- Productivity (t/h)
- Power consumption (kwh/t) during normal operation
  - EAF
  - Auxiliary equipment (water, dust collecter)
- Cooling water rate

2) Reheating furnace

- Fuel consumption during normal operation
- Furnace data
- Control system
- Operation standard



Te									
To	1240								
T_1	858								
T_2	667				T6	321			
T_3	372				T5				
O_2	2				02				
t/h									

3) Forge heat furnace and heat treatment furnace

- Fule consumption ········ daily
- Furnace data
- Control system
- Operation standard
    - Heating up and down standavd
    - During low productivity and operation stop
- Exhaust gas O_2 content during low load
- Furnace radiation loss and cooling loss
- Exhaust gas loss

9.1.2 Iron and Steel Industry (Labedy)

(1) Middle section mill and reheating furnace

a. Purpose of measurement

The purpose of measurement is to survey the current operating status of a middle section mill in order to obtain the electricity intensity of the middle section mill and perform heat balancing of a reheating furnace.

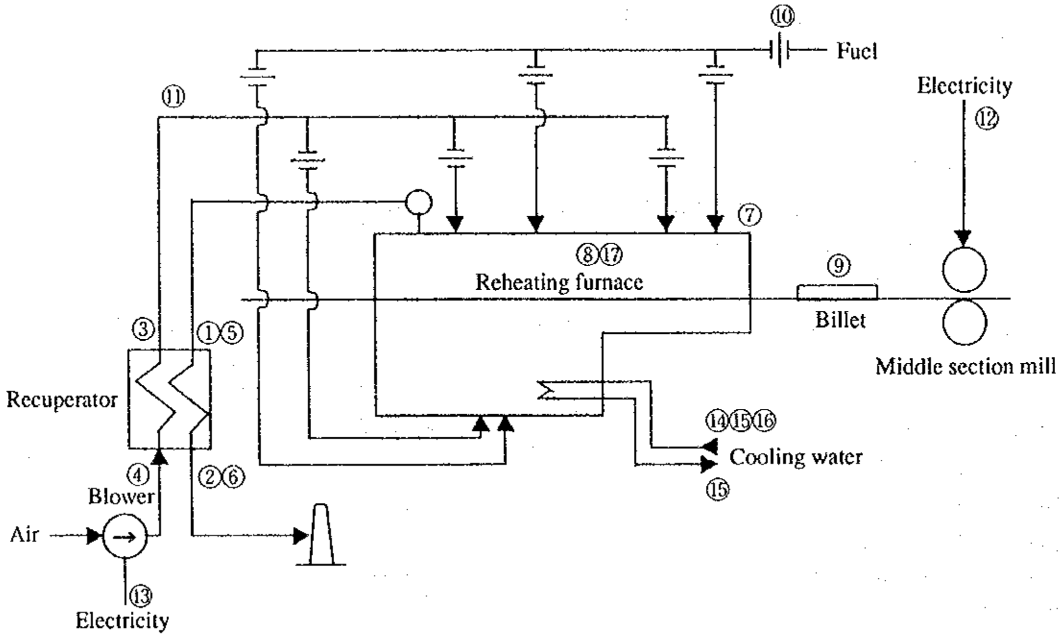
b. Measurement item, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Exhaust gas temperature at recuperator inlet	24 h	Thermocouple	to Recorder
② Exhaust gas temperature at recuperator outlet	24 h	Thermocouple	to Recorder
③ Combustion air temperature at recuperator outlet	24 h	Thermocouple	to Recorder
④ Combustion air temperature at recuperator inlet	24 h	Thermocouple	to Recorder
⑤ Exhaust gas O_2 % at recuperator inlet	24 h	O_2 meter	to Recorder
⑥ Exhaust gas O_2 % at recuperator outlet	24 h	O_2 meter	to Recorder
⑦ Reheating furnace wall temperature	spot	Radiation thermometer	Memo
⑧ Furnace internal temperature	spot	Operation record	Memo
⑨ Billet delivery amount	24 h	Meters for operation	to Recorder
⑩ Fuel flow rate	24 h	Meters for operation	to Recorder
⑪ Combustion air flow rate	24 h	Radiation thermometer	Memo
⑫ Power consumption for rolling mill	24 h	Meters for operation	to Recorder
⑬ Current, power consumption and power factor of reheating furnace blower	24 h	Clamp meter	to FDD
⑭ Amount of cooling water	1 heat	Ultrasonic flowmeter	to Recorder
⑮ Cooling water temperature at inlet/outlet	1 heat	Thermocouple	to Recorder
⑯ Pressure of cooling water	1 heat	Pressure gauge	to Recorder
⑰ O_2 % in the furnace	spot	O_2 meter	Memo
⑱ Area of the opening	spot		Memo

c. Measurement points

Figure 9.1.4 shows the measuring points of the middle section mill and the reheating furnace.

Figure 9.1.4 Measuring Points of Middle Section Mill and Reheating Furnace



(2) Universal mill and reheating furnace

a. Purpose of measurement

The purpose is to survey the current operating status in order to obtain the electricity intensity of a universal mill and perform heat balance of a reheating furnace.

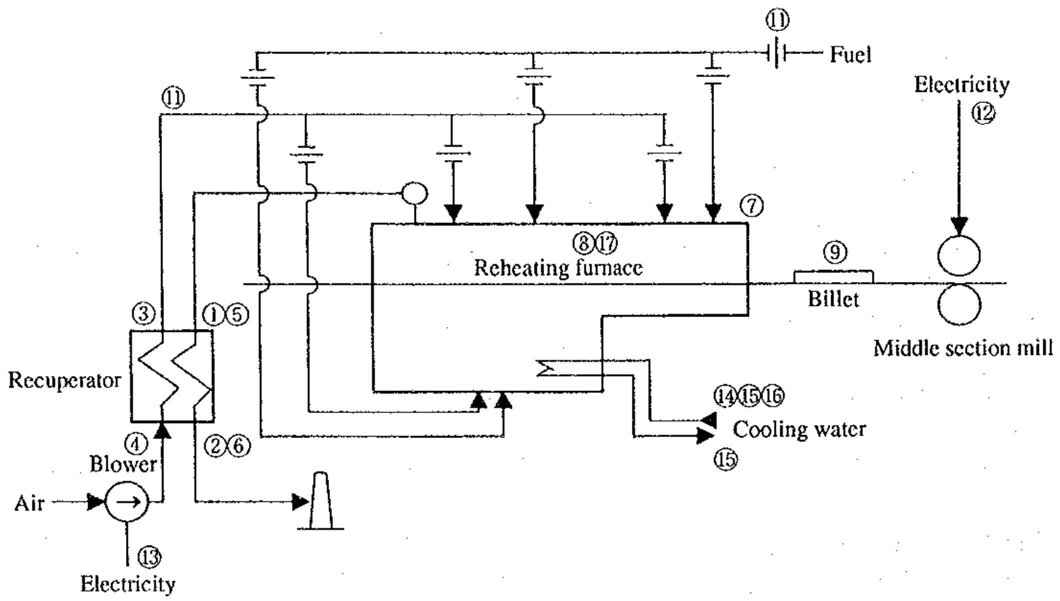
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Exhaust gas temperature at recuperator inlet	24 h	Thermocouple	to Recorder
② Exhaust gas temperature at recuperator outlet	24 h	Thermocouple	to Recorder
③ Combustion air temperature at recuperator outlet	24 h	Thermocouple	to Recorder
④ Combustion air temperature at recuperator inlet	24 h	Thermocouple	to Recorder
⑤ Exhaust gas O_2 % at recuperator inlet	24 h	O_2 meter	to Recorder
⑥ Exhaust gas O_2 % at recuperator outlet	24 h	O_2 meter	to Recorder
⑦ Reheating furnace wall temperature	spot	Radiation thermometer	Memo
⑧ Furnace internal temperature	spot	Operation record	Memo
⑨ Billet delivery amount	24 h	Meters for operation	to Recorder
⑩ Fuel flow rate	24 h	Meters for operation	to Recorder
⑪ Combustion air flow rate	24 h	Operation record	Memo
⑫ Power consumption for a rolling mill	24 h	Meters for operation	to Recorder
⑬ Current, electric power and power factor of blower	24 h	Clamp meter	to FDD
⑭ Amount of cooling water	1 heat	Ultrasonic flowmeter	to Recorder
⑮ Cooling water temperature at inlet/outlet	1 heat	Thermocouple	to Recorder
⑯ Cooling water pressure	1 heat	Pressure gauge	to Recorder
⑰ Furnace internal O_2 %	spot	O_2 meter	Memo
⑱ Area of the opening	spot		Memo

c. Measuring points

Figure 9.1.5 shows the measuring points of a universal mill and a reheating furnace.

Figure 9.1.5 Measuring Points of Universal Mill and Reheating Furnace



(3) Cooling water system

a. Purpose of measurement

The purpose is to survey the water volume, water pressure and power consumption of the cooling water system in order to grasp the current operating status.

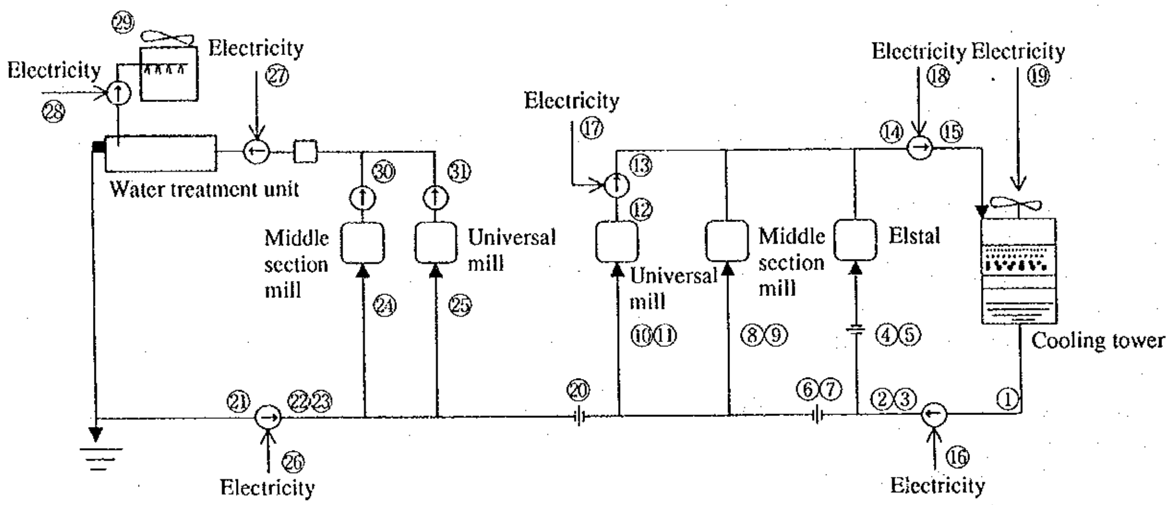
b. Measurement item, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Suction pressure of a feedwater pump	12 h	Pressure gauge	to Recorder
② Discharge pressure of a feedwater pump	12 h	Pressure gauge	to Recorder
③ Discharge pressure of a feedwater pump	spot	Ultrasonic flowmeter	to Recorder
④ Feedwater flow rate for Elstal	12 h	Meter for operation	Memo
⑤ Feedwater pressure for Elstal	spot	Pressure gauge	Memo
⑥ Flow rate of feedwater to rolling mill	12 h	Meter for operation	Memo
⑦ Pressure of feedwater to rolling mill	spot	Pressure gauge	Memo
⑧ Flow rate of feedwater to middle section mill	spot	Ultrasonic flowmeter	Memo
⑨ Pressure of feedwater to middle section mill	spot	Pressure gauge	Memo
⑩ Flow rate of feedwater to universal mill	spot	Ultrasonic flowmeter	Memo
⑪ Pressure of feedwater to universal mill	spot	Pressure gauge	Memo
⑫ Pump suction pressure	spot	Pressure gauge	Memo
⑬ Pump discharge pressure	spot	Pressure gauge	Memo
⑭ Suction pressure of cooling tower feedwater pump	spot	Pressure gauge	Memo
⑮ Discharge pressure of cooling tower feedwater pump	spot	Pressure gauge	Memo
⑯ Power consumption for feedwater pump	12 h	Meter for operation	to Recorder
⑰ Power consumption for universal mill pump	spot	Clamp meter	to FDD
⑱ Power consumption for cooling tower feedwater pump	spot	Clamp meter	to FDD
⑲ Power consumption for cooling tower fan	spot	Clamp meter	to FDD
⑳ Flow rate of feedwater direct to the cooling system	12 h	Meter for operation	Memo
㉑ Pump suction pressure	spot	Pressure gauge	Memo
㉒ Pump discharge pressure	spot	Pressure gauge	Memo
㉓ Pump discharge flow rate	12 h	Ultrasonic flowmeter	Memo
㉔ Flow rate of feed water to middle section mill	spot	Ultrasonic flowmeter	Memo
㉕ Flow rate of feedwater to universal mill	spot	Clamp meter	to FDD
㉖ Power consumption for pump	12 h	Clamp meter	to FDD
㉗ Power consumption for pump	spot	Clamp meter	to FDD
㉘ Power consumption for pump	spot	Clamp meter	to FDD
㉙ Power consumption for pump	spot	Clamp meter	to FDD
㉚ Power consumption for pump	spot	Clamp meter	to FDD
㉛ Power consumption for pump	spot	Clamp meter	to FDD

c. Measuring points

Figure 9.1.6 shows the measuring points of the cooling water system.

Figure 9.1.6 Measuring Points of Cooling Water System



(4) Air compressor

a. Purpose of measurement

The purpose is to grasp the current operating status of the air compressor.

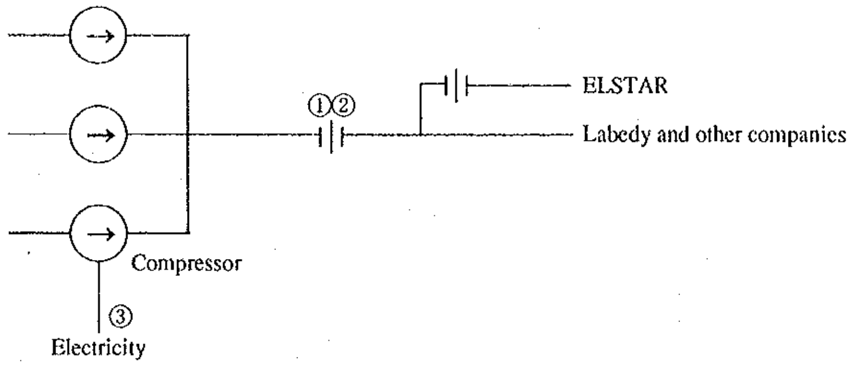
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Compressed air	24 h	Meter for operation	to Recorder
② Discharge pressure of compressed air	24 h	Meter for operation	to Recorder
③ Power consumption for compressor	24 h	Meter for operation	to Recorder

c. Measuring points

Figure 9.1.7 shows the measuring points of the air compressor.

Figure 9.1.7 Measuring Points of Air Compressor



(5) Hot water system

a. Purpose of measurement

The purpose is to prepare a heat balance table in order to grasp the current operating status of the hot water system.

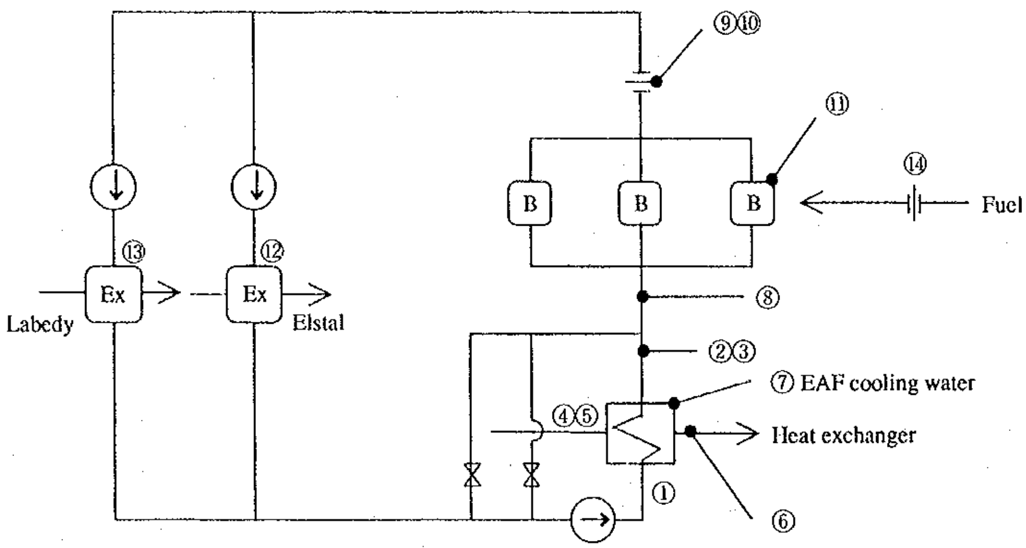
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Heat exchanger inlet temperature	spot	Thermocouple	Memo
② Heat exchanger outlet temperature	spot	Thermocouple	Memo
③ Heat exchanger outlet flow rate	spot	Ultrasonic flowmeter	Memo
④ Heat exchanger inlet temperature	spot	Thermocouple	Memo
⑤ Heat exchanger inlet temperature	spot	Thermocouple	Memo
⑥ Heat exchanger outlet temperature	spot	Thermocouple	Memo
⑦ Amount of heat exchanged	12 h	Meter for operation	to Recorder
⑧ Boiler inlet temperature	spot	Thermocouple	Memo
⑨ Boiler outlet temperature	spot	Thermocouple	Memo
⑩ Boiler outlet flow rate	spot	Ultrasonic flowmeter	Memo
⑪ Boiler heat output	12 h	Meter for operation	to Recorder
⑫ Heat value for Elstal	12 h	Meter for operation	to Recorder
⑬ Heat value for Labedy	12 h	Meter for operation	to Recorder

c. Measuring points

Figure 9.1.8 shows the measuring points of the hot water system.

Figure 9.1.8 Measuring Points of Hot Water System



(6) Energy utilization facilities

Equipment name	Targeted devices or locations	Measurement time
Electricity management	Power receiving facilities Substation	24 h 24 h
Fan/blower	Blower for reheating furnace	24 h
Electric motor	Major equipment	24 h
Air compressor	Major equipment	24 h
Pump	Cooling water pump	24 h
Transformer	Major equipment	24 h
Lighting	Various locations in the factory	spot
Boiler	Boiler room	24 h
Steam pipe	Various locations in the factory	spot

For the measurement method and the measuring points, see "10. ENERGY UTILIZATION FACILITIES".

HUTA Labedy Check List

1. Factory out-line

(1) Factory name — Huta Labedy

(2) Adress — 45 Zawadzkiego street, 44-109 Gliwice

(3) No.of employee — 1,500

(4) Main products — Mine roadway steel supports (shape)
Steel plate

(5) Production capacity — Mine roadway steel supports 200,000t/y
Steel plate and sheet 30,000t/y

(6) Process outline

(7) History
- foundation 1848
- history of expansion and inprovement
  - In 1995, New steel-making works started to operate as New company, "ELSTAR"
  - In 1995, steel support woks control system was renewed

Huta Labedy is old state works, and started to modernize and privatize themselves, therefore now three companies are operating in the works.

Company	Nain product
Elstar	Bloom
Labedy	Shape and plate
Ferropol	Bar

- Shear of products in poland
- Evaluation on products quality
- Feature of process

(8) Plant layout

(9) Electricity one line diagram

(10) Eergy price
Electricity
Natural gas
Oil
light oil

2. Production and energy consumption

(1) Trend of production

	Unit	1992	1993	1994	1995	1996
OHF (ingot)	t	308,363	271,617	314,328	232,191	
EAF (molten steel)	t	—	—	—	—	
Bloom	t	276,500	241,352	311,980	278,500	
Shapes and cramps	t	248,936	204,920	285,202	246,244	
Plate	t	24,028	28,605	32,463	36,467	

(2) Trend of energy consumption

	Unit	1992	1993	1994	1995	1996
Fuel oil	kl	24,359.7	17,047.00	22,749.00	14,171.50	
Diesel oil	kl	595.4	573	611.2	580.4	
Kerosene						
Natural gas	$10^3 m^3$	—	15,792.30	74,464.00	66,371.30	
Gasolime	kl	24.8	20.2	22.2	24.5	
Others		116,254.2	75,957.80	—	—	
Coal	t	—	100	25	9.8	
Electricity	Mwh	57,808.8	51,444.90	59,818.80	53,050.30	
Raw water (River)	t	608,126	364,381	374,409	485,584	
Raw water (City)	t	275,279	260,491	266,738	267,326	

(3) Trend of energy intensity

	Unit	1992	1993	1994	1995	1996
Fuel oil						
Diesel oil						
Kerosene						
Natural gas						
Gasolime						
Others						
Coal						
Electricity						
Raw water (River)						
Raw water (City)						
Total						

(4) Rate of energy cost vs product cost : about %

3. Energy conservation activity

(1) Energy conservation strategy and target

(2) How do you follow about it ?

(3) Problems on promotion of energy conservation .... list attached

(4) Energy conservation items in the past or future .... list attached
- Operation improvement
- Process modification

(5) Energy conservation promotion organization

(6) Activity of energy conservation committee

(7) Do you have the group that execute mainly energy conservation activity, and how they do it ?

(8) Personal evaluation for energy conservation activities such as promotion and award

4. Energy management

(1) Data of energy consumption by process

(2) Cost sheet of main product

(3) Monthly report of production and energy consumption showing comparison between planning and actual data.

(4) Energy supply flow diagram showing flow meter location

(5) Commendation or award system for man and group in energy conservation activity

5. Eletar

(1) Main specifications

Equipment	Specification	
EAF (set)	Type	Electric arc furnace with EBT
	Nominal capacity	70 ton/charge (350,000 t/y)
	Fabricator	
	Installation	
	Trans former capacity	Nominal MVA (48MW)
	Voltage 1st/2nd	110 KV/
	Ampere (2nd)	A
	Type of dust collecter	
	Capacity of fan	KW
	Oil burner capacity	l/h× set
Ladle furnace (set)	Type	
	Capacity	ton/ch
	Fabricator	
	Installation	
	Trans former capacity	Nominal MVA (13MW)
	Voltage 1st/2nd	KV/ V
	Function	
	Heating	
	Decarburization	
	Degassing	
	Alloying	

Equipment	Specification	
Continuous caster (set)	Type	
	Strand	3 /set
	Capacity	t/h
	Fabricator	CONCAST
	Installation	
	Casting speed	m/min
	Product	Bloom 150mm × 200mm
		mm × mm

(2) Design and operational information

Process	Item	Design		Actual	
EAF	Production		t/ch		t/ch
	Productivity		t/h		t/h
	Tap-to-tap		min		min
	Scrap ratio		%		%
	Molten steel temp.		℃		℃
	Electricity consumption		kwh/t		kwh/t
	Electrode consumption		kg/t		kg/t
	O2 injection		Nm^3/t		Nm^3/t
	Oil injection		l/t		l/t
	Cabon injection		kg/t		kg/t
	Scrap pre-heating temp.	scrap	℃	scrap	℃
		exhaust gas	℃	exhaust gas	℃
	Other fuel consumption		Nm^3/t		Nm^3/t

Process	Item	Design	Actual
Ladle furnace	Treatment rate	%	%
	Treatment time (net)	min	min
	Electricity consumption		
	Fule consumption		
	Other energy consumption		
Continuous caster	Productivity	t/h	t/h
	Casting speed	m/min	m/min
	Ave. continuous c. rate		
	Electricity consumption	kwh/t	kwh/t
	Fuel consumption	Nm^3/	Nm^3/t
Time from starting of EF tap to finishing of casting		min	min

(3) Energy balance date .... Preformance test or design or during operation

1) Energy balance of EAF mesuring date

Heat input (Mcal/t)	Heat output (Mcal/t)
Electricity (kwh/t) :	Heat content of molten steel :
Electrode (kg1/t) :	Sensible heat of exhaust gas :
Oxidation heat :	Heat of cooling water :
Oil injection (l//kg) :	Sensible heat of slag :
Slag formation heat :	Heat loss :
Heat content of scrap :	Heat recoverd by scrap preheating :( )
Heat recoverd by scrap preheating :( )	
Total	Total

6. Lebedy

(1) Main specifications

(V shape and billet mill)

Equipment	Specification	
Reheating furnace (set)	Type	Pusher type
	Capacity	60 t/h
	Fabricator	
	Installation	
	Furnace dimention	width ×effective length
	Charged materials	Bloom
	Kind of fuel	Natural gas
	Burner capacity	max Mcal/h
	Target of furnace temperature	Heating zone ℃ Soaking zone ℃
Rolling mill (set)	Type Capacity Product Max.rolling speed Motor capacity	 t/h V shape and billet m/s (rougher sub-total) MW (intermediate sub-total) MW (finisher sub-total) MW

(Steel support and cramp)

Equipment	Specification	
Vending machine	Type	
	Capacity	t/h
	Fabricator	
	Installation	
	motor	kw
Press and mechanical working	Press type	
	Press capacity	t/h

(Plate mill)

Equipment	Specification	
Reheating furnace (set)	Type	Pusher type
	Capacity	60 t/ch
	Fabricator	
	Installation	
	Furnace dimention	width ×effective length
	Charged materials	Bloom
	Kind of fuel	Natural gas
	Burner capacity	max Mcal/h
	Target of furnace temperature	Heating zone ℃ Soaking zone ℃
Rolling mill (set)	Type Capacity Product Max.rolling speed Motor capacity	 t/h Plate (sheet and flat bar) m/s (rougher sub-total) MW (intermediate sub-total) MW (finisher sub-total) MW

(Open-hearth furnace)

Equipment	Specification	
Open-hearth furnace (set)	Type	
	Capacity	t/ch
	Fabricator	
	Installation	
	Charged materials	
	Fuel	
	Burner capacity	Mcal/h× set

(2) Design and operational information
(V shape and billet mill)

Item		Design	Actual
Reheating furnace (set)	Productivity	t/h	t/h
	Fuel consumption	Mcal/t	60Nm³/t. (Mcal/t)
	Yield in furnace	%	%
	Kind of fuel	oil	Natural gas
	Burner capacity		
	Preheating zone upper	l /hx set	Nm³/hx set
	lower		
	Heating zone upper		
	lower		
	Soaking zone upper		
	lower		
	Heat insulation material		
	Electricity consumption	kwh/t	kwh/t
	Disccharge temp of bloom	℃	℃
	O2 content of exhaust gas	%	%
Rolling mill	Productivity	t/h	t/h
	Electricity consumption	kwh/t	kwh/t
	Yield		
	Max. rolling speed	m/s	m/s
	Cooling water rate	t/h	t/h

(Steel support and cramp)

Item		Design	Actual
Vending machine			
Press and mechanical working			

(Plate mill)

Item		Design	Actual
Reheating furnace (set)	Productivity	t/h	t/h
	Fuel consumption	Mcal/t	60N㎥/t. (Mcal/t)
	Yield in furnace	%	%
	Kind of fuel	oil	Natural gas
	Burner capacity		
	Preheating zone upper	Nm^3/hx set	Nm^3/hx set
	lower		
	Heat insulation material		
	Heating zone upper		
	lower		
	Soaking zone upper		
	lower		
	Electricity consumption	kwh/t	kwh/t
	Disccharge temp of billet	℃	℃
	O_2 content of exhaust gas	%	%
Rolling mill	Productivity	t/h	t/h
	Electricity consumption	kwh/t	kwh/t
	Yield		
	Max. rolling speed	m/s	m/s
	Cooling water rate	t/h	t/h

(Open-hearth furnace)

Item	Design	Actual
Productivity	t/h	t/h
Tap-to-tap	min	min
Fuel consumption	Mcal/t	Mcal/t
Kind of fuel		Natural gas, oil benzol
O_2 consumption	Nm^3/h	Nm^3/h
Air temp. after preheater	℃	℃

(3) Energy balance data

1) Heat balance data of reheating furnace

- Mesurement day
- Charged billet temperature : ℃
- Productivity : t/h

Heat Input	Mcal/t	Heat Output	Mcal/t
Combustion heat of fuel		Heat content of extracted billet	
Sensible heat of fuel		Sensible heat of scale	
Heat content of charged billet		Sensible heat of exhaust gas	
Scale formation heat		Heat of cooling water	
		Heat loss	
Heat recovered by recuperator ( )		Heat recovered by recuperator ( )	
Total		Total	

2) Heat balance data of reheating furnace

- Mesurement day
- Charged billet temperature : ℃
- Productivity : t/h

Heat Input	Mcal/t	Heat Output	Mcal/t
Combustion heat of fuel		Heat content of extracted billet	
Sensible heat of fuel		Sensible heat of scale	
Heat content of charged billet		Sensible heat of exhaust gas	
Scale formation heat		Heat of cooling water	
		Heat loss	
Heat recovered by recuperator ( )		Heat recovered by recuperator ( )	
Total		Total	

3) Heat balance data of reheating furnace

- Mesurement day
- Charged billet temperature : ℃
- Productivity : t/h

Heat Input	Mcal/t	Heat Output	Mcal/t
Combustion heat of fuel		Heat content of extracted billet	
Sensible heat of fuel		Sensible heat of scale	
Heat content of charged billet		Sensible heat of exhaust gas	
Scale formation heat		Heat of cooling water	
		Heat loss	
Heat recovered by recuperator ( )		Heat recovered by recuperator ( )	
Total		Total	

4) Heat balance data of open-hearth furnace

- Mesurement date
- Productivity : t/h

Heat Input	Mcal/t	Heat Output	Mcal/t
Combustion heat of fuel	:	Heat content of molten steel	:
Sensible heat of fuel	:	Sensible heat of slag	:
Heat content of scrap	:	Sensible heat of exhaust gas	:
Scale formation heat	:	Heat of cooling water	:
Slag formation heat	:	Heat loss	:
Heat content of atomize steam	:	Heat recovered by air preheater	: ( )
Heat recovered by air preheater	: ( )		
Total		Total	

7. Energy supply equipment

(1) Main specification

Equipment	Specification	
Power receiving Station	Voltage Main franformer	kv to steel-making MVA (kv) to rolling mill and others MVA (v)
Emergency generator (set)	Type Capacity	kw
Boiler (set)	Type Capacity Kind of fuel	t/h
Waste heat boiler (set)	Type Capacity Location	t/h kg/cm^2
Oxygen plant (set)	Type Capacity Feed air compressor	O_2 gas gene. 1200Nm^2/h Liquid O_2 gene. t/h N_2 gas gene. Nm^3/h Nm^3/h× kg/cm^2× KW
Air compressor (set)	Type Capacity	
Tank and Holder	Oxygen Oil	m^3≒× kg/ cm^2× set kl× set
Water supply system	reference :electricity check list	

(2) Design and operation information

Equipment	Item	Design	Actual
Power receiving Station	Contract demand Maximum demand Average power supply	MW MW MW	MW MW MW
Boiler	Average steem supply Average fuel comsumption	t/h Mcal/t	t/h Mcal/t
Waste heat boiler	Average heat recovery	Mcal/tp	Mcal/tp
Oxygen plant	Average O_2 comsumption Average power omsumption Average O_2 generation Average power omsumption Average feed air supply Average feed air supply (press.)	Nm^3/h kwh/N m^3O_2 Nm^3/h kwh/h Nm^3/h kg/ cm^2	Nm^3/h kwh/N m^3O_2 Nm^3/h kwh/h Nm^3/h kg/ cm^2
Air compressor	Average air supply volume Average power omsumption Average air supply presse	Nm^3/h kwh/h kg/ cm^2	Nm^3/h kwh/h kg/ cm^2
Water supply system	refer to electricity check list		

8. Energy consumption in 1996 (Labedy)

Process	Production		Electricity	Natural G.	Oil		Oxygen	Compressed air	Hot water	Steam	Recircu.water
	Product	Ton	10^3 kwh	10^3 Nm^3	l		10^3 Nm^3	10^3 Nm^3	ton	ton	10^3 m^3
[Generated energy]											
[Consumed energy]											
Open-heath furnace	Ingot										
Ingot casting											
EAF and LF	Molten steel										
Continuous casting											
Rolling mill	Bloom										
	shaped.p										
Bending machine	Mine roadway steel support										
Press machine	Yoke and cramp										
(Sub-total)											
Rolling mill(plate)	plate and flat bar										
Energ supply											
Air separation	Oxygen										
Air compressor	Compressed air										
Reciycu. water											
Others											
(Sub-total)											
Others											
Consumption total	Crude steel										
Purchased energy total											
Demand											

(Nore) In case that each process has own air compresser and it electricity is supplied from each,it is not necessary to put it's data in "compressed air"

8. Energy consumption in 1994 (Labedy)

Process	Production		Electricity	Natural G.	mazut Oil 9,388	Benzol 9,700	Oxygen	Compressed air	Hot water	Steam	Recircu. water
	Product	Ton	10^3 kwh	10^3 Nm^3	l	t	10^3 Nm^3	10^3 Nm^3	ton	ton	10^3 m^3
[Generated energy]											
[Consumed energy]											
Open-heath furnace	Ingot	314,328	(22.2) 6,981.4	(1028) 39,038.2	(679) 22,749.0	(141) 4,564					
Ingot casting											
EAF and LF	Molten steel		—	—	—	—	—	—	—	—	—
Continuous casting			—	—	—	—	—	—	—	—	—
Rolling mill	Bloom	311,980	(22.9) 7,148.0	(618) 23,303.1	—						
	shaped.p	269,500	(58.2) 15,697.9	(275) 8,959.2	—						
Bending machine	Mine roadway steel support	267,513	(6.3) 1,673.0	—	—						
Press machine	Yoke and cramp	17,689	(157.1) 2,779.0	—	—						
(Sub-total)											
Rolling mill (plate)	plate and sheet	32,463	(76.2) 2,474	(786) 3,083.6	—						
Energ supply											
Air separation	Oxygen										
Air compressor	Compressed air										
Recycu. water											
Others											
(Sub-total)			( )	( )	(0)						
Others			23,065.50	79.9	0						
Consumption total	Crude steel	311,980	(191.7) 59,818.80	(1974.6) 74,464.00	(684.6) 22,749.00						
Purchased energy total											
Demand			13.1 MW								

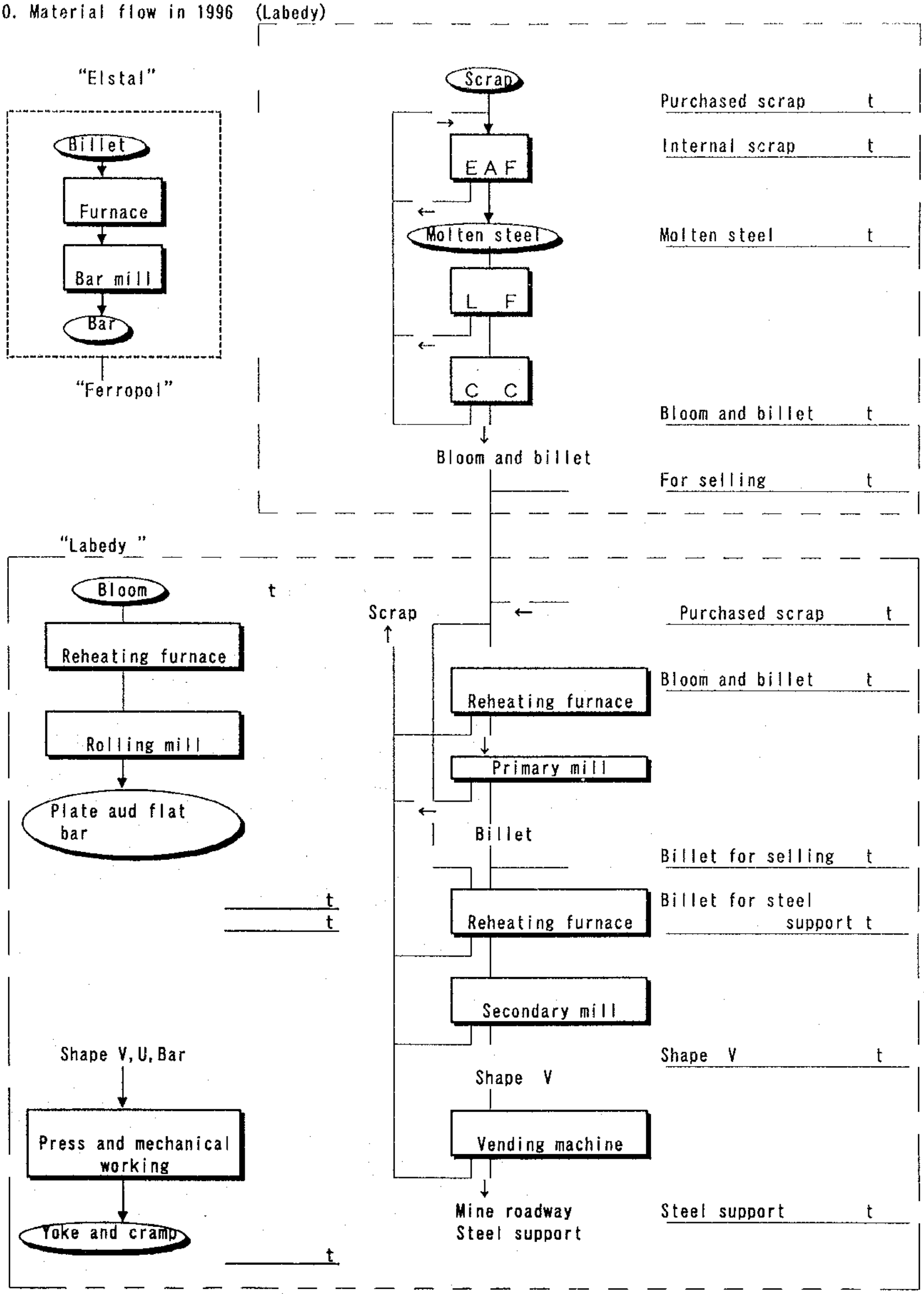
(Nore) In case that each process has own air compresser and it electricity is supplied from each, it is not necessary to put it's data in "compressed air" 3090.5 Mcal/t

9 . Main equipment working rate

unit (hour)

	(暦時間) 【A】 Calendar hour	(予定修理) 【B】 Programmed Maintenance	(稼働可能時 [C=A-B] Available time for operation	Non-operating time (非稼働時間) 【D】 Equipment trouble (Down time)	【E】 Inspection or survey	【F】 Operational maintenance (ex.roll change)	【G】 Others	【H】 Sub-total D+E+F+G	(作業率) 【I】 Operating rate (C-H)÷C	(稼働率) 【J】 Working rate I × C / A
Elstar EAF										
CC										
Labedy V shape and bilet Reheating furnace A										
B										
C										
D										
Rolling mill										
Plate mill Reheating furnace										
Rolling mill										
Press of roadway support										

10. Material flow in 1996 (Labedy)

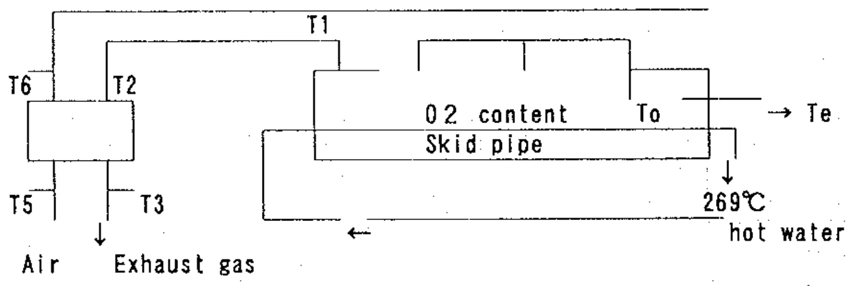


11. Site survey plan

1. General observation of operation and equipment
   - operation
   - maintenace of equipment
   - energy conservation equipment
   - energy conservation potentiality
   - data collecing for analisis
     - main equipments
     - pumps
     - blowers
     - compressors

2. Actual operation data
   (Labedy)
   1) Reheating furnace of shape V mill

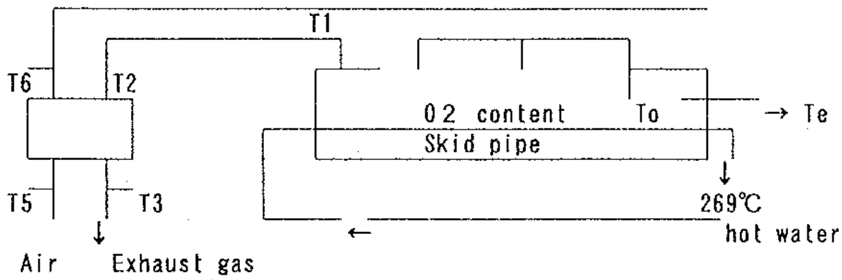
   - Fuel consumption during normal operation
   - Furnace data
   - Control system
   - Operation standard



Te					Fuel				
To	#				Air				
T 1	#								
T 2					T 6	349			
T 3	#				T 5				
0 2	2				0 2				
t/h									

2) Reheating furnace of billet mill

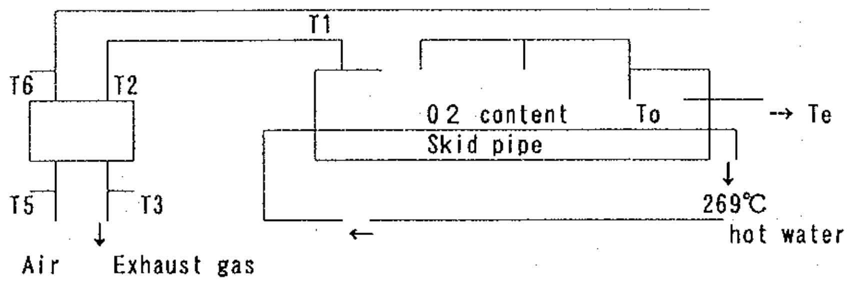
- Fuel consumption during normal operation
- Furnace data
- Control system
- Operation standard



Te					Fuel				
To					Air				
T 1									
T 2					T 6				
T 3					T 5				
0 2					0 2				
t/h									

3) Reheating furnace of plate mill

- Fuel consumption during normal operation
- Furnace data
- Control system
- Operation standard



Te					Fuel				
To					Air				
T 1									
T 2					T 6				
T 3					T 5				
O 2					O 2				
t/h									

4) Pumps
- Cooling fower fan
- Pump capacity and actual fecd water condition
  Press.and volume

5) O 2 Plant
- Campressor capacity and actual flow rate
  Press.and volume

6) Air Campressor
- Capacity and actual flow rate
  Press.and volume

7) Boiler
- Capacity and actual flow rate
- Exhaust gas O 2 content

(Elstar)
1) EAF and Ladle furnace
- Productivity (t/h)
- Power consumption (kwh/t)during normal operation
  - EAF
  - Auxiliary equipment (water,dust collecter)
- Cooling water rate

9.1.3 Joint Manufacturing Factory (Lacznikow)

(1) Cupola

a. Purpose of measurement

The purpose of measuremnt is to calculate the input energy and heat loss of the cupola in order to obtain the potential for energy conservation. Also the amount of energy loss is estimated based on the difference between melting speed and casting speed, thereby to evaluate the possible countermeasure.

b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Outlet exhaust gas temperature	1 charge	Thermocouple	to Recorder
② Outlet exhaust gas CO vol%	1 charge	CO, CO_2 meter	to Recorder
③ Outlet exhaust gas CO_2 vol%	1 charge	CO, CO_2 meter	to Recorder
④ Outlet exhaust gas temperature	spot	Thermocouple	Memo
⑤ Outlet exhaust gas CO vol%	spot	CO, CO_2 meter	Memo
⑥ Outlet exhaust gas CO_2 vol%	spot	CO, CO_2 meter	Memo
⑦ Outlet exhaust gas temperature	1 charge	Thermocouple	to Recorder
⑧ Outlet exhaust gas CO vol%	1 charge	CO, CO_2 meter	to Recorder
⑨ Outlet exhaust gas CO_2 vol%	1 charge	CO, CO_2 meter	to Recorder
⑩ Hot blast volume	spot	Anemomaster	Memo
⑪ Hot blast volume	1 charge	Meter for operation	to Recorder
⑫ Hot blast pressure	1 charge	Meter for operation	to Recorder
⑬ Hot blast feed temperature	1 charge	Thermocouple	to Recorder
⑭ Power consumption for blower and fan	1 charge	Clamp meter	to Recorder
⑮ Molten metal temperature	1 charge	Meter for operation	to Recorder
⑯ Carbon content in molten metal	1 charge	Meter for operation	to Recorder
⑰ Amount of cooling water			
⑱ Cooling water temperature (Inlet)	1 charge	Ultrasonic flowmeter	to Recorder
⑲ Cooling water temperature	1 charge	Thermocouple	to Recorder
(Outlet)	1 charge	Thermocouple	to Recorder
⑳ Power consumption for cooling			
water pump	spot	Clamp meter	Memo
㉑ Furnace surface temperature			
㉒ Air volume	spot	Radiation thermometer	Memo
	spot	Anemomaster	Memo

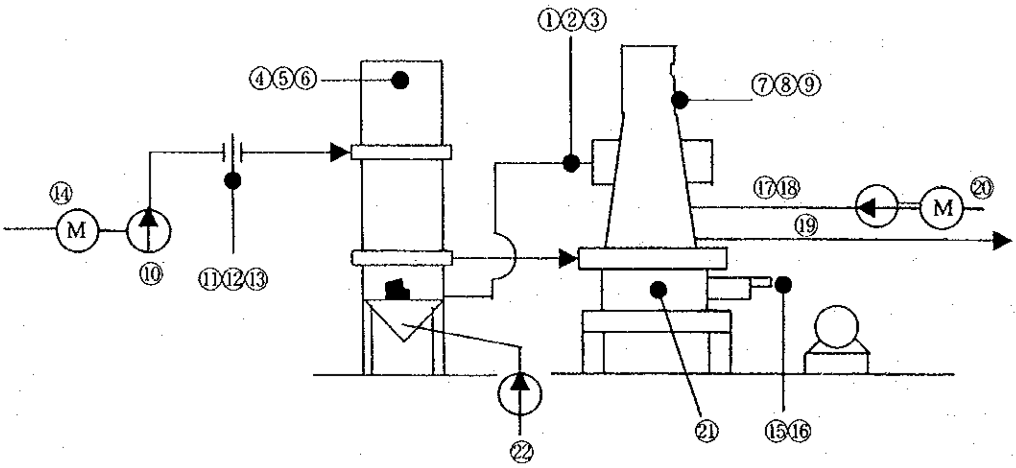
Note 1) Exhaust gas should be obtained based on N_2 balance in hot blast volume/exhaust gas amount

2) The following operation data are required for grasping the current state of operation. (Amount of molten metal, amount of slag, amount of dust, composition of dust, composition of slag, molten metal pouring amount, carbon content in the molten metal, silica content, pig iron, return cast iron, and scrap amount)

c. Measuring points

The measuring points for the cupola are shown in Figure 9.1.9.

Figure 9.1.9 Measuring Points of Cupola



(2) Heat treatment furnace

a. Purpose of measurement

The purpose is to survey the current operating status in order to perform heat balancing of the heat treatment furnace.

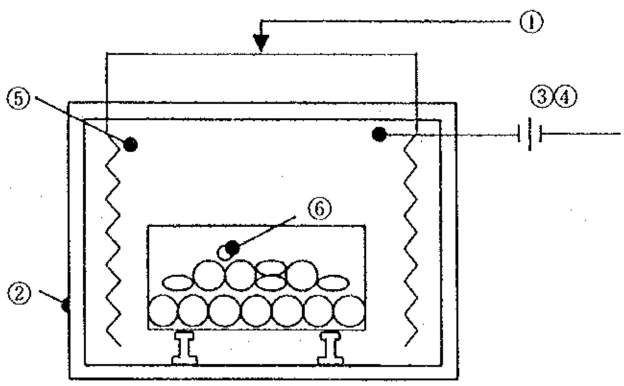
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Power consumption	8 h	Meter for operation	to Recorder
② Furnace surface temperature	spot	Surface thermometer	Memo
③ Atmospheric gas: air consumption	8 h	Meter for operation	to Recorder
④ Atmospheric gas: steam consumption	8 h	Meter for operation	to Recorder
⑤ Furnace internal temperature	8 h	Meter for operation	to Recorder
⑥ Heat treatment amount	spot	Operation record	Memo

c. Measuring points

Figure 9.1.10 shows the measuring points of the heat treatment furnace.

Figure 9.1.10 Measuring Points of Reheating Furnace



(3) Zinc coating line

a. Purpose of measurement

The purpose is to estimate the heat loss and study the current operating status in order to calculate the potential for energy conservation.

b. Measurement items, measurement time, measuring equipment, and data processing

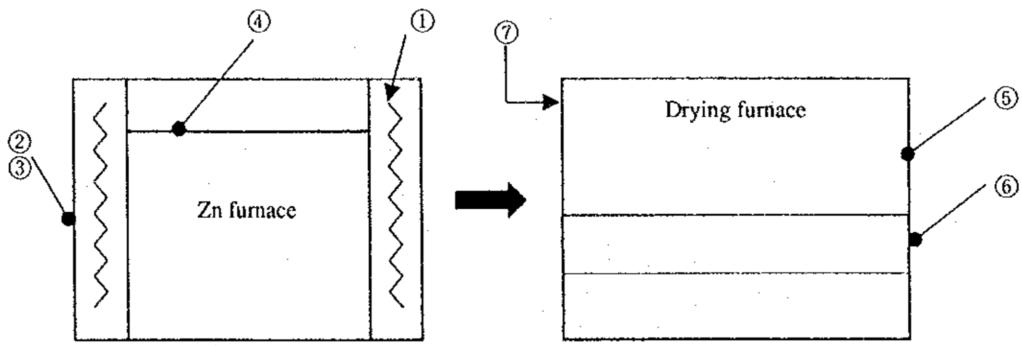
Measurement items	Measurement time	Measuring equipment	Data processing
① Power consumption	8 h	Meter for operation	to Recorder
② Zinc furnace surface temperature	spot	Surface thermometer	Memo
③ Zinc tank surface area	–	–	Memo
④ Zinc temperature	8 h	Meter for operation	to Recorder
⑤ Drying oven surface temperature	spot	Surface thermometer	Memo
⑥ Drying oven outlet gas temperature	spot	Thermocouple	Memo
⑦ Power consumption for drying oven	8 h	Meter for operation	to Recorder

Note 1) The weight of zinc-coated products should be recorded in order to grasp the operating status.

c. Measuring points

Figure 9.1.11 shows the measuring points of the zinc coating line.

Figure 9.1.11 Measuring Points of Zinc Coating Line



(4) Compressed air system

a. Purpose of measurement

The purpose is to survey changes in the consumption of compressed air as well as to study the performance of air compressor.

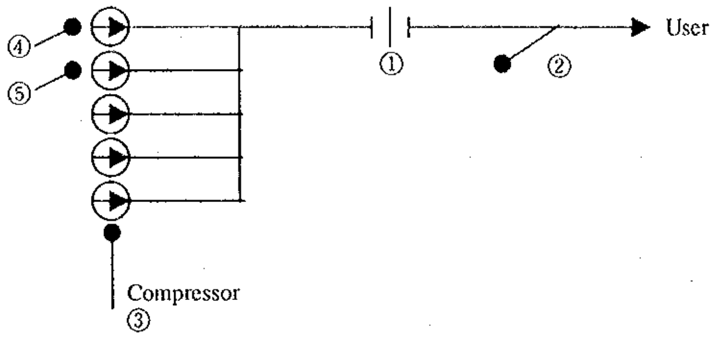
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Compressed air flow rate	24 h	Meter for operation	to Recorder
② Supply pressure	24 h	Meter for operation	to Recorder
③ Power consumption (Total)	24 h	Meter for operation	to Recorder
④ Power consumption (compressor)	spot	Clamp meter	Memo
⑤ Power consumption (compressor)	spot	Clamp meter	Memo

c. Measuring points

Figure 9.1.12 shows the measuring points of the compressed air system

Figure 9.1.12 Measuring Points of Compressed Air System



(5) Boiler and hot water system

a. Purpose of measurement

The purpose is to check the performance of the heat exchangers and the boiler as well as to survey changes in the heating load and other hot water load.

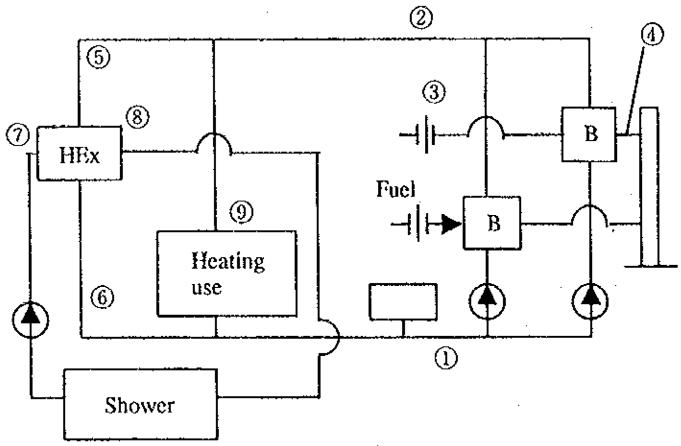
b. Measurement items, measurement time, measuring equipment, and data processing

Measurement items	Measurement time	Measuring equipment	Data processing
① Water volume and temperature	6 h	Meter for operation	to Recorder
② Temperature	6 h	Meter for operation	to Recorder
③ Lime consumption	6 h	Meter for operation	to Recorder
④ Exhaust gas O_2 %	6 h	O_2 meter	to Recorder
⑤ Water volume	spot	Ultrasonic flowmeter	Memo
⑥ Temperature and pressure	spot	Meter for operation	Memo
⑦ Water volume	spot	Ultrasonic flowmeter	Memo
⑧ Temperature and pressure	spot	Meter for operation	Memo
⑨ Heating load	6 h	Meter for operation	to Recorder

c. Measuring points

Figure 9.1.13 shows the measuring points of the boiler and hot water system.

Figure 9.1.13 Measuring Points of Boiler and Hot Water System



(6) Energy utilization facilities

Equipment name	Targeted equipment or location	Measurement time
Electricity management	Power receiving facilities	24 h
	Heat treatment furnace	24 h
	Drying oven	24 h
	Zinc furnace	24 h
Fan/blower	For cupola	24 h
Electric motor	Major equipment	24 h
Air compressor	No. 3, 4 and 6	24 h
Pump	For cupola Cupola cooling pump	24 h
Transformer	Major equipment	24 h
Lighting	Various locations in the factory	spot
Boiler	Boiler room	24 h
Steam pipe	Various locations in the factory	spot

For the measurement method and the measuring points, see "10. ENERGY UTILIZATION FACILITIES".