12-14-6 Calculation Results

Examples of calculation results for heat input and heat output are shown in Table 12-41 and 12-42.

Table 12-41 Calculation Results for Heat Input

Date	Aug. 14	Aug. 14	Aug. 14
Heat No.	965751	965752	965753
(1) Heat quantity of electric power, Q_1 (1000 x kcal/t-output)			
Ratio of heat quantity of electric power in heat input (%)			
Unit consumption of electric power, w_1 (kWh/t-output)			
(2) Potential heat of hot heel, Q_2 (1000 x kcal/t-output)			
Ratio of potential heat of hot heel in heat input (%)			
Unit weight of hot heel of raw materials, m_2 (kg/t-output)			
Temperature of hot heel (°C)			
Heat content of hot heel, h_2 (kcal/kg)			
(3) Sensible heat of raw materials, Q_3 (1000 x kcal/t-output)			
Ratio of sensible heat of raw materials in heat input (%)			
Unit consumption of raw materials, m_3 (kg/t-output)			
Mean temperature of raw materials after SPH (°C)			
Heat content of raw materials after SPH h_{3h} (kcal/kg)			
(4) Calorific power of fuel oil, Q_4 (kcal/t-output)			
Ratio of calorific power of fuel oil in heat input (%)			
Unit consumption of fuel oil, m_4 (kg/t-output)			
Low heating value of fuel oil, q_4 (kcal/kg)			
(6) Oxidation heat of electrode, Q_6 (1000 x kcal/t-output)			
Ratio of oxidation heat of electrode in heat input (%)			
Unit consumption of electrode, m_6 (kg/t-output)			
C content of electrode (%)			
Amount of C oxidation of electrode (kg/t-output)			
Oxidation heat of electrode in CO_2 formation, q_{6CO_2} (kcal/kg)			
Oxidation heat of electrode in CO formation, q_{6CO} (kcal/kg)			
Mean CO_2 content in exhaust gas (CO_2) (%)			
Mean CO content in exhaust gas (CO) (%)			
(7) Oxidation heat of charge, Q_7 (1000 x kcal/t-output)			
Ratio of oxidation heat of charge in heat input (%)			
(7a) Oxidation heat of charged C, Q_{7a} (1000 x kcal/t-output)			
Unit consumption of scrap (kg/t-output)			
Unit consumption of pig iron (kg/t-output)			
C content of scrap (%)			
C content of pig iron (%)			
C content of molten steel before tapping (%)			
Oxidation amount of charged C, m_{7a} (kg/t-output)			

Heat of C oxidation in CO_2 formation, q_{7cco2} (kcal/kg)
Heat of C oxidation in CO formation, q_{7cco} (kcal/kg)

(7b) Oxidation heat of charged Si, Q_{7b} (1000 x kcal/t-output)
Si content of scrap (%)
Si content of pig iron (%)
Si content of molten steel before tapping (%)
Oxidation amount of charged Si, m_{7b} (kg/t-output)
Heat of Si, q_{7bSi} (kcal/kg)

(7c) Oxidation heat of charged Mn, Q_{7C} (1000 x kcal/t-output)
Mn content of scrap (%)
Mn content of pig iron (%)
Mn content of molten steel before tapping (%)
Oxidation amount of Mn m_{7c} (kg/t-output)
Heat of Mn, q_{7cMn} (kcal/kg)

(7d) Oxidation heat of charged P, Q_{7d} (1000 x kcal/t-output)
P content of scrap (%)
P content of pig iron (%)
P content of molten steel before tapping (%)
Oxidation amount of P, m_{7d} (kg/t-output)
Heat of P, q_{7dP} (kcal/kg)

(7e) Oxidation heat of charged Cr, Q_{7e} (1000 x kcal/t-output)
Cr content of scrap (%)
Cr content of pig iron (%)
Cr content of molten steel before tapping (%)
Oxidation amount of Cr, m_{7e} (kg/t-output)
Heat of Cr, q_{7eCr} (kcal/kg)

(7f) Oxidation heat of charged Al, Q_{7f} (1000 x kcal/t-output)
Al content of scrap (%)
Al content of pig iron (%)
Al content of molten steel before tapping (%)
Oxidation amount of Al, m_{7f} (kg/t-output)
Heat of Al, q_{7fAl} (kcal/kg)

(7g) Oxidation heat of charged Fe, Q_{7g} (1000 x kcal/t-output)
Unit weight of slag, m_{7g} (kg/t-output)
Heat of Fe oxidation in FeO formation, q_{7gFeO} (kcal/kg)
Heat of Fe oxidation in Fe_2O_3 formation, $q_{7gFe2O3}$ (kcal/kg)
FeO content in slag, (FeO) (%)
Fe_2O_3 content in slag (Fe_2O_3) (%)

(8) Oxidation heat of carbon injection, Q_8 (1000 x kcal/t-output)
Ratio of oxidation heat of carbon injection (%)
Unit consumption of carbon injection (kg/t-output)
C content in carbon injection (%)
Oxidation amount of carbon injection, m_{8a} (kg/t-output)

(9) Heat of slag formation, Q_9 (1000 x kcal/t-output)
Ratio of heat of slag formation in heat input (%)

Heat of SiO_2 reaction in Ca_2SiO_4 formation, q_{9SiO2} (kcal/kg)	
Heat of P_2O_5 reaction in $Ca_3P_2O_3$ formation, q_{9P2O5} (kcal/kg)	
SiO_2 content in slag (%)	
P_2O_5 content in slag (%)	
Heat Input, **Q_{Input} (1000 x kcal/t-output)**	

Table 12-42 Calculation Results of Heat Output

Date	Aug. 14	Aug. 14	Aug. 14
Heat No.	965751	965752	965753
(10) Potential heat of molten steel, Q_{10} (1000 x kcal/t-output)			
Ratio of potential heat of molten steel (%)			
(10a) Potential heat of output, q_{10a} (1000 x kcal/t-output)			
Temperature of molten steel before tapping (°C)			
Heat content of molten steel before tapping, h_{10a} (kcal/kg)			
(10b) Potential heat of hot heel, q_{10b} (1000 x kcal/t-output)			
Unit weight of hot heel of molten steel, m_2 (kg/t-output)			
(11) Potential heat of slag, Q_{11} (1000 x kcal/t-output)			
Ratio of potential heat of slag in output (%)			
Unit weight of slag, m_{11} (kg/t-output)			
Temperature of slag (°C)			
Heat content of slag, h_{11} (kcal/kg)			
(12) Heat of limestone decomposition, Q_{12} (1000 kcal/t-output)			
Ratio of heat of limestone decomposition (%)			
Unit consumption of limestone, m_{12} (kg/t-output)			
Heat of decomposition of limestone, q_{12CaCO_3} (kcal/kg)			
CaO content in limestone (%)			
(14) Heat in cooling water, Q_{14} (1000 x kcal/t-output)			
Ratio of heat in cooling water (%)			
(14a) Heat in cooling water for elbow, Q_{14a} (1000 x kcal/t-output)			
Average quantity of cooling water for elbow, m_{14a} (kg/t-output)			
Mean outlet temperature of cooling water for elbow (°C)			
Inlet temperature of cooling water for elbow (°C)			
(14b) Heat in cooling for roof, Q_{14b} (1000 x kcal/t-output)			
Average quantity of cooling water for roof, m_{14b} (kg/t-output)			
Mean outlet temperature of cooling water for roof (°C)			
Inlet cooling water for roof (°C)			
(14c) Heat in cooling water for EBT, Q_{14c} (1000 x kcal/t-output)			
Average quantity of cooling water for EBT, m_{14c} (kg/t-output)			
Mean outlet temperature of cooling water for EBT (°C)			
Inlet temperature of cooling water for EBT (°C)			
(14d) Heat in cooling water for shell-1, Q_{14d} (1000 x kcal/t-output)			
Average quantity of cooling water for shell-1, m_{14d} (kg/t-output)			
Mean outlet temperature of cooling water for shell-1 (°C)			
Inlet temperature of cooling water for shell-1 (°C)			
(14e) Heat in cooling water for shell-2, Q_{14e} (1000 x kcal/t-output)			
Average quantity of cooling water for shell-2, m_{14d} (kg/t-output)			
Mean outlet temperature of cooling water for shell-2 (°C)			

Inlet temperature of cooling water for shell-2 (°C)	
(15) Sensible heat of exhaust gas, Q_{15} (1000 x kcal/t-output) Ratio of sensible heat in exhaust gas (%) Heat in average flow of exhaust gas (kcal/min.) Power on-to-power off time, t_h (hr) Output (t/heat)	
(16) Heat loss at furnace body, Q_{16} (1000 kcal/t-output) Ratio of heat loss at furnace body in heat input (%) Indoor temperature, T_{aa} (°K) Indoor temperature (°C)	
(16a) Heat loss at roof, Q_{16a} (1000 x kcal/t-output) Surface area of furnace roof, A_a (m^2) (16a1) Radiation heat loss at roof, q_{ra} (kcal/m_2, hr) Surface temperature of roof, T_{0aa} (°K) Surface temperature of roof (°C) (16a2) Convection heat loss at roof, q_{ca} (kcal/m^2, hr)	
(16b) Heat loss at shell, Q_{16b} (1000 x kcal/t-output) Surface area of shell, A_a (m^2) (16b1) Radiation heat loss at shell, q_{rb} (kcal/m^2, hr) Mean surface temperature of shell T_{0aa} (°K) Mean surface temperature of shell, t_{0b} (°C) (16b2) Convection heat loss at shell, q_{cba} (kcal/m^2, hr)	
(16c) Heat loss at bottom, Q_{16c} (1000 x kcal/t-output) Surface area of furnace bottom, A_c (m^2) (16c1) Radiation heat loss at bottom, q_{rc} (kcal/m^2, hr) Mean surface temperature of bottom, T_{0aa} (°K) Surface temperature of bottom, t_{0c} (°C) (16c2) Convection heat loss at bottom, q_{cc} (kcal/m^2, hr)	
(17) Other heat losses (1000 kcal/t-output) Ratio of other heat losses (%)	
Heat output, O_{utput} (1,000 kcal/t-output)	

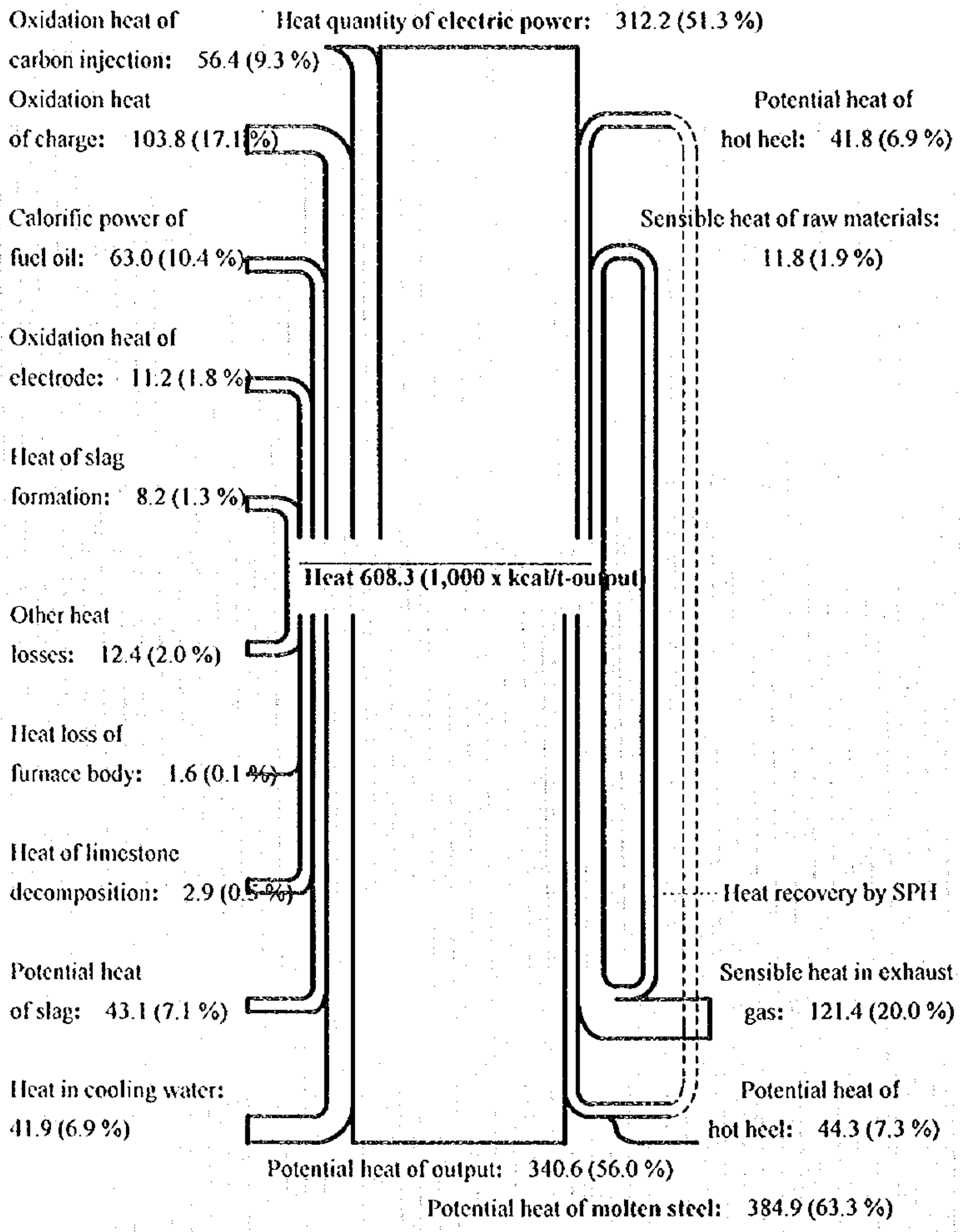


Figure 12-38 Heat Balance of Heat No. 965751

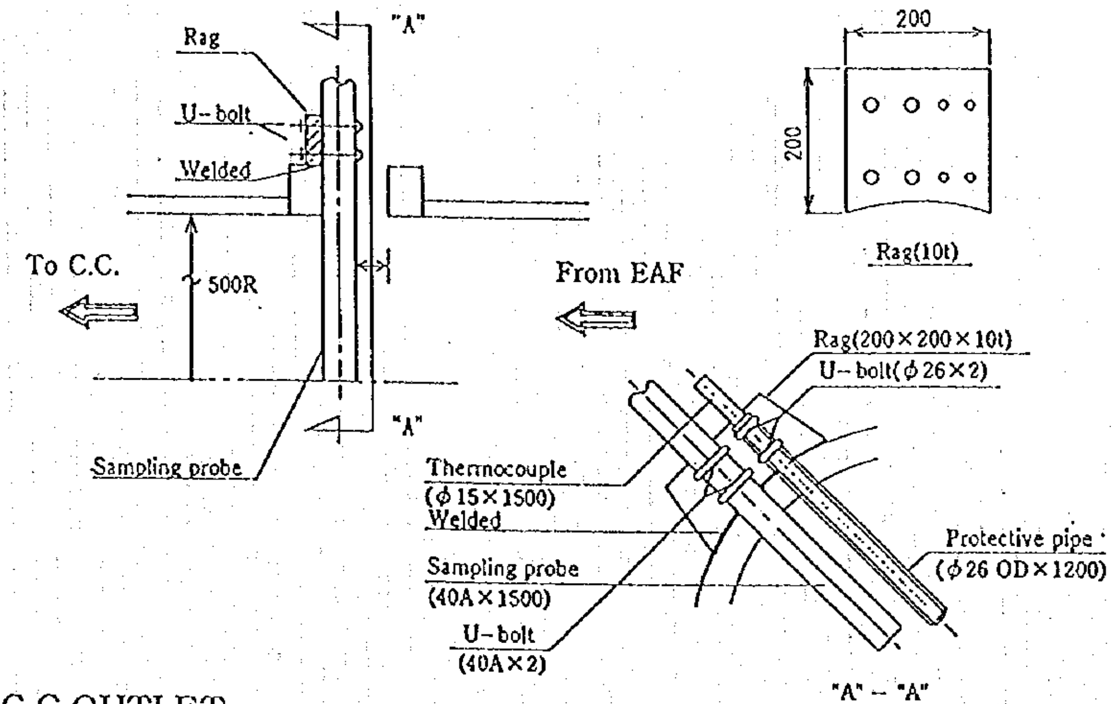
12-14-8 Details of Measurement for Exhaust Gas, Outlet Temperature of Cooling Water and Surface Temperature of Furnace Body

(1) Layout of Measuring Equipment

Figure 12-39 and 12-40 show the layout of measuring equipment and fitting the sampling probe, for example.

1. C.C. INLET

(fitting rag for gas sampling probe and thermocouple)



2. C.C.OUTLET

(fitting nozzles for Pitot's tube and sampling probe)

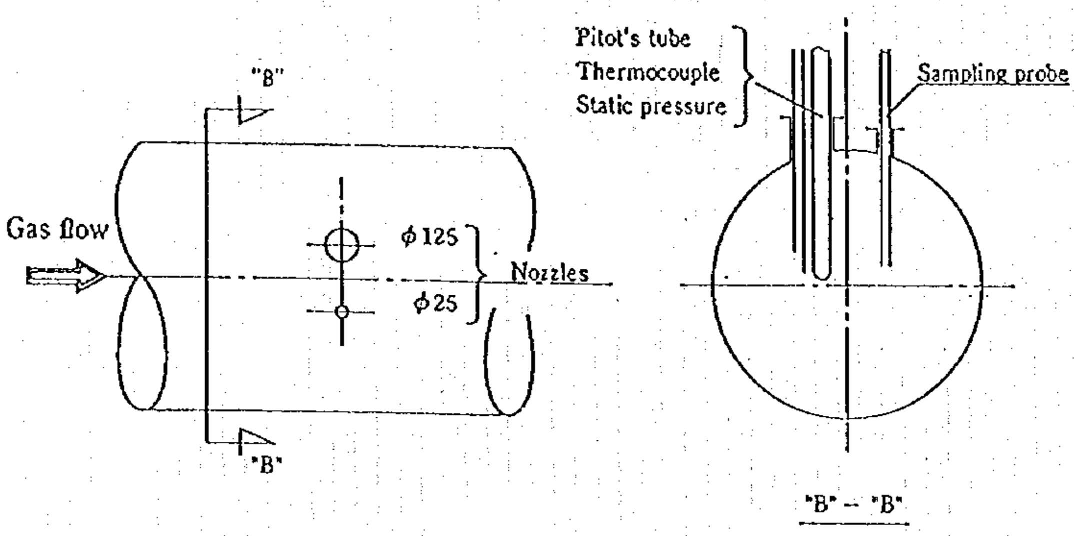


Figure 12-39 Fitting Sample Devices for Measurement of Exhaust Gas

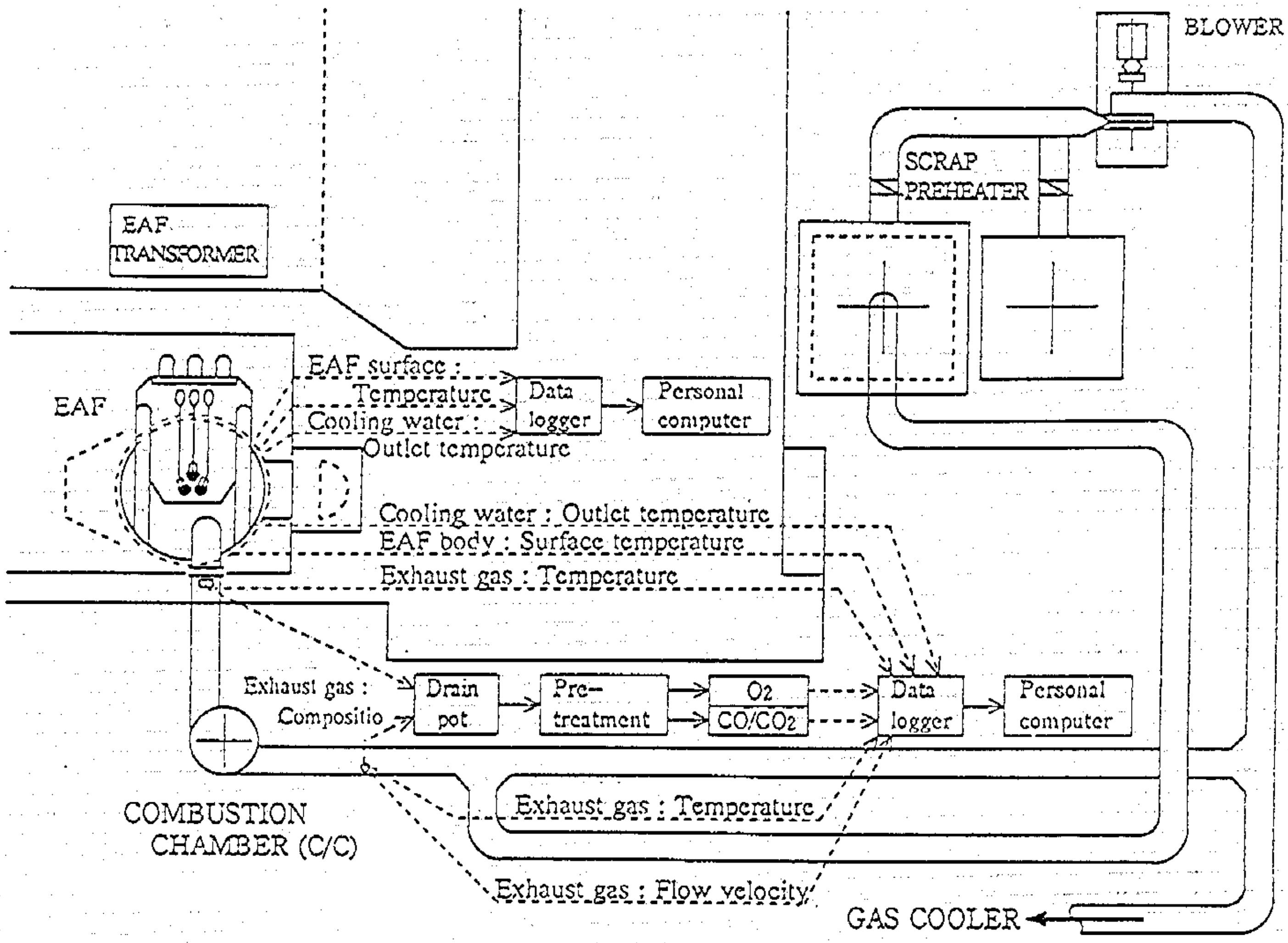


Figure 12-40 Layout of Measuring Equipment of Exhaust Gas, Outlet temperature of cooling water and Surface temperature of furnace Body

(2) Measurement of Flow Rate and Temperature of Exhaust Gas

1) Measuring Position

(a) Temperature

Combustion chamber inlet

Combustion chamber outlet

(b) Flow rate

Combustion chamber outlet duct (one point)

2) Measuring Interval

Continuously perform the measurement, and input the data to the data processor every 10 seconds to compute the average values per minute.

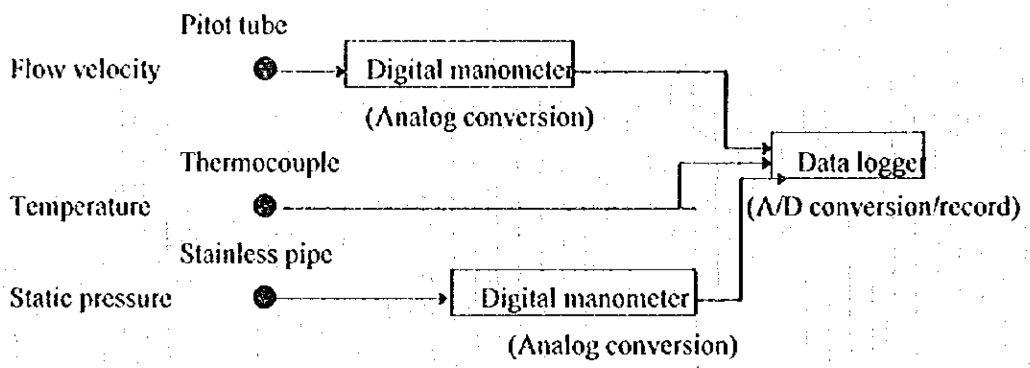
3) Instruments

1. Pitot tube: Special double-head type pitot tube for measuring flow velocity
2. Measuring pipe: Stainless steel pipe I.D. ϕ 10 mm or so for measuring static pressure
3. Digital manometer: For measuring dynamic pressure
4. Digital manometer: For measuring static pressure
5. Thermocouple: JIS type K, PR, and B

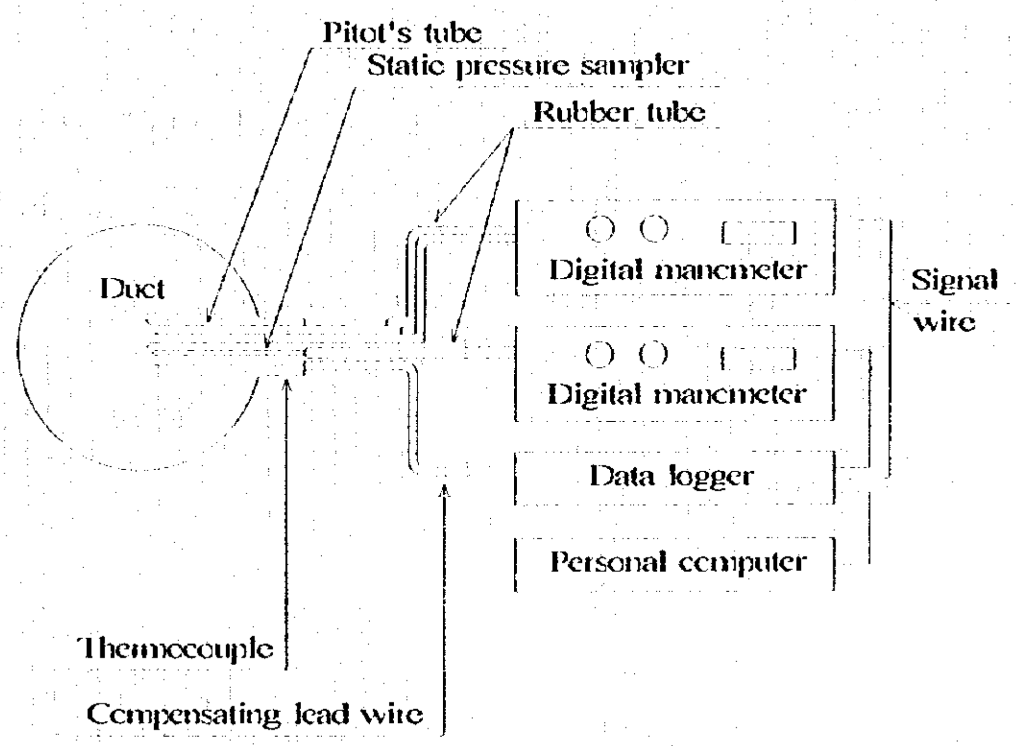
4) Measurement Method

1. Fix a pitot tube, a measuring pipe for static pressure, and a thermocouple to the measuring point, and carry out measurement.
2. Convert the indication of dynamic pressure into analog signals by a digital manometer, and record them in the data logger.
3. Measure temperature by a thermocouple, and input the data to the data logger through a compensating lead for recording.
4. Convert the indication of static pressure into analog signals by a digital manometer, and record them in the data logger.

5) **Measuring flow**



6) **Measurement Outline**



(3) Measurement of CO, CO_2, and N_2 Content in Exhaust gas

1) **Measuring Position**

Combustion chamber inlet

Combustion chamber outlet

2) Measuring Interval

Continuously perform the measurement, and input the data to the data processor every 10 seconds to compute the average values per minute. N_2 is to be calculated.

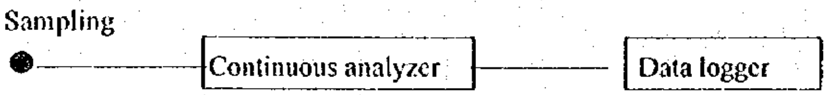
3) Instruments

1. CO meter: Non-disperse infrared continuous analyzer
2. CO_2 meter: Non-disperse infrared continuous analyzer
3. O_2 meter: Magnetic force continuous analyzer
4. Pretreatment unit

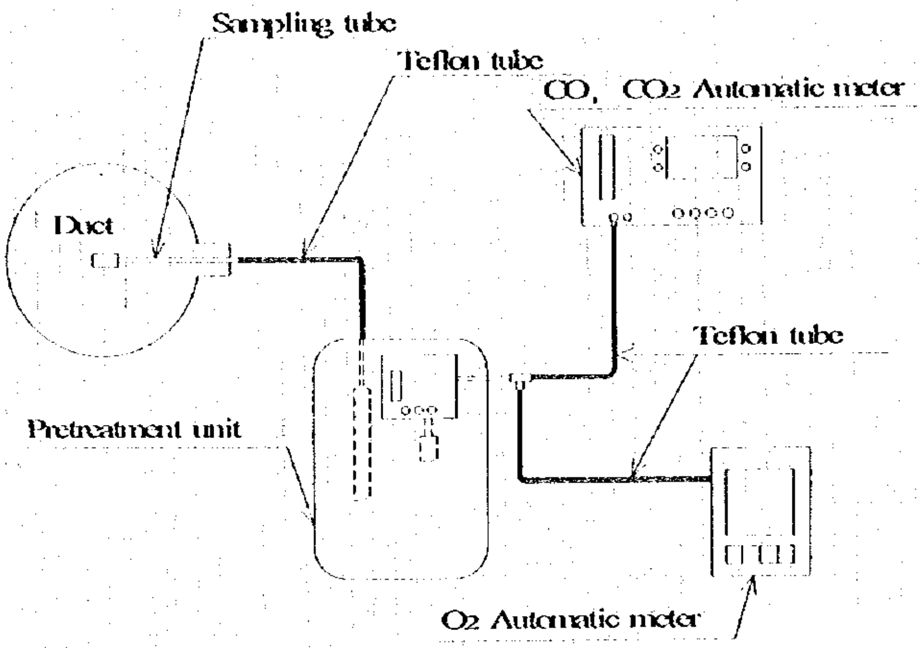
4) Measuring Method

1. Measure the concentration of CO, CO_2, and O_2 by a continuous analyzer.
2. Insert a sampling pipe into the measuring position.
3. Connect filter and trap for dust removal to the connection of the sampling pipe and the gas conduit.
4. Introduce sample gas to the continuous analyzer previously calibrated by the standard gas.
5. Perform content analysis by a continuous analyzer, allowing sample gas to flow at the rate of 1- 2 litters per minute.
6. Input the measured data into the data logger for recording.
7. Determine N_2 concentration by calculation, obtaining N_2 as the remainder of the same of CO, CO_2 and O_2 concentrations.

5) Measuring Flow



6) **Measurement Outline**



(4) Measurement of Outlet Temperature of Cooling Water

1) Measuring Position

Return cooling water piping for EBT, elbow, roof-1, roof-2 shell-1 and shell-2.

2) Measuring Interval

Continuously perform the measurement, and input the data into the data logger every 10 seconds for the calculation of average values per minute.

3) Instruments

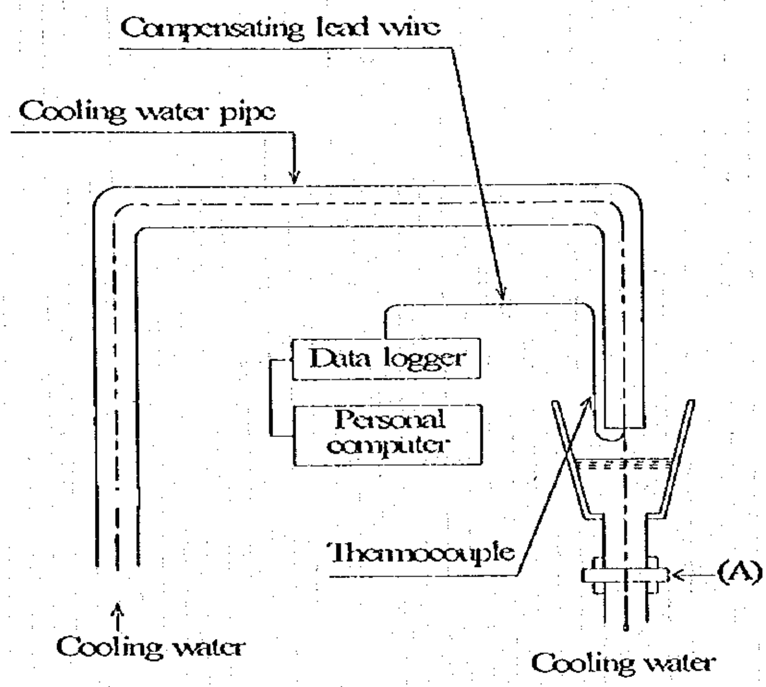
1. Thermocouple (JIS type T)

4) Measuring Method

1. Measure temperature by a thermocouple (JIS type T).
2. Insert a thermocouple for measurement of temperature from the drainage to the piping to be fixed.
3. Input temperature data into the data logger for recording.

5) **Measuring Flow**

6) **Measurement Outline**



(5) Measurement of Surface Temperature of the Furnace Body

1) **Measuring Positions**

Surfaces of the furnace shell and bottom

2) **Measuring Interval**

Continuously perform the measurement, and input the data to the data processor every 10 seconds to computer the average values per minute.

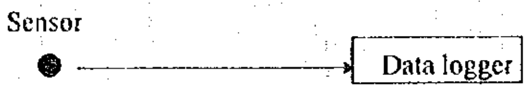
3) **Instrument**

Thermocouple (JIS type K)

4) Measurement Method

1. Measure temperature by a thermocouple (JIS type K).
2. Fix the thermocouple for measuring temperature to the surface of the furnace shell and bottom by welding.
3. Connect a compensating lead to the thermocouple fixed to the surface, and extend it to a data logger.
4. Input temperature data to the data logger for recording.

5) Measuring Flow



12-14-9 Site Survey and Preparatory Work

(1) Site Survey

1) General

In order to plan measurement methods in detail, a preparatory site survey shall be done before the measurement. Site survey includes explanation and discussions with objective EAF's personnel on the plant operation, site conditions, assistance of objective EAF's personnel to the measurement, and measuring methods.

The site survey shall be carried out by the measurement experts for :

1. Proper locations for installation of instruments and protection shelter
2. Utility supply for the field instruments (electric wiring and water supply)
3. Existing on-line instruments (kinds and location)

2) Site Check

(a) Location of Measuring Points

1. Elbow (Combustion Chamber (C/C) inlet):

   Fitting point of sampling probe

   Approach to the fitting point

   Area for preparation and maintenance for sampling probe

   Feeding of cooling water for probe

   Outlet of cooling water for probe

2. Duct (C/C outlet):

   Probe inserting hole

   Approach to measuring point for maintenance work

3. EAF cooling water:

   Measuring points

   Approach to measuring points

4. EAF wall and bottom:

   Fitting thermocouples

   Approach to fitting points

5. Scrap bucket:

   Approach to bucket with hand-carrying thermometers

6. Measuring instruments:

   Space for 2 sets for exhaust gas and EAF cooling water

7. Others:

   Operation room

(b) Utility on Site

1. Electric source:

   2-3 points for instruments, 200 V, 20-30 A

2. Cooling water:

   For sampling probe, 3/4"

3. Extension bar :

   For thermometer for measuring bucket temperature, 2-3 meters

4. Others:

   If necessary

(c) Modifications for Measurement

1. Rag plate:

   Welding a rag plate of 200 x 200 x 10 mm thickness to sliding duct for U-bolt to fit sampling probe

2. Thermocouple:

   Welding thermocouples to the furnace shell and bottom

3. Water tap:

   Installation of a water tap for cooling water of sampling probe

4. Stage:

Preparation for measurement and maintenance

5. Others:

Prepared as found necessary

(d) Data Collection from Plant Instruments

1. Control room:

Timer

Watt meter

Weighing of scrap

Weighing of molten steel, etc.

2. Inlet energy:

O_2 meter

Fuel meter, etc.

3. Others:

As necessary

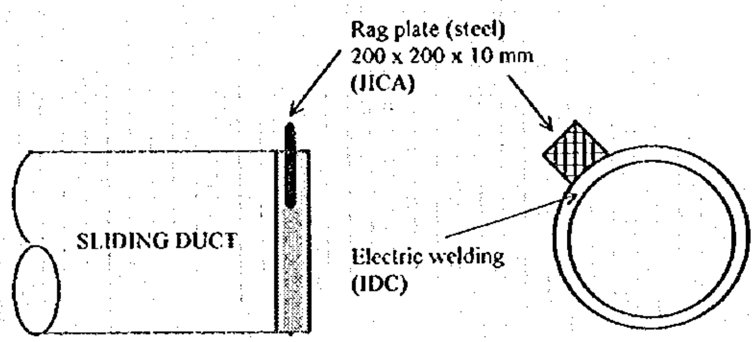
(2) Preparatory Work

For example, preparatory work shall be done before measurement as follows:

1) Welding a Rag Plate to Sliding Duct (C/C inlet)

A rag plate shall be welded at the end of the sliding duct of EAF (C/C inlet, combustion chamber inlet).

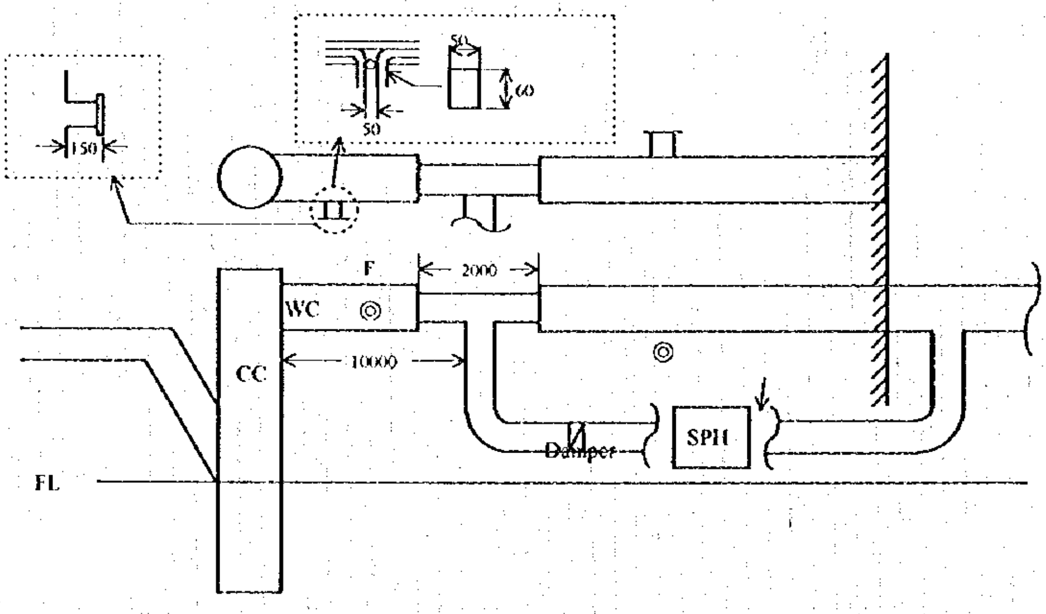
Note: A rag plate with U-bolts is used to hold a sampling probe for analysis of the exhaust gas and thermocouple for measuring the temperature of the exhaust gas.



2) Opening the Holes (C/C outlet)

A hole of 50 x 60 mm shall be opened at the tubular cooling duct behind C/C (combustion chamber).

Note: A hole of 50 x 60 mm is for measuring the flow rate, composition and temperature of the exhaust gas.



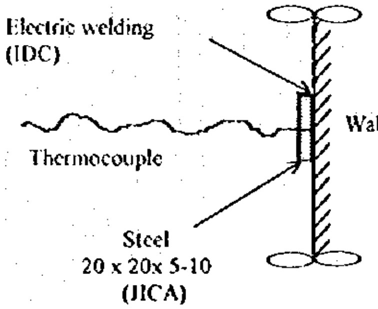
3) Welding Thermocouples to the Furnace Shell and Bottom

Steel plates containing thermocouple shall be welded to the furnace shell and bottom.

Shell: 12 points on the cooling pipe of center of the cooling panel. 2 points for each panel of No. 2, 4, 6, 8, 10 and 12

Bottom: 4 points on the bottom equally

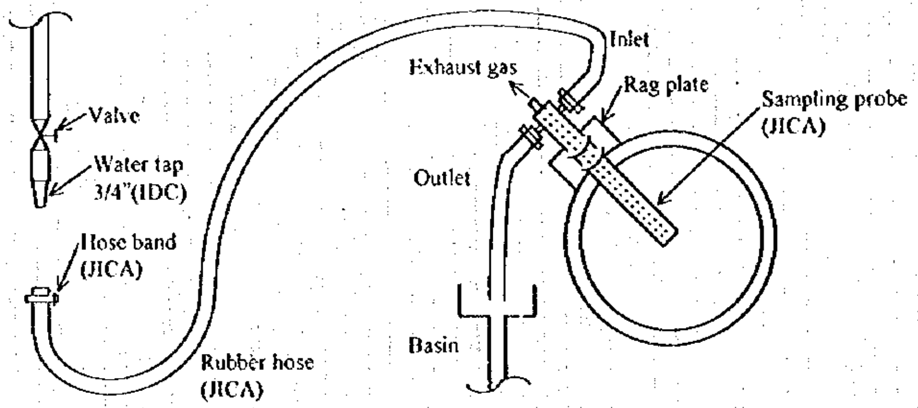
Note: Thermocouples are to measure the furnace temperature.



4) Water Supply

Water tap device and basin for return water shall be installed near the C/C.

Note: Water is used for cooling the sampling probe at the C/C inlet.

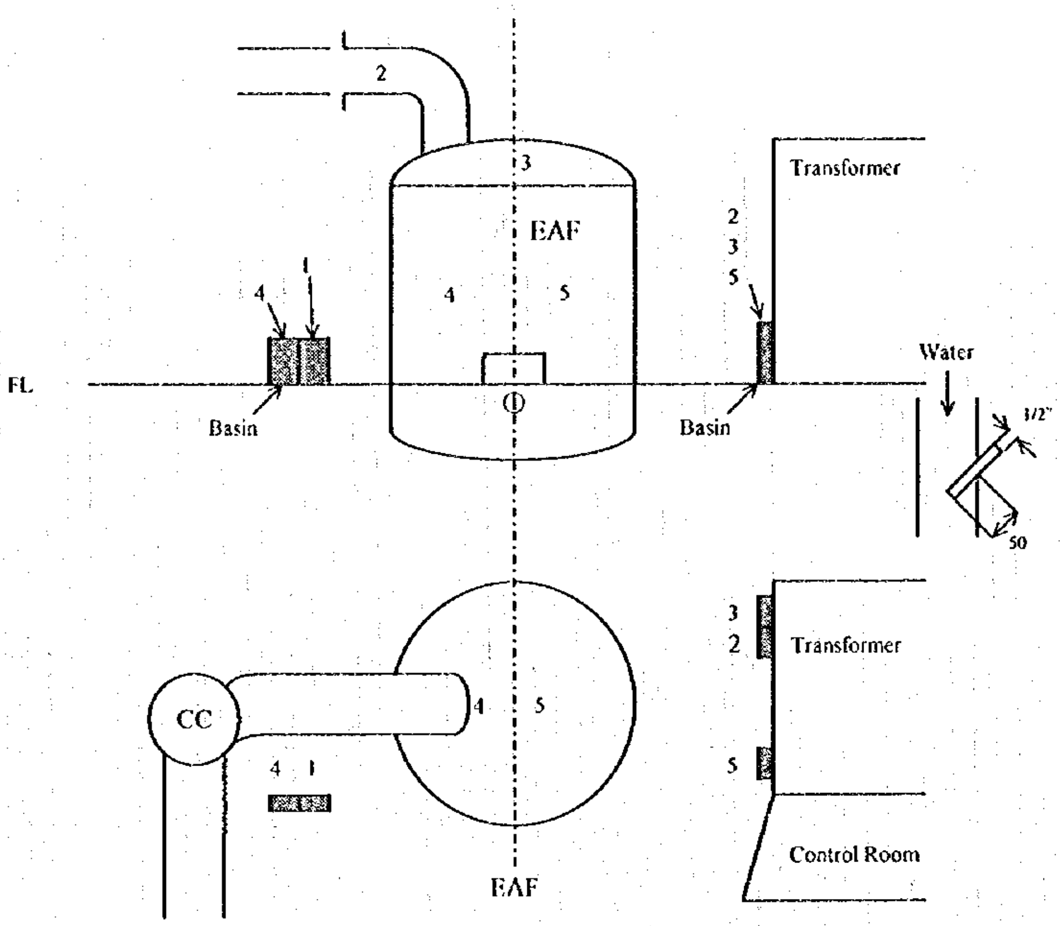


5) Installation of the Holder for Outlet Temperature of Cooling Water

A pipe shall be installed at each return water piping system.

Note: A pipe is to hold the thermocouple to measure the outlet temperature of the furnace cooling water.

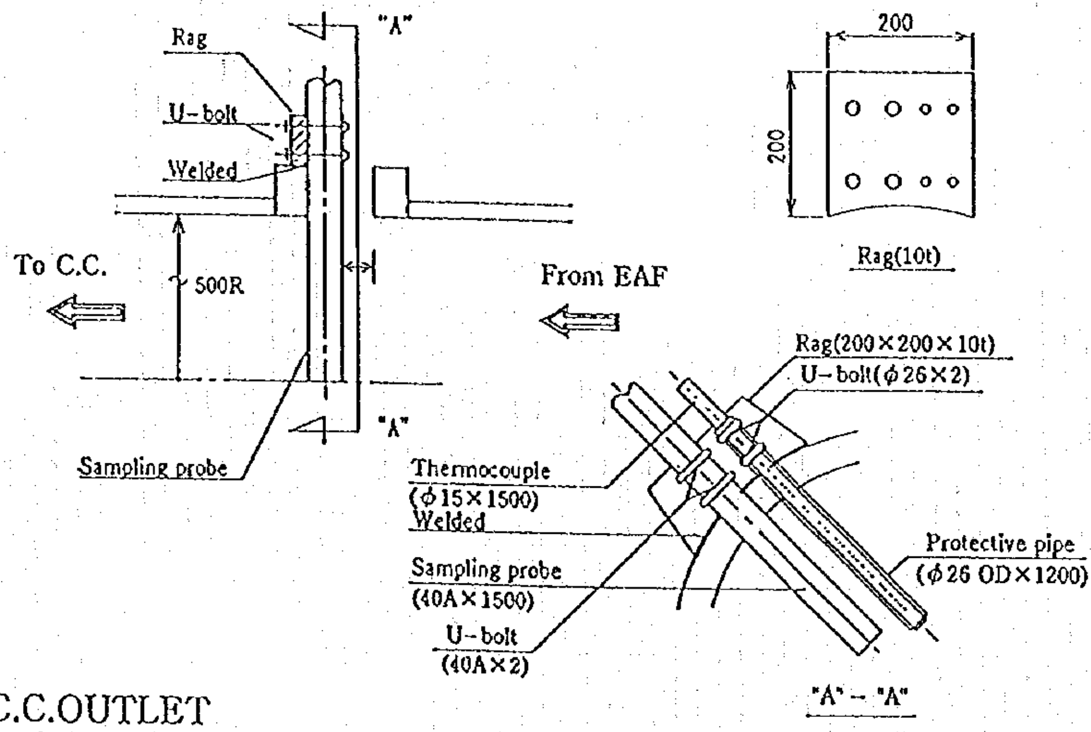
1: Return water piping system for the EBT
2: Return water piping system for the elbow
3: Return water piping system for the roof
4: Return water piping system for the shell-1
5: Return water piping system for the shell-2


2
3
EAF
4
5
1
Transformer
2
3
5
Water
FL
Basin
Basin
1/2"
50
3
2
Transformer
CC
4
5
4 1
5
Control Room
EAF

Annex

1 Measuring of Exhaust Gas

1. C.C. INLET
(fitting rag for gas sampling probe and thermocouple)



2. C.C.OUTLET
(fitting nozzles for Pitot's tube and sampling probe)

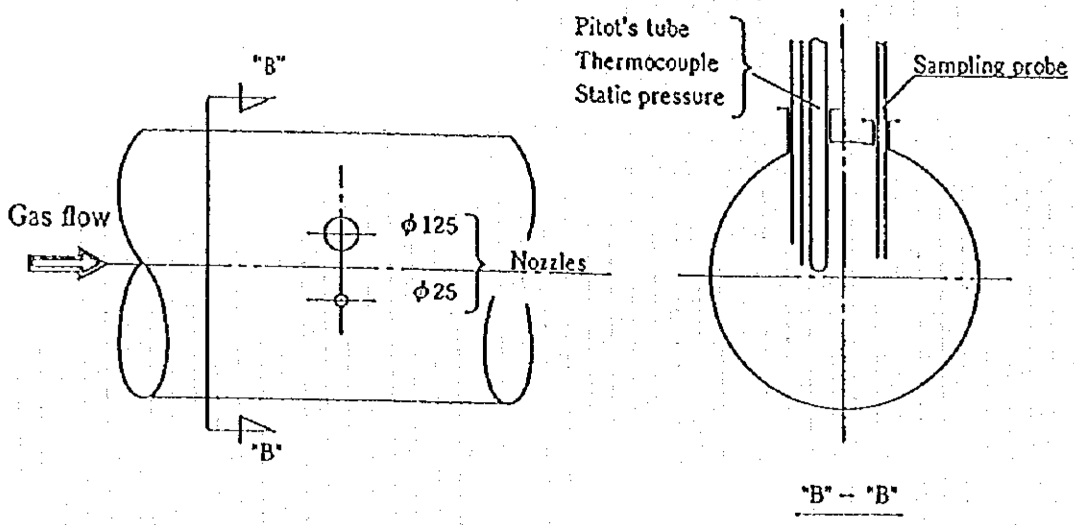


Figure AN-1-1 Fitting of Sampling Devices

1-1 Measurement of Flow Rate and Temperature of Exhaust Gas

(1) Measuring Position

1) Temperature

Combustion chamber inlet

Combustion chamber outlet

2) Flow rate

Combustion chamber outlet duct (one point)

(2) Measuring Interval

Continuously perform the measurement, and input the data to data processor every 10 seconds to compute the average values per minute.

(3) Instruments

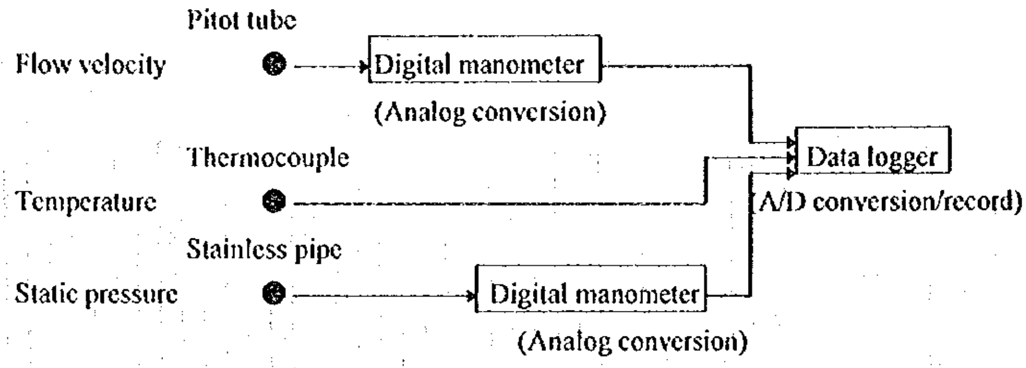
1. Pitot tube: Special double-head type pitot tube for measuring flow velocity
2. Measuring pipe: Stainless steel pipe I.D. ϕ 10 mm or so for measuring static pressure
3. Digital manometer: For measuring dynamic pressure
4. Digital manometer: For measuring static pressure
5. Thermocouple: JIS type K, PR, and B

(4) Measurement Method

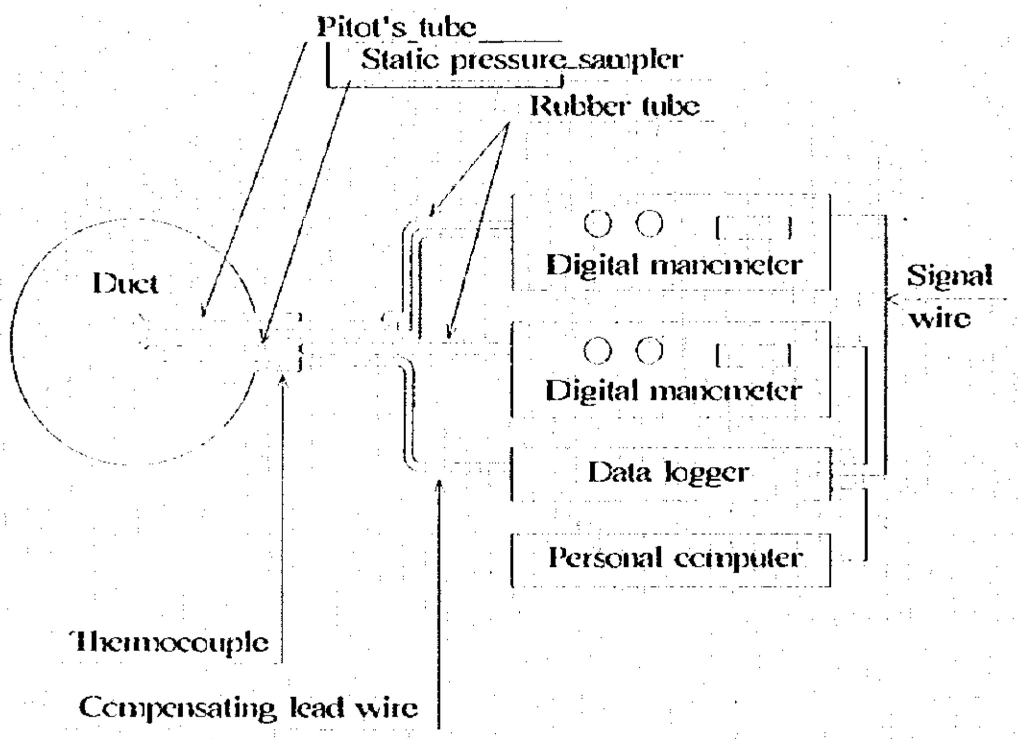
1. Fix a pitot tube, a measuring pipe for static pressure, and a thermocouple to the measuring point, and carry out measurement.
2. Convert the indication of dynamic pressure into analog signals by a digital manometer, and record them in the data logger.
3. Measure temperature by a thermocouple, and input the date to the data logger through a compensating lead for recording.
4. Convert the indication of static pressure into analog signals by a digital manometer, and record them in the data logger.

(5) Measuring Flow

The measuring flow is shown below.



(6) **Measurement Outline**



1-2 Measurement of CO, CO_2, and N_2 Content in Exhaust gas

(1) **Measuring Position**

Combustion chamber inlet

Combustion chamber outlet

(2) Measuring Interval

Continuously perform the measurement, and input the data to the data processor every 10 seconds to compute the average values per minute. N_2 is to be calculated.

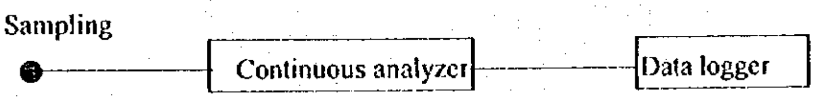
(3) Instruments

1. CO meter: Non-dispersing infrared continuous analyzer
2. CO_2 meter: Non-dispersing infrared continuous analyzer
3. O_2 meter: Magnetic force continuous analyzer
4. Pretreatment unit

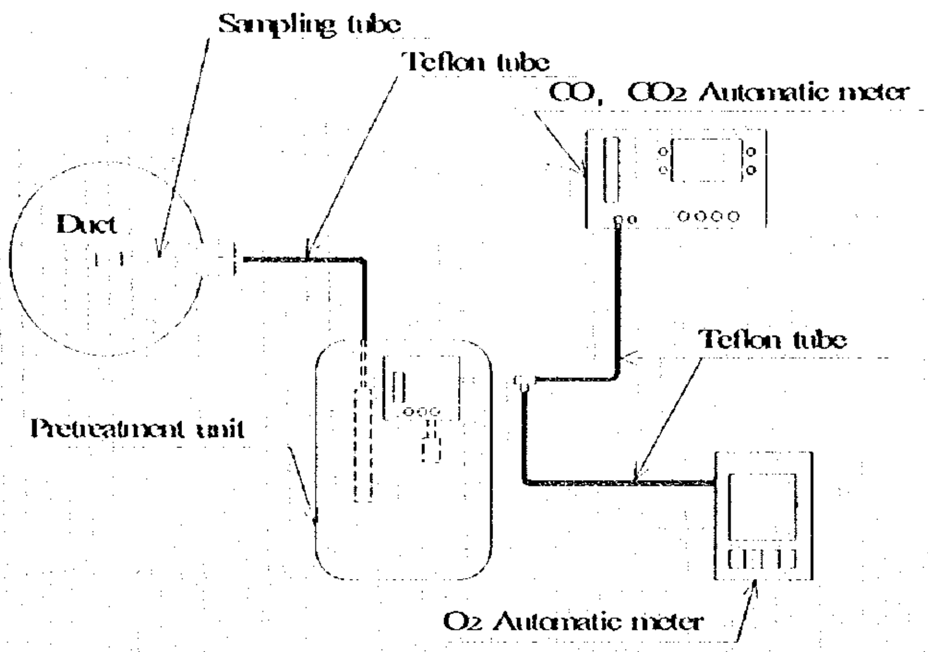
(4) Measuring Method

1. Measure the concentration of CO, CO_2, and O_2 by a continuous analyzer.
2. Insert a sampling pipe into the measuring position.
3. Connect filter and trap for dust removal to the connection of the sampling pipe and the gas conduit.
4. Introduce sample gas to the continuous analyzer previously calibrated by the standard gas.
5. Perform content analysis by a continuous analyzer, flowing sample gas at the flow rate of 1- 2 liters per minute.
6. Input the measured data into the data logger for recording.
7. Determine N_2 concentration by calculation, obtaining N_2 as the remainder of the same of CO, CO_2 and O_2 concentrations.

(5) Measuring Flow



(6) Measurement Outline



2 **Measurement of Outlet Temperature of Cooling Water**

(1) Measuring Position

Return cooling water piping for EBT, elbow, roof-1, roof-2 shell-1 and shell-2.

(2) Measuring Interval

Continuously perform the measurement, and input the data into the data logger every 10 seconds for the calculation of average values per minute.

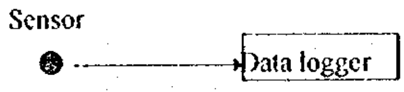
(3) Instruments

1. Thermocouple (JIS type T)

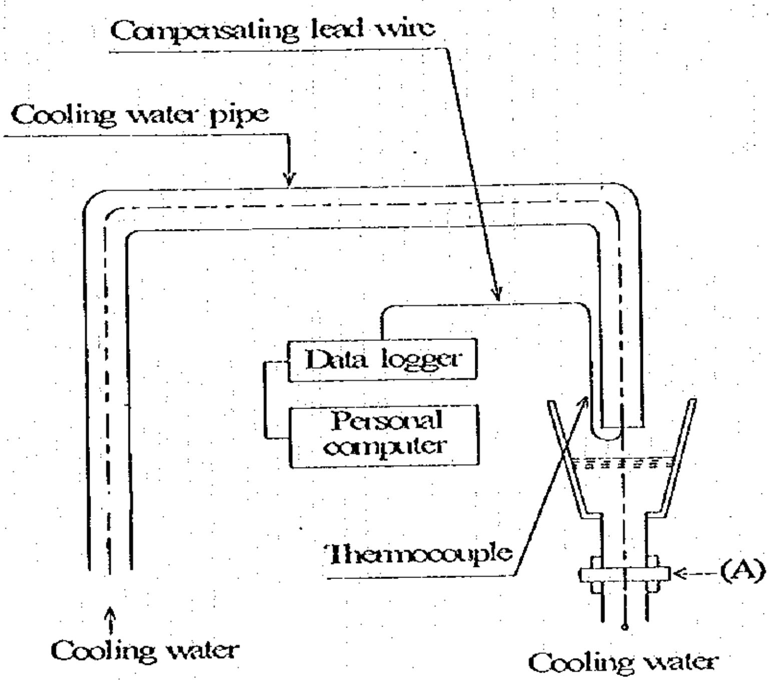
(4) Measuring Method

1. Measure temperature by a thermocouple JIS type T.
2. Insert a thermocouple for the measurement of temperature from the drainage to the piping to be fixed.
3. Input the data of temperature into the data logger for recording.

(5) Measuring Flow



(6) **Measurement Outline**



3 Measurement of Surface Temperature of the Furnace Body

(1) Measuring Positions

Surfaces of the furnace shell and bottom

(2) Measuring Interval

Continuously perform the measurement, and input the data to the data processor every 10 seconds to computer the average values per minute.

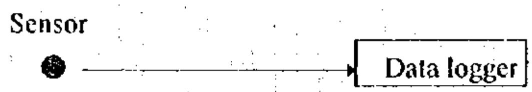
(3) Instrument

Thermocouple (JIS type K)

(4) Measuring Method

1. Measure temperature by a thermocouple JIS type K.
2. Fix the thermocouple for measuring temperature to the surface of the furnace shell and bottom by welding.
3. Connect a compensating lead to the thermocouple fixed to the surface, and extend it to a position where measuring work can safely be performed.
4. Input temperature measuring data to the data logger for recording.

(5) Measuring Flow



Annex-2: Heat Content, Flow Rate, Temperature and Composition of Exhaust Gas

Heat content, flow rate, temperature and composition of exhaust gas are graphically shown as follows:

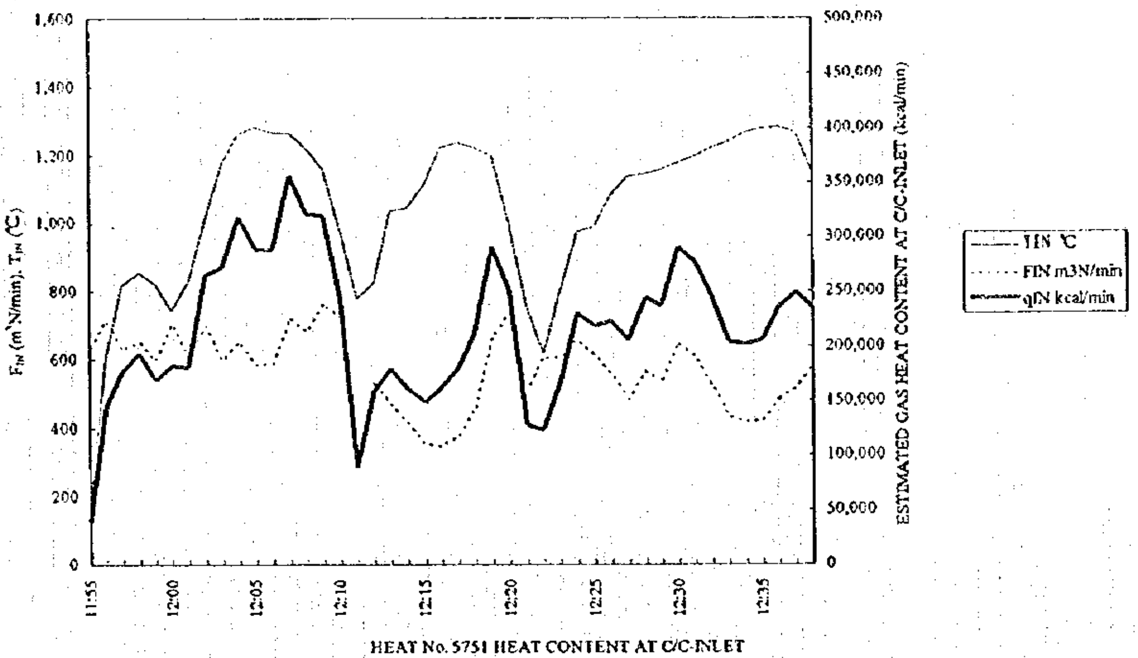


Figure 12-18 Heat Content and Flow Rate of Exhaust Gas at C/C-Inlet, Heat No. 965751

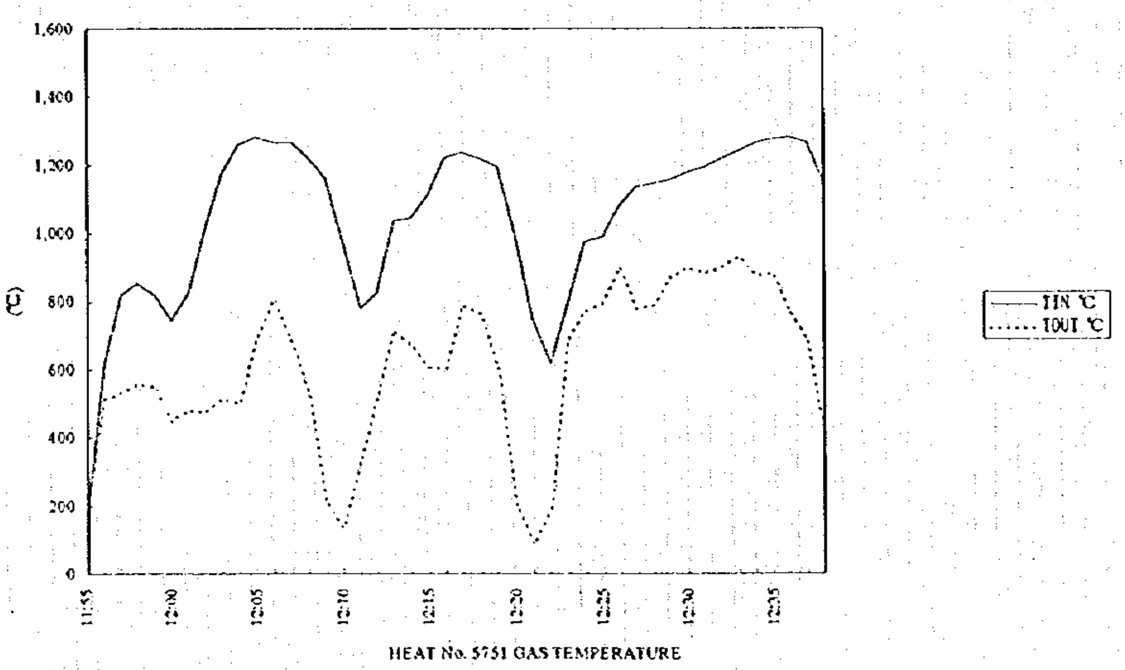


Figure 12-19 Temperature of Exhaust Gas at C/C-Inlet and Outlet, Heat No. 965751

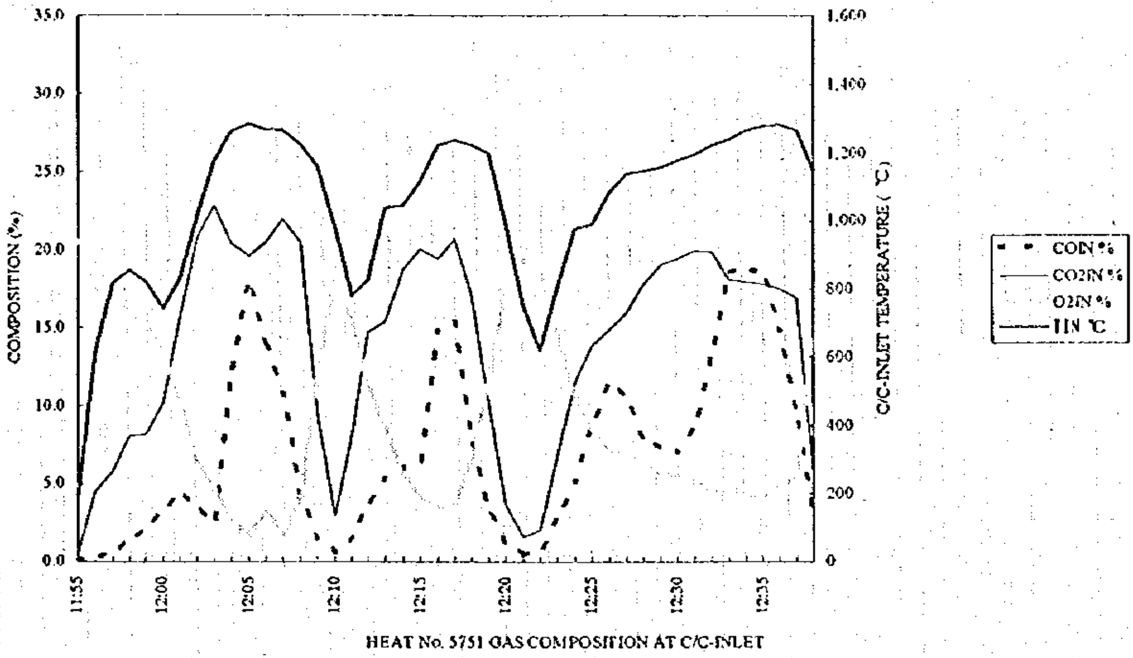


Figure 12-20 Composition of Exhaust Gas at C/C-Inlet, Heat No. 965751

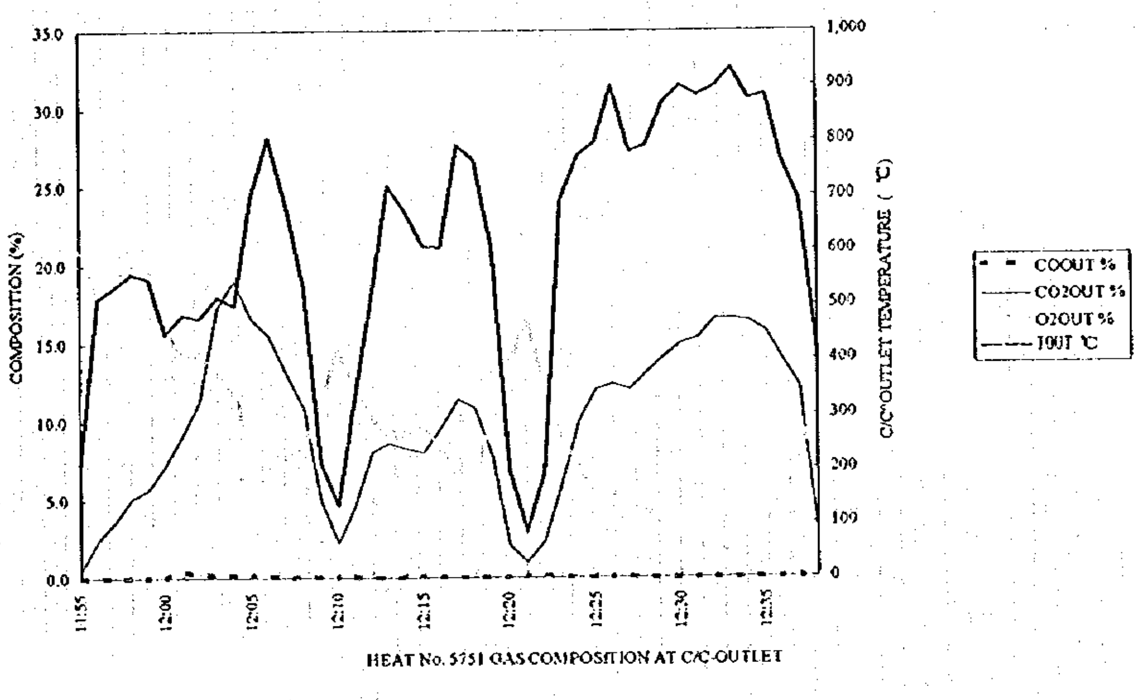


Figure 12-21 Composition of Exhaust Gas at C/C-Outlet, Heat No. 965751

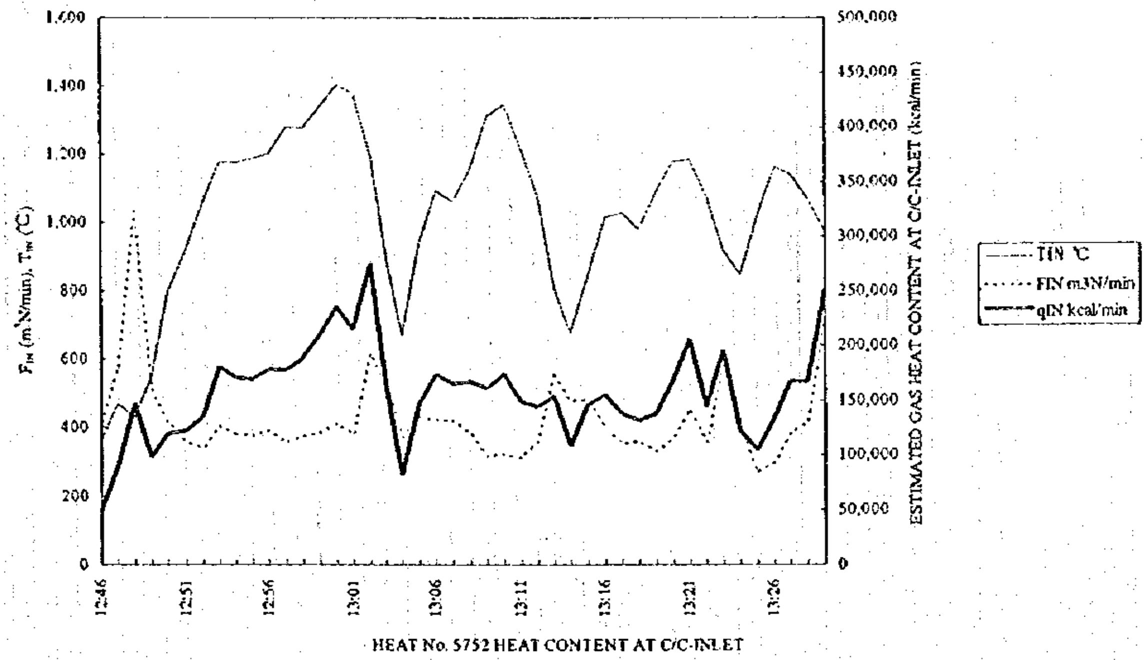


Figure 12-22 Heat Content and Flow Rate of Exhaust Gas at C/C-Inlet, Heat No. 965752

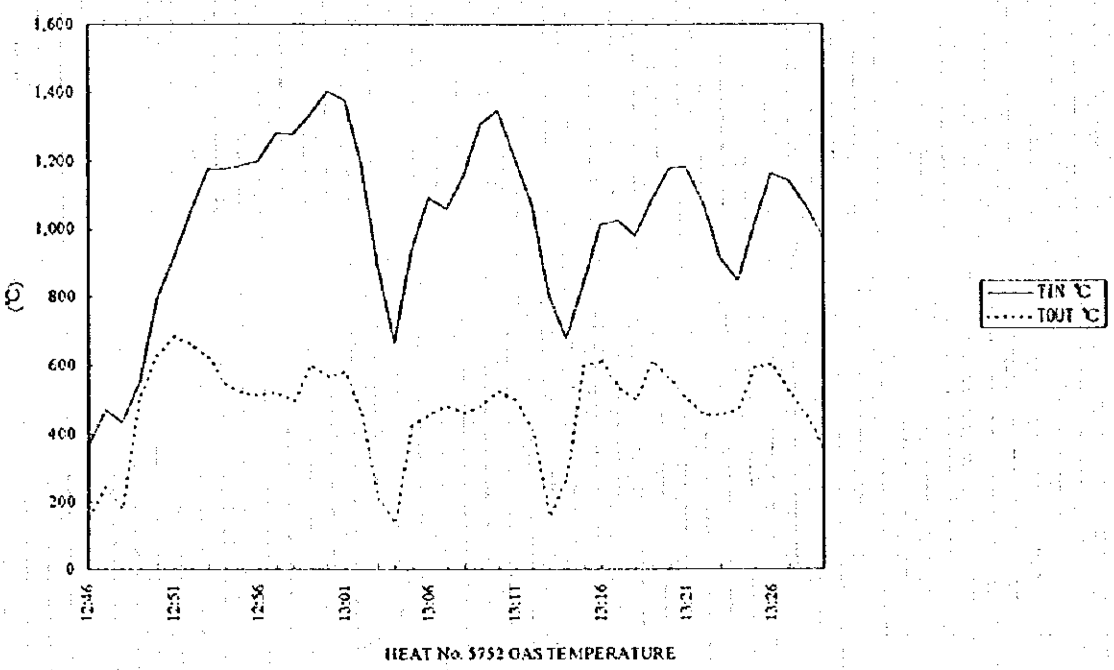


Figure 12-23 Temperature of Exhaust Gas at C/C-Inlet and Outlet, Heat No. 965752

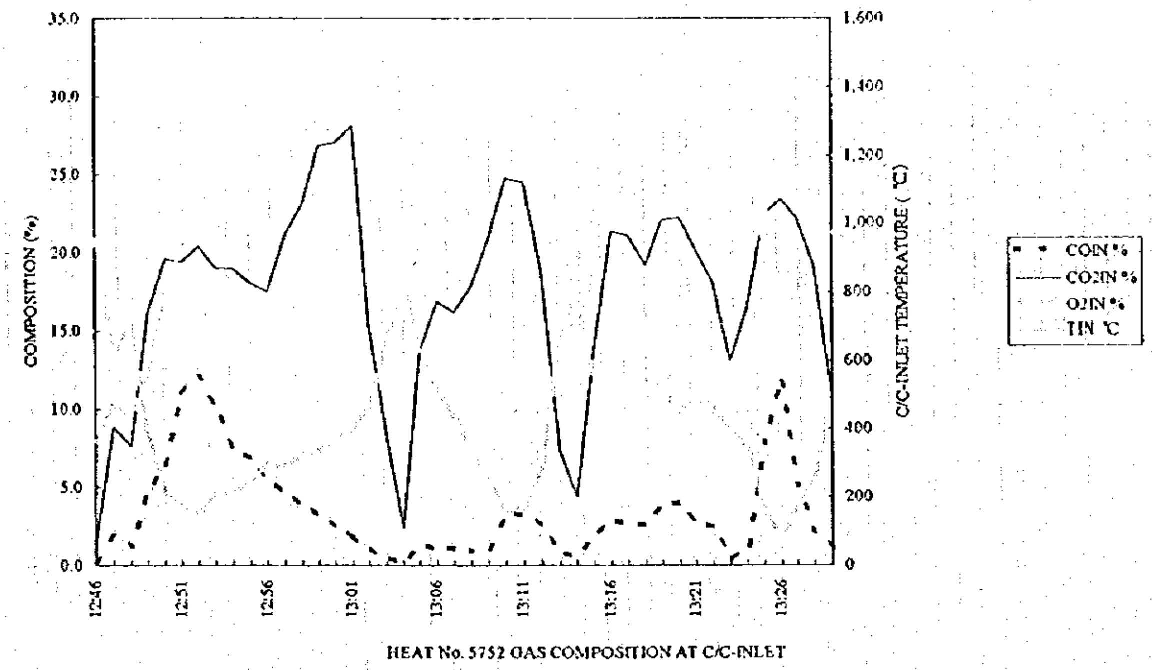


Figure 12-24 Composition of Exhaust Gas at C/C-Inlet, Heat No. 965752

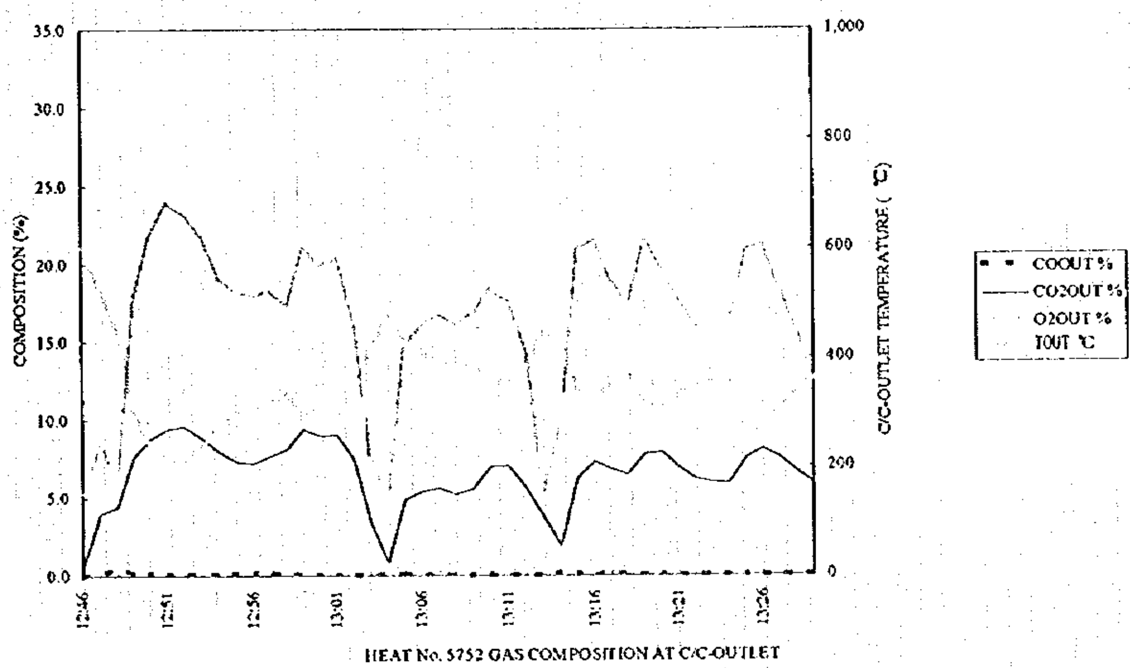


Figure 12-25 Composition of Exhaust Gas at C/C-Outlet, Heat No. 965752

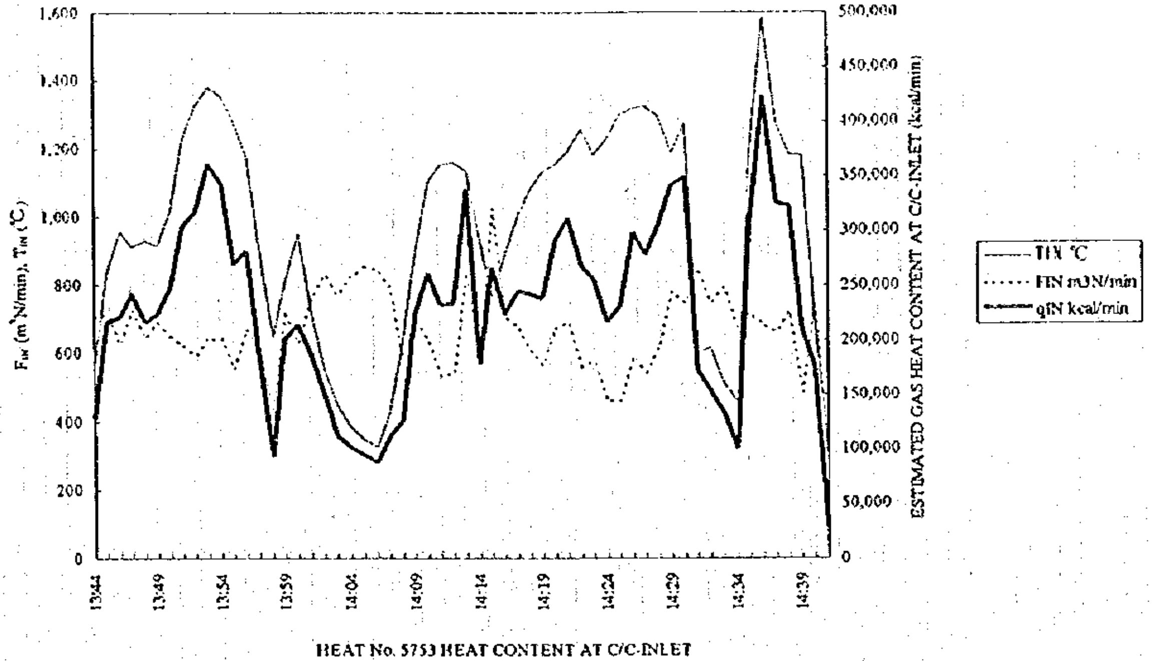


Figure 12-26 Heat Content and Flow Rate of Exhaust Gas at C/C-Inlet, Heat No. 965753

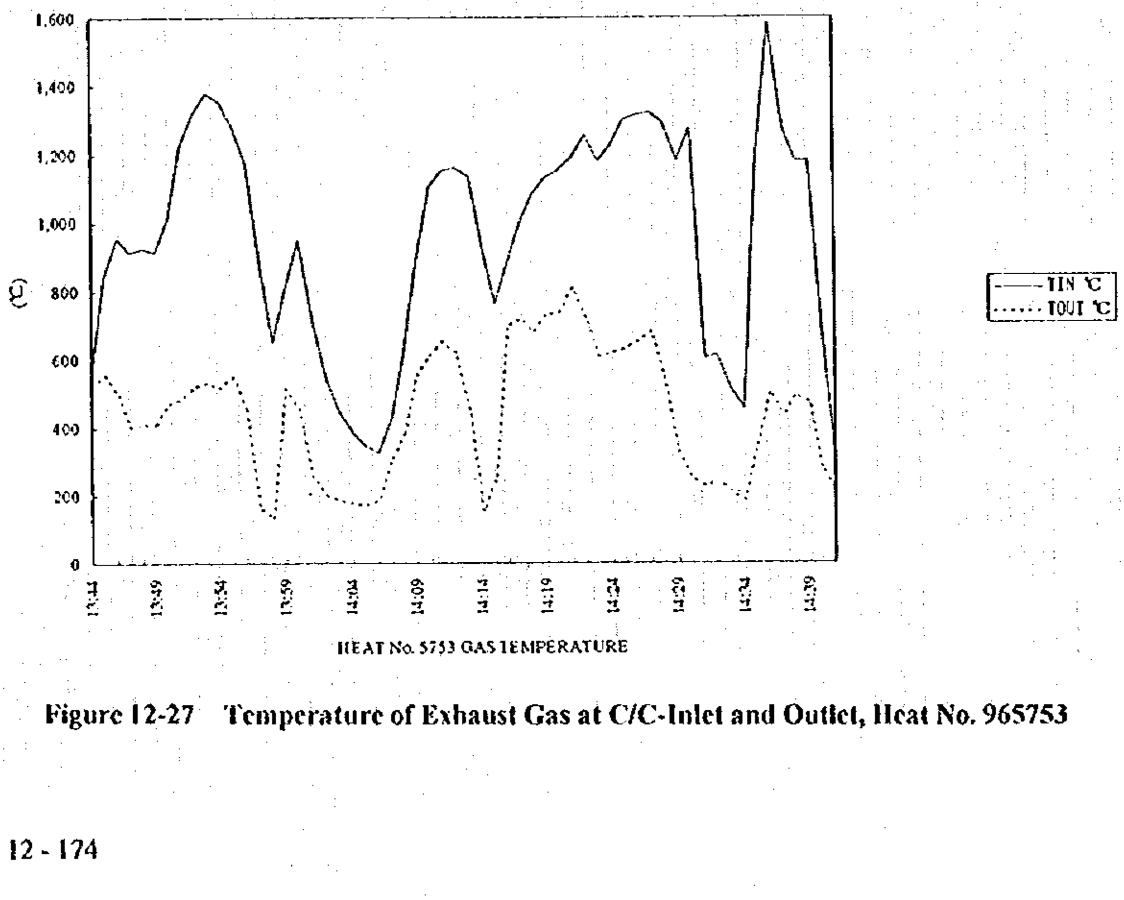


Figure 12-27 Temperature of Exhaust Gas at C/C-Inlet and Outlet, Heat No. 965753

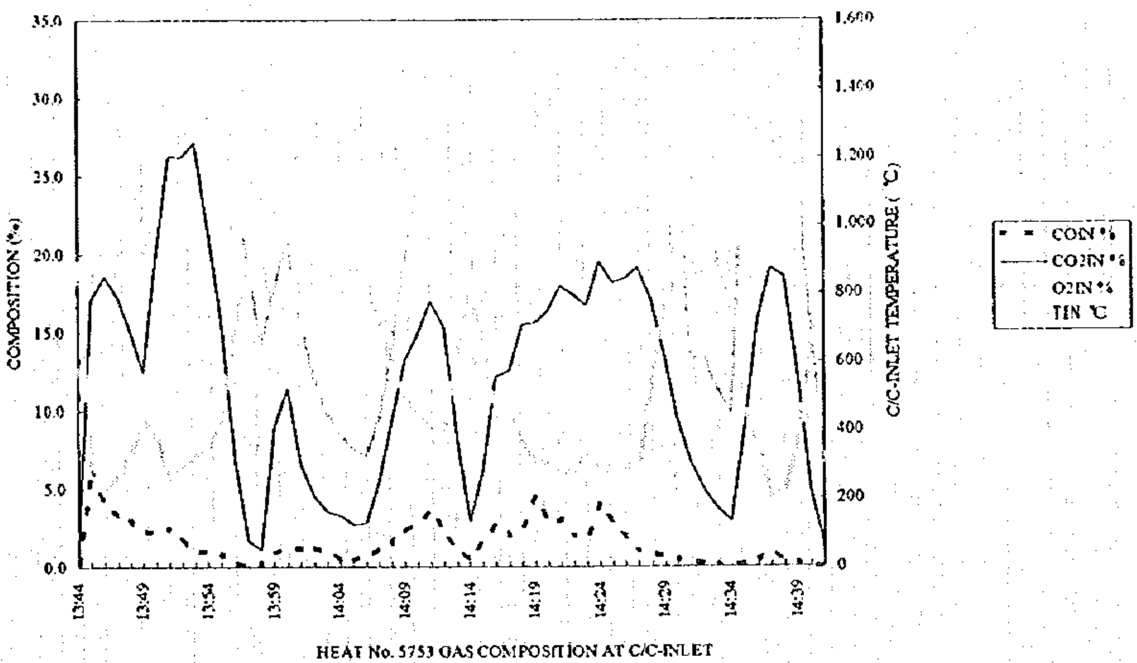


Figure 12-28 Composition of Exhaust Gas at C/C-Inlet, Heat No. 965753

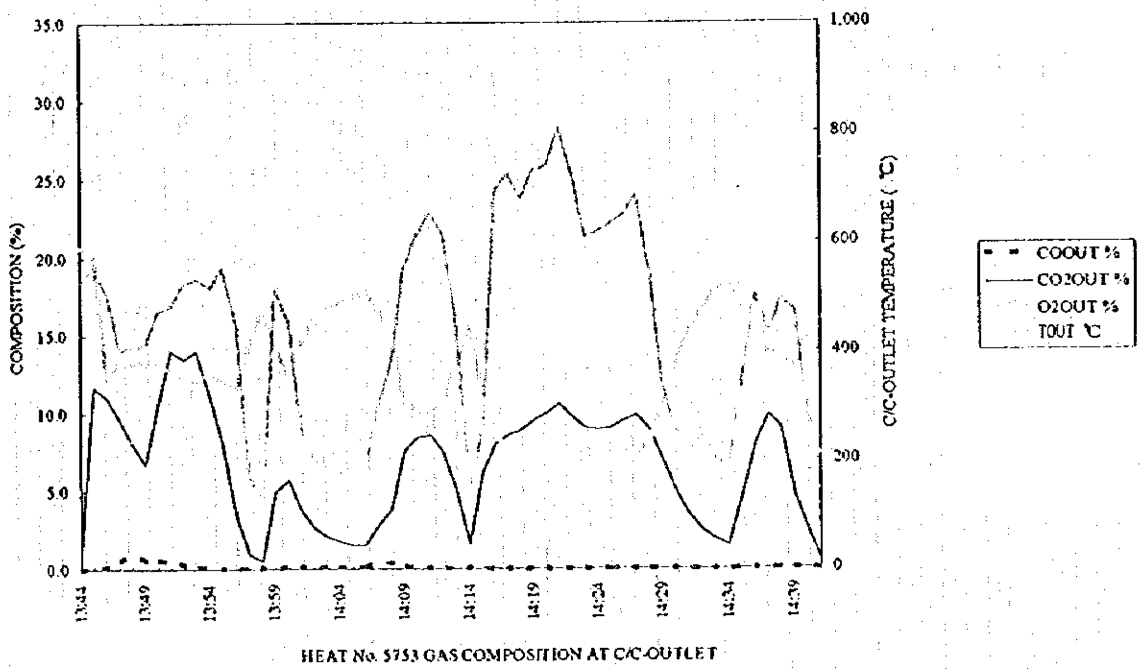


Figure 12-29 Composition of Exhaust Gas at C/C-Outlet, Heat No. 965753

Annex-3: Hot Charge of Billet

RE: HOT CHARGE OF BILLET

1. General

Billets transferred from the cooling bed of CCM are charged into the walking beam type reheating furnace equipped with oil burners. Some 60 to 70 % of the billets are now subjected to hot charge of from 300 to 600°C. Billets are heated to from 1,100 to 1,150°C in the reheating furnace and then are rolled into eight to 50 mm plain and deformed bars at the mill trains.

If the surface temperature of the billets could be higher at charging into the reheating furnace, fuel consumption would be saved. At present, however, hot charge at higher temperature is not carried out because defects are generated at the surface of the products.

The study team introduces the mechanism of surface defect generation and a protective method based on NKK's experience for implementation of higher temperature hot charge and saving energy in IDC.

2. Generation of the Defects

In order to reduce fuel consumption in the reheating furnace, it is tested to shorten the truck time for a cast piece (CC Bloom) of 400 x 520 mm. As shown in Figure AN-3-1, it was found that defects increased rapidly on the rolled products when the truck time was shorter than two hours.

Note: Truck time means the time from casting to charging into the reheating furnace. Longer truck-time means lower temperature of the cast piece and shorter time at higher temperature.

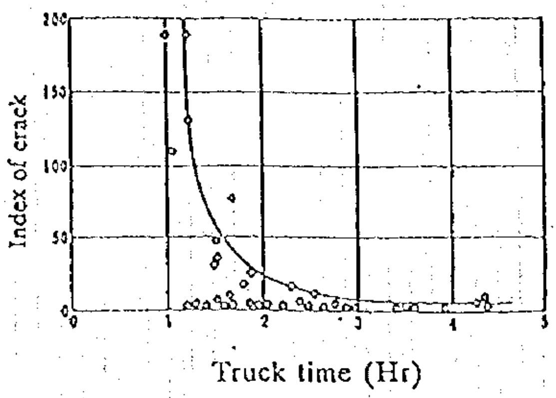
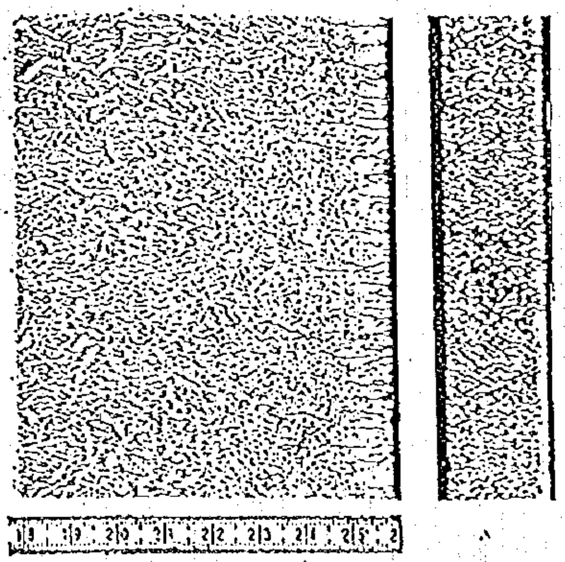


Figure AN-3-1 Relationship between Truck Time and Product Surface Defects

According to the macrophoto of the cast piece after heating, no defects are visually observed on the surface. However, cracks are found on the layer approximately 10 mm under the surface (Photograph AN-3-1) . Photograph AN-3-2 shows cracks found on the surface after rough rolling. According to microscope inspection, subscales are not found in the crack and decarburization is also small. Therefore these cracks are considered to be generated during the rolling process.



Layer 10 mm below the surface

Photo. AN-3-1 Macrophoto of Cast Piece after Heating

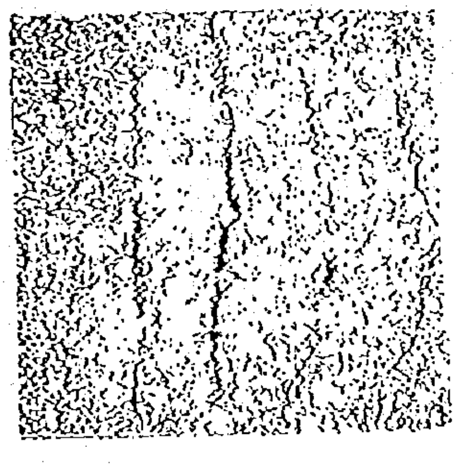


Photo. AN-3-2 Surface Defects on Cast Piece after Rough Rolling

3. Mechanism of Crack Generation at Grain Boundaries

Figure AN-3-2 shows the heating history in which a cast piece is cooled and reheated, the structure changes and precipitation takes place on the surface of the cast piece.

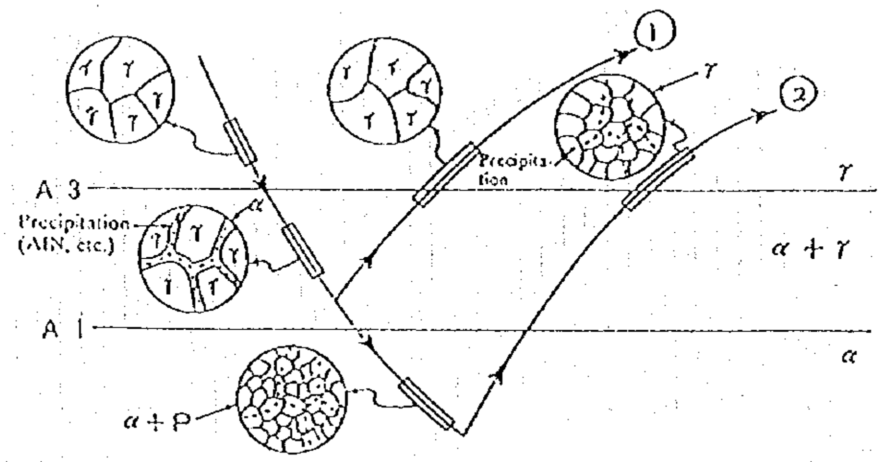


Figure AN-3-2 Model Illustration of Heating Histories, and Structure Change and Precipitation

In case of longer truck time, reheating of the part of the cast piece under the surface starts from the alpha phase area as shown in Case 2 of Figure AN-3-2. Brittleness does not occur since precipitation at the old gamma grain boundaries disperses into the grains. In case of shorter truck time, on the other hand, reheating starts from the (alpha + gamma) two phases area and embrittlement proceeds due to pro-eutectic ferrite and precipitation at grain boundaries. Generally the tensile strength considerably drops in the high temperature area. On materials with shorter truck time, decrease of the tensile strength is accelerated further together with embrittleness at grain boundaries.

It is considered that cracks are generated if the tensile strength exceeds the breakage strength soon after reheating. According to the above estimation, cracks are considered to be generated by the mechanism shown in Figure AN-3-3.

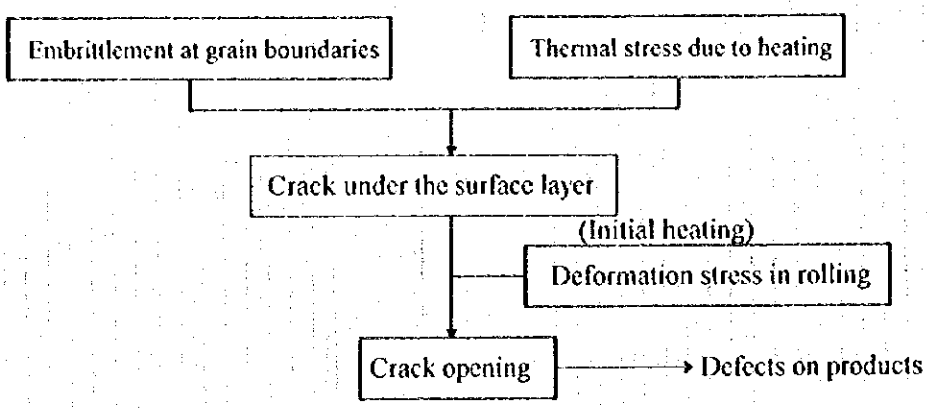


Figure AN-3- 3 Mechanism of Crack Generation

4. Method to Prevent Cracks

4-1 Concept

According to the concept that the two-phase area of the surface layer of the cast piece is transformed into the ferrite area by rapid cooling as shown in Case 3 of heating history in Figure AN-3-4, crack generation could be prevented by water cooling of the cast billet at higher temperature just before reheating.

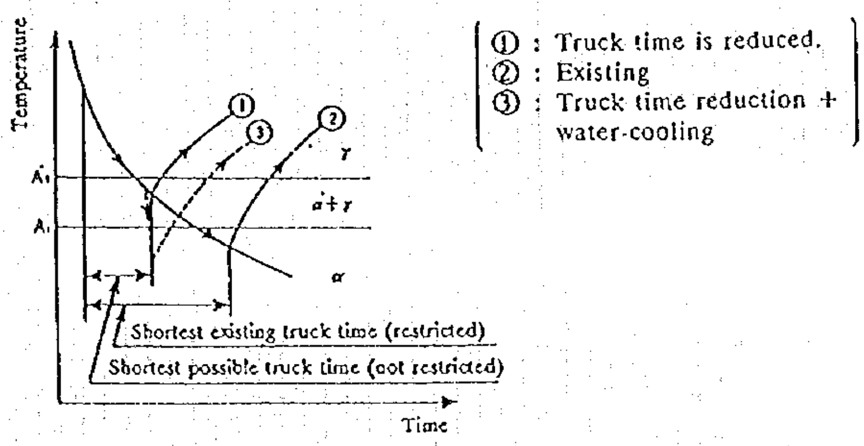


Figure AN-3-4 Heating History of Surface Layer of CC Bloom

4.2. Effect of Water Cooling in the Preparatory Test

Figure AN-3-5 shows the results of the relationship between truck time and the crack generation of the CC bloom at the preparatory tests with water cooling and without water cooling. The products from the water cooled CC bloom have no cracks for the shorter truck time of one hour.

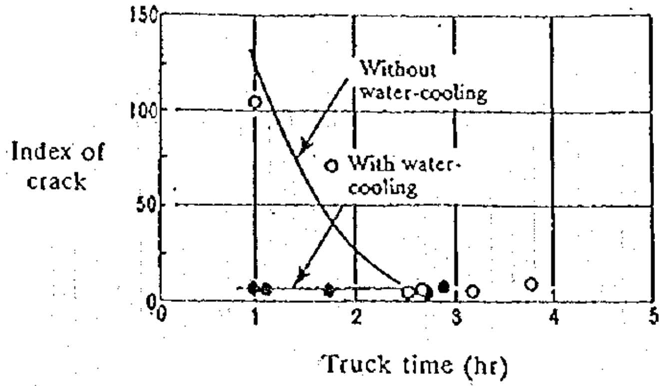


Figure AN-3-5 Relationship between truck time and billet surface defects

5. Water cooling equipment of CC bloom

It is verified that the truck time can be shortened without crack generation at the grain boundaries by water cooling of the CC bloom before reheating. Therefore, water cooling equipment for the CC bloom is installed in front of the reheating furnace. The installation layout and equipment outline are shown in Figure AN-3-6 and Figure AN-3-7.

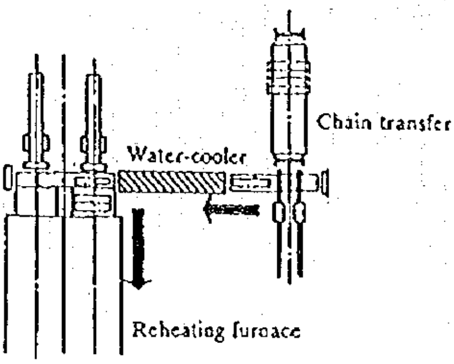
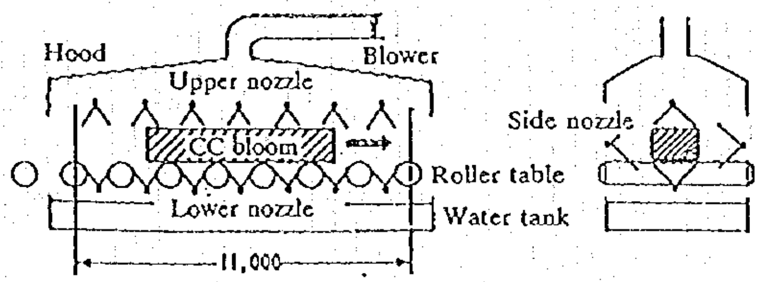


Figure AN-3-6 Installation layout of water cooling equipment



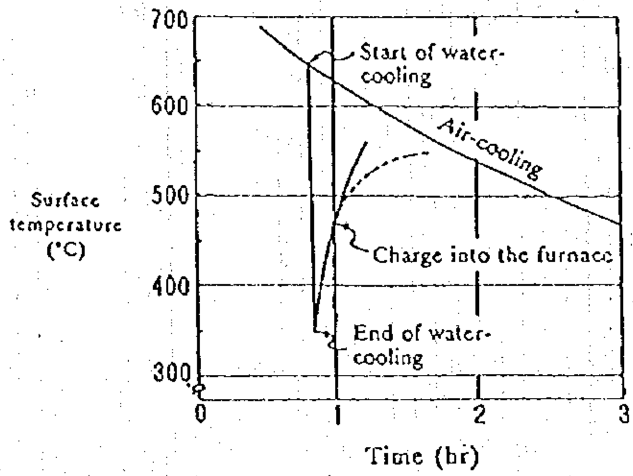
Bloom size : 400ᵗ x 520ᵂ x 3,300 - 4,500ᵗ (mm)
Start up : September 1985

Figure AN-3- 7 Concept of bloom water cooling equipment

6. Water Cooling Conditions

1 Object material: CC bloom with surface temperature of 500℃ or higher
2 Water flow rate: 170 liters/min,m^2
3 Water cooling time: 40 sec

Figure AN-3-8 shows the surface temperature transition in case of the CC bloom with a truck time of one hour under the above conditions. The dotted line shows the temperature transition in which the peak of recovery is observed at the bloom left as it is after water cooling. Temperature was recovered up to 550℃ after 50 min.



FigureAN-3- 8 Surface Temperature Transition of Water Cooled Cast Piece

7. Conclusion

By water cooling the CC bloom before reheating, NKK succeeded in shortening the truck time, namely decreased fuel consumption by 13 % in reheating furnace without defect generation on the surface of the products.

The study team believes that IDC can find the optimum operation conditions by experimental invesigation of the relationship between the surface temperature of the water cooled billets and defects.

Annex-4: Calculation Formulas and Reference figures for Heat Balance, and Calculation of Heat Content of Exhaust Gas

Heat balance calculating method in arc furnace complies with the Heat Balance System in Arc Furnace (JIS G 0703)

1. **Calculation Formulas for Heat Input**
2. **Calculation Formulas for Heat Output**
3. **Reference Figures for Heat Balance**
4. **Calculation of Heat Content of Exhaust Gas**

1. Heat Input

(1) Heat Quantity of Electric Power, Q_1 (kcal/t-output)	$Q_1 = W_1 \times 860$ W_1: Unit consumption of electric power (kWh/t-output) 860: Conversion factor (kcal/kWh)
(2) Potential Heat of Hot Metal, Hot Heel of Raw Materials and Slag, Q_2 (kcal/t-output)	$Q_2 = Q_3 + Q_{2b} + Q_{2c}$ **(a) Potential Heat of Hot Metal, Q_{2a} (kcal/t-output)** $Q_{2a} = M_{2a} \times H_{2a}$ M_{2a} : Unit consumption of hot metal (kg/t-output) H_{2a} : Heat content of metal (kcal/kg) Note: Hot metal was not used in this study. **(b) Potential Heat of Hot Heel, Q_{2b} (kcal/t-output)** $Q_{2b} = M_{2b} \times H_{2b}$ M_{2b} : Unit consumption of hot heel (kg/t-output) H_{2b} : Heat content of hot heel (kcal/kg) Note: 1) Amount of hot heel was estimated 10 t/heat in this study. 2) Heat content is depend on the hot heel temperature which was estimated 1,550 °C in this study. **(c) Potential Heat of Residual Slag, Q_{2a} (kcal/t-output)** $Q_{2c} = M_{2c} \times H_{2c}$ M_{2c} : Unit consumption of residual slag (kg/t-output) H_{2c} : Heat content of residual slag (kcal/kg) Note: Small amount of residual slag was not considered in this study.
(3) Sensible Heat of Raw Materials, Q_3 (kcal/t-output)	$Q_3 = M_3 \times (H_{3b} - H_{3a})$ M_3: Unit consumption of raw materials (kg/t-output) H_{3h}: Heat content of raw materials at temperature after preheating (kcal/kg) H_{3a}: Heat content of raw materials at indoor temperature (kcal/kg) Note: 1) H_{3a} was assumed o kcal/kg of heat content

	at 0 °C as basis in this study.
(4) Calorific Power of Fuel Oil, Q4 (kcal/t-output)	$Q_4 = M_4 \times q_4$ M_4: Unit consumption of fuel oil (kg/t-output) q_4: Low heating value of fuel oil (kcal/kg)
(5) Sensible Heat of Fuel Oil, Q_5 (kcal/t-output)	$Q_5 = M_5 \times C_5 \times (Z_{5f} - Z_{5a})$ M_5: Unit consumption of fuel oil (kg/t-output) C_5: Mean specific heat of fuel oil (kcal/kg) Z_{5f}: Temperature of fuel oil (°C) Z_{5a}: Indoor temperature (°C) Note: Small sensible heat of fuel oil was not considered in this study.
(6) Oxidation Heat of Electrode, Q6 (kcal/t-output)	$Q_6 = M_6 \times C_e \times 10^{-2} \times (q_{6CO2} \times CO_2/(CO_2 + CO) + q_{6CO} \times CO/(CO_2 + CO))$ M_6: Unit consumption of electrode (kg/t-output) C_e: Carbon content of electrode (%) q_{6CO2} : Oxidation heat of electrode at CO_2 formation (kcal/kg) q_{6CO} : Oxidation heat of electrode at CO formation (kcal/kg) CO_2 : CO_2 content of exhaust gas (%) CO: CO content of exhaust gas (%) Note: Unit consumption of electrode was estimated 1.9 kg/t-output.
(7) Oxidation Heat of Charge, Q7 (kcal/t-output)	$Q_7 = Q_{7a} + Q_{7b} + Q_{7c} + Q_{7d} + Q_{7e} + Q_{7f} + Q_{7g}$ **(a) Oxidation Heat of Charged Carbon, Q_{7a} (kcal/t-output)** $Q_{7a} = M_{7a} \times (q_{7CO2} \times CO_2/(CO_2 + CO) + q_{7CO} \times CO/(CO_2 + CO))$ $M_{7a} = M_{7aPig\ iron} + M_{7aScrap} + M_{7aCarbon\ powder} - 1{,}000 \times C_{Tap} \times 10^{-2}$ $M_{7aPig\ iron} = M_{7Pig\ iron\ Charge} \times C_{Pig\ iron} \times 10^{-2}$ $M_{7aScrap} = M_{7Scrap\ Charge} \times C_{Scrap} \times 10^{-2}$ $M_{7aCarbon\ powder} = M_{7Carbon\ powder\ Charge} \times C_{Carbon\ powder} \times 10^{-2}$ M_{7a}: Oxidation amount of charged carbon (kg/t-output) $M_{7aPig\ iron}$: Carbon in pig iron (kg/t-output)

$M_{7aScrap}$: Carbon in scrap (kg/t-output)

$M_{7aCarbon\ powder}$: Carbon in charged carbon powder (kg/t-output)

$M_{7Pig\ iron\ Charge}$: Unit consumption of pig iron (kg/t-output)

$M_{7Scrap\ Charge}$: Unit consumption of scrap (kg/t-output)

$M_{7Carbon\ powder\ Charge}$: Unit consumption of charged carbon powder (kg/t-output)

$C_{Pig\ iron}$: C content of pig iron (%)

C_{Scrap}: C content of scrap (%)

$C_{Carbon\ powder}$: C content of charged carbon powder (%)

C_{Tap}: C content of molten steel before tapping (%)

1,000: Output (kg)

q_{7CO2} : Heat of carbon oxidation at CO_2 formation (kcal/kg)

q_{7CO} : Heat of carbon oxidation at CO formation (kcal/kg)

CO_2 : CO_2 content of exhaust gas (%)

CO: CO content of exhaust gas (%)

Note: Charged carbon powder was not used in this study.

(b) Oxidation Heat of Charged Silicon, Q_{7b} (kcal/t-output)

$Q_{7b} = M_{7b} \times q_{7b}$

$M_{7b} = M_{7bPig\ iron} + M_{7bScrap} - 1{,}000 \times Si_{Tap} \times 10^{-2}$

$M_{7bPig\ iron} = M_{7Pig\ iron\ Charge} \times Si_{Pig\ iron} \times 10^{-2}$

$M_{7bScrap} = M_{7Scrap\ Charge} \times Si_{Scrap} \times 10^{-2}$

M_{7b}: Oxidation amount of charged silicon (kg/t-output)

$M_{7bPig\ iron}$: Silicon in pig iron (kg/t-output)

$M_{7bScrap}$: Silicon in scrap (kg/t-output)

$M_{7Pig\ iron\ Charge}$: Unit consumption of pig iron (kg/t-output)

$M_{7Scrap\ Charge}$: Unit consumption of scrap (kg/t-output)

$Si_{Pig\ iron}$: Si content of pig iron (%)

Si_{Scrap}: Si content of scrap (%)

Si_{Tap}: Si content of molten steel before tapping (%)

1,000: Output (kg)

q_{7b} : Heat of silicon (kcal/kg)

(c) Oxidation Heat of Charged Manganese, Q_{7c} (kcal/t-output)

Same as (b).

(d) Oxidation Heat of Charged Phosphorus, Q_{7d} (kcal/t-output)

Same as (b).

(e) Oxidation Heat of Charged Chromium, Q_{7e} (kcal/t-output)

Same as (b).

(f) Oxidation Heat of Charged Aluminum, Q_{7f} (kcal/t-output)

Same as (b).

(g) Oxidation heat of Charged Iron, Q7g (kcal/t-output)

$Q_{7g} = M_{7g} \times (FeO \times 0.777 \times q_{7gFeO} + Fe_2O_3 \times 0.699 \times q_{7gFe2O3}) \times 10^{-2}$

M_{7g}: Unit weight of slag (kg/t-output)

FeO: FeO content of slag (%)

Fe_2O_3: Fe_2O_3 content of slag (%)

q_{7gFeO}: Heat of iron oxidation at FeO formation (kcal/kg)

$q_{7gFe2O3}$: Heat of iron oxidation at Fe_2O_3 formation (kcal/kg)

0.777: Ratio of Fe in FeO

0.699: Ratio of Fe in Fe_2O_3

Note: Unit weight of slag was calculated as follows in this study.

$M_{7g} = M_{7gLime} \times CaO_L / CaO_S$

M_{7gLime}: Unit consumption of burnt lime (kg/t-output)

CaO_S: CaO content of slag (%)

CaO_L : CaO contentof burnt lime (%)

Note: Mean value of seven heats was used for slag analysis in this study.

(8) Oxidation Heat of Additives, Q_8 (kcal/t-output)

$Q_8 = Q_{8a} + Q_{8b} + Q_{8c}$

(a) Oxidation Heat of Carbon of Additives, Q_{8a} (kcal/t-output)

$Q_{8a} = M_{8a} \times (q_{8CO2} \times CO_2/(CO_2 + CO) + q_{8CO} \times CO /(CO_2 + CO))$

$M_8 = M_{8aCarbon\ injection} + M_{8aSi\text{-}Mn} + M_{8aFe\text{-}Si} + M_{8aFe\text{-}Mn}$

$M_{8aCarbon\ injection} = M_{8Carbon\ injection\ Additives} \times C_{Carbon\ injection} \times 10^{-2}$

$M_{8aSi\text{-}Mn} = M_{8Si\text{-}Mn\ Additives} \times C_{Si\text{-}Mn} \times 10^{-2}$

$M_{8aFe\text{-}Si} = M_{8Fe\text{-}Si\ Additives} \times C_{Fe\text{-}Si} \times 10^{-2}$

$M_{8aFe\text{-}Mn} = M_{8Fe\text{-}Mn\ Additives} \times C_{Fe\text{-}Mn} \times 10^{-2}$

M_{8a}: Carbon of additives(kg/t-output)

$M_{8aCarbon\ injection}$: Carbon in carbon injection (kg/t-output)

$M_{8aSi\text{-}Mn}$: Carbon in Si-Mn (kg/t-output)

$M_{8aFe\text{-}Si}$: Carbon in Fe-Si (kg/t-output)

$M_{8aFe\text{-}Mn}$: Carbon in Fe-Mn (kg/t-output)

$M_{8Carbon\ injection\ Additives}$: Unit consumption of carbon injection (kg/t-output)

$M_{8Si\text{-}Mn\ Additives}$: Unit consumption of Si-Mn (kg/t-output)

$M_{8Fe\text{-}Si\ Additives}$: Unit consumption of Fe-Si (kg/t-output)

$M_{8Fe\text{-}Mn\ Additives}$: Unit consumption of Fe-Mn (kg/t-output)

$C_{Carbon\ injection}$: C content of carbon injection (%)

$C_{Si\text{-}Mn}$: C content of Si-Mn (%)

$C_{Fe\text{-}Si}$: C content of Fe-Si (%)

$C_{Fe\text{-}Mn}$: C content of Fe-Mn (%)

q_{8CO2} : Heat of carbon oxidation at CO_2 formation (kcal/kg)

q_{8CO} : Heat of carbon oxidation at CO formation (kcal/kg)

CO_2 : CO_2 content of exhaust gas (%)

CO: CO content of exhaust gas (%)

Note: Si-Mn Fe-Si and Fe-Mn were not used in this

	study. **(b) Oxidation Heat of Silicon of Additives, Q_{8b} (kcal/t-output)** $Q_{8b} = M_{8b} \times q_{8b}$ $M_{8b} = M_{8bSi\text{-}Mn} + M_{8bFe\text{-}Si} + M_{8bFe\text{-}Mn}$ $M_{8bSi\text{-}Mn} = M_{8Si\text{-}Mn\ Additives} \times Si_{Si\text{-}Mn} \times 10^{-2}$ $M_{8bFe\text{-}Si} = M_{8Fe\text{-}Si\ Additives} \times Si_{Fe\text{-}Si} \times 10^{-2}$ $M_{8bFe\text{-}Mn} = M_{8Fe\text{-}Mn\ Additives} \times Si_{Fe\text{-}Mn} \times 10^{-2}$ M_{8b}: Silicon of additives (kg/t-output) $M_{8bSi\text{-}Mn}$: Silicon in Si-Mn (kg/t-output) $M_{8bFe\text{-}Si}$: Silicon in Fe-Si (kg/t-output) $M_{8bFe\text{-}Mn}$: Silicon in Fe-Mn (kg/t-output) $M_{8Si\text{-}Mn\ Additives}$: Unit consumption of Si-Mn (kg/t-output) $M_{8Fe\text{-}Si\ Additives}$: Unit consumption of Fe-Si (kg/t-output) $M_{8Fe\text{-}Mn\ Additives}$: Unit consumption of Fe-Mn (kg/t-output) $Si_{Si\text{-}Mn}$: Si content of Si-Mn (%) $Si_{Fe\text{-}Si}$: Si content of Fe-Si (%) $Si_{Fe\text{-}Mn}$: Si content of Fe-Mn (%) 1,000: Output (kg) q_{8b} : Heat of silicon (kcal/kg) Note: Si-Mn, Fe-Si and Fe-Mn were not used in this study. **(c) Oxidation Heat of Manganese of Additives, Q_{8c} (kcal/t-output)** Same as (b).
(9) Heat of Slag Formation, Q_9 (kcal/t-output)	**$Q_9 = M_9 \times (SiO_2 \times q_{9SiO2} + P_2O_5 \times q_{9P2O5}) \times 10^{-2}$** M_9: Unit weight of slag (kg/t-output) Note: See (7) (g). q_{9SiO2}: Heat of SiO_2 reaction at Ca_2SiO_4 formation (kcal/kg) q_{9P2O5}: Heat of P_2O_5 reaction at $Ca_3P_2O_3$ formation (kcal/kg) SiO_2: SiO_2 content of slag (%)

	P_2O_5: P_2O_5 content of slag (%) Note: Mean value of seven heats was used for slag analysis in this study.
Heat Input, $Q_{Heat\ Input}$ (kcal/t-output)	**$Q_{Heat\ Input} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8 + Q_9$ (kcal/t-output)**

2. Heat Outout

(10) Potential Heat of Molten Steel, Q_{10} (kcal/t-output)	$Q_{10} = Q_{10a} + Q_{10b}$ **(a) Potential Heat of Output (excluding hot heel), Q_{10a} (kcal/t-output)** $Q_{10a} = 1{,}000 \times H_{10a}$ 1,000: Output (kg) H_{10a}: Heat content of molten steel before tapping (kcal/g) Note: Heat content is dependent on temperature. **(b) Potential Heat of Hot heel, Q_{10a} (kcal/t-output)** $Q_{10b} = M_{10b} \times H_{10b}$ M_{10b}: Unit weight of hot heel (kg/t-output) H_{10b}: Heat content of hot heel (kcal/g) Note: 1) Amount of hot heel was assumed 10 t/heat in this study. 2) Heat content is dependent on temperature.
(11) Potential Heat of Slag, Q_{11} (kcal/t-output)	$Q_{11} = M_{11} \times H_{11}$ M_{11}: Unit weight of slag (kg/t-output) H_{11}: Heat content of slag (kcal/g) Note: 1) Concerning unit weight of slag, see (7) (g) in Heat Input. 2) Heat content is dependent on temperature which is same as that of molten steel in this study.
(12) Heat of Decomposition, Q_{12} (kcal/t-output)	$Q_{12} = Q_{12a} + Q_{12b}$ **(a) Heat of Limestone Decomposition, Q_{12a} (kcal/t-output)** $Q_{12a} = 10^{-2} \times M_{12a} \times CaO \times q_{12aCaCO_3}$ M_{12a}: Unit consumption of limestone (kcal/t-output) $q_{12aCaCO_3}$: Heat of decomposition of limestone (kcal/kg) CaO: CaO content of limestone (%) Note: 1) 30 % of limestone was included in burnt

	lime in this study.
	(b) Heat of Iron Ore Decomposition, Q_{12b} (kcal/t-output) $Q_{12b} = 10^{-2} \times M_{12b} \times (FeO \times q_{12bFeO} + Fe_2O_3 \times q_{12bFe2O3})$ M_{12b}: Unit consumption of iron ore (kcal/t-output) q_{12bFeO}: Heat of decomposition of FeO in iron ore (kcal/kg) $q_{12bFe2O3}$: Heat of decomposition of Fe_2O_3 in iron ore (kcal/kg) FeO: FeO content in iron ore (%) Fe_2O_3: Fe_2O_3 content in iron ore (%) Note: Iron ore was not used in this study.
(13) Electrical heat Loss, Q_{13} (kcal/t-output)	$Q_{13} = Q_{13a} + Q_{13b}$ **(a) Heat Loss in Secondary Conductors, Q_{12a} (kcal/t-output)** $Q_{13a} = (R_0 \times I_0^2 \times T \times 860) \times 3.6/T$ $R_0 = R_S + O \times (E_1 + E_2 + E_3)/S$ $I_0 = (W_0 \times 10{,}000)/(3^{1/2} V0 \times \cos U)$ $W_0 = W_p/T$ $V_0 = V \times T'/T$ $\cos U = W_p/(W_p^2 + W_Q^2)^{1/2}$ R_0: Combined resistance of secondary conductor and electrode (Ohm) I_0: Mean current (A) t: Output (ton) R_S: Combined resistance of secondary conductor resistance and contact resistance between electrode and holder (Ohm) O: Specific resistance of electrode (Ohm-cm) S: Sectional area of electrode (cm^2) E_1, E_2, E_3: Average length of electrode in each phase exposed from roof W_0: Mean electric power (kW) V_0: Mean voltage (V)

cos U: Mean power factor (-)

W_p: Electric power consumed (kW)

W_Q: Reactive energy (kVar)

V: Secondary voltage of transformer tap(V)

T': Conducting period of each tap in transformer (hr)

T: Power-o to power-off time (hr)

Note: Heat loss in secondary conductor was not measured.

(b) Heat Loss of Transformer, Q_{13b} (kcal/t-output)

$Q_{13b} = (W_1 - W_2) \times 860/t$

W_1 = Electric power on primary side of transformer (kWh)

W_2 = Electric power on secondary side of transformer (kWh)

Note: Heat loss in secondary conductor was not measured.

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(14) Heat in Cooling Water, Q_{14} (kcal/t-output)

$Q_{14} = Q_{14a} + Q_{14b} + Q_{14c} + Q_{14d}$

(a) Heat in Cooling Water for Elbow, Q_{14a} (kcal/t-output)

$Q_{14a} = M_{14a} \times C_{14} \times (t_{a14aO} - t_{14aI})$

$M_{14a} = F_{14a} \times T/t$

M_{14a}: Average quantity of cooling water (kg/t-output)

C_{14}: Specific heat of water (kcal.kg, °C) = 1

t_{14aO}: Mean outlet temperature of cooling water (°C)

t_{14aI}: Mean inlet temperature of cooling water (°C)

F_{14a}: Flow rate of cooling water (kg/hr)

T: Power-on to power-off time (hr)

t: Output (ton)

(b) Heat in Cooling Water for Roof, Q_{14b} (kcal/t-output)

Same as (a).

(c) Heat in Cooling Water for EBT, Q_{14c} (kcal/t-output)

Same as (a).

(d) Heat in Cooling Water for Shell, Q_{14d} (kcal/t-output)

Same as (a).

(15) Sensible Heat of Exhaust Gas, Q_{15} (kcal/t-output)

$Q_{15} = H_{15} \times T \times 60/t$

H_{15} = Heat in average flow of exhaust gas (kcal /min)

T = Power-on to power-off time (hr)

t = Output (ton)

Note: Heat in average flow of exhaust gas is described in another pages (3. Calculation of Heat Content of Exhaust Gas).

(16) Heat Loss at Furnace Body, Q_{16} (kcal/t-output)

$Q_{16} = Q_{16a} + Q_{16b} + Q_{16c}$

(a) Heat Loss at Roof, Q_{16a} (kcal/t-output)

$Q_{16a} = T \times (q_{16aR} + q_{16aC}) \times A/t$

$q_{16aR} = 4.88 \times r \times [(T_0/100)^4 - (T_a/100)^4]$

$q_{16aC} = p \times (t_0 - t_a)^{1.25}$

q_{16aR}: Radiation heat loss at roof (kcal/m_2, hr)

q_{16aC}: Convection heat loss at roof (kcal/m_2, hr)

T: Power-on to power-off time (hr)

A: Surface area of roof (m_2)

t: Output (ton)

r. Degree of blackness on furnace surface due to radiation (0.8)

T_0: Surface temperature of roof (°C)

T_a: Indoor temperature (°C)

p: 2.8 for horizontal wall facing upward, roof

2.2 for vertical wall facing sideways, shell

1.5 for horizontal wall facing downward, bottom

Note: Degree of blackness of 0.8 is based on "Heat Calculating Figures for Iron and Steel Making (1966)" by the Japan and Steel Association, Society of Japan Academic Development).

(b) Heat Loss at Shell, Q_{16b} (kcal/t-output)

Same as (a)

(c) Heat Loss at Bottom, Q_{16c} (kcal/t-output)

	Same as (a)
(17) Other Heat Loss, Q_{17} (kcal/t-output)	$Q_{17} = Q_{heat\ Input} - (Q_{10} + Q_{11} + Q_{12} + Q_{13} + Q_{14} + Q_{15} + Q_{16}$

3. Reference Figures for Heat Balance

3-1 Heat Content (Iron, Steel and Slag)

Unit: kcal/kg

Temperature (°C)	Pig iron	Pure iron	Mild steel	0.23 % C	0.4 % C	0.8 % C	1.2 % C	18 Cr - 8 Ni	13 Cr	Slag *
0	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0	-
50	-	-	-	5.6	5.6	5.4	5.4	5.9	5.2	-
100	-	11.0	-	11.4	11.4	11.2	11.2	12.0	10.8	19.1
150	-	-	-	17.4	17.4	17.4	17.4	18.3	16.8	-
200	-	23.0	-	23.6	23.5	23.8	23.9	24.7	23.0	39.9
250	-	-	-	30.0	29.8	30.3	30.4	31.1	29.3	-
300	-	35.0	-	36.6	36.4	37.1	37.1	37.7	35.9	60.0
350	-	-	-	43.5	43.2	44.1	44.0	44.3	42.8	-
400	-	49.0	-	50.6	50.2	51.3	51.1	51.1	50.0	81.0
450	-	-	-	58.1	57.5	58.8	58.8	58.1	57.6	-
500	-	64.0	-	66.0	65.3	66.8	66.1	65.2	65.8	104.9
550	-	-	-	74.4	73.5	75.1	74.0	72.7	74.4	-
600	-	82.0	-	83.3	82.0	83.6	82.3	80.5	83.8	129.0
650	-	-	-	92.7	90.7	92.3	91.2	88.0	93.5	-
700	-	102.0	-	102.8	99.9	101.5	101.0	95.5	104.0	151.9
750	-	-	-	119.9	118.8	126.8	125.9	102.9	114.8	-
800	-	125.0	-	131.3	126.2	133.6	133.7	110.6	123.0	177.0
850	-	-	-	140.1	132.3	141.5	141.5	118.3	132.6	-
900	-	145.7	-	147.8	138.8	148.9	148.9	126.0	140.6	201.8
950	-	-	-	155.6	146.3	156.3	156.4	133.8	148.4	-
1000	-	163.0	-	163.3	153.7	163.9	163.8	141.5	156.1	227.9
1050	-	-	-	171.1	161.3	171.5	171.5	149.3	163.9	-
1100	-	178.0	-	178.8	168.8	179.3	179.1	157.2	171.7	254.8
1150	-	-	-	186.7	176.5	187.2	186.9	165.2	179.5	-
1200	264.9	194.0	-	194.6	184.3	195.2	194.7	173.2	187.2	286.9
1250	-	-	-	202.7	192.3	203.3	202.7	181.3	195.0	-
1300	280.9	209.0	-	210.9	200.5	211.4	210.7	189.4	202.8	321.7
1350	-	-	-	(219.2)	(208.9)	(219.5)	(218.7)	(197.5)	(210.6)	-
1400	301.9	231.0	-	(227.5)	(217.5)	(227.5)	(226.7)	(205.6)	(218.4)	365.7
1450	-	-	-	(236.1)	(226.3)	(235.6)	(234.7)	(213.6)	(226.2)	-
1500	322.0	247.9	(311.0)	-	-	-	-	-	-	406.8
1550	-	-	-	-	-	-	-	-	-	431.6
1600	343.0	331.0	332.0	-	-	-	-	-	-	459.8
1650	-	-	-	-	-	-	-	-	-	489.6
1700	364.0	349.9	353.0	-	-	-	-	-	-	519.7

* Basic slag of steelmakig process; CaO = 43.55 %, SiO_2 = 34.22 %, FeO = 10.27 %, Fe_2O_3 = 3.68 %, Al_2O_3 = 4.68 %,

MgO = 11.84 % and MnO = 6.60 %

3-2 Reaction Heat

Unit: kcal/kg

Item		Reaction Heat		Reaction
Oxidation Heat	Graphite carbon	7,829	(Graphite carbon)	$C + O_2 = CO_2$
	Graphite carbon	2,200	(Graphite carbon)	$C + 1/2\ O_2 = CO$
	C	8,075	(C)	$C + O_2 = CO_2$
	C	2,448	(C)	$C + 1/2\ O_2 = CO$
	Si	7,459	(Si)	$Si + O_2 = SiO_2$
	Mn	1,674	(Mn)	$Mn + 1/2\ O_2 = MnO$
	P	5,811	(P)	$P + 5/4\ O_2 = 1/2\ P_2O_5$
	Cr	2,620	(Cr)	$Cr + 3/4\ O_2 = 1/2\ Cr_2O_3$
	Al	7,419	(Al)	$Al + 3/4\ O_2 = 1/2\ Al_2O_3$
	Fe	1,151	(Fe)	$Fe + 1/2\ O_2 = FeO$
	Fe	1,756	(Fe)	$Fe + 3/4\ O_2 = 1/2\ Fe_2O_3$
Formation Heat	Slag	502	(SiO_2)	$2\ CaO + SiO2 = CaSiO_4$
	Slag	1,070	(P_2O_5)	$3\ CaO + P_2O_5 = Ca_3P_2O_3$
Decomposition Heat	Iron ore	896	(FeO)	$FeO = Fe + 1/2\ O_2$
	Iron ore	1,228	(Fe_2O_3)	$Fe_2O_3 = 2\ Fe + 3/2\ O_2$
	Lime stone	757	(CaO)	$CaCo3 = CaO + CO_2$

4. Calculation of Heat Content of Exhaust Gas

(1) Measurement of Velocity, Flow Rate and Composition of Exhaust Gas

At C/C-outlet point, velocity and flow rate of exhaust gas were continuously measured based on JIS Z 8808 -7 ("Method of measuring dust concentration in flue gas" 7. Measurment of Velocity and Flow of Flue Gas).

Gas composition was also measured continuously both at the C/C-outlet point and the C/C-inlet point.

(2) Calculation of Heat Content of Ehaust Gas

Combined gas flow rate at C/C-outlet with change of gas composition from CC-inlet point to CC-outlet point, mass balance equilibrium gives gas flow rate at C/C-inlet. To calculate the heat content of exhaust gas at C/C-inlet point, linearlized specific heat was referred to JIS G 0703 ("Method of heat balance calculation of arc furnace")

$$g_0 = [\{44 \times CO_{2OUT} + 32 \times O_{2OUT} + 28 \times (100 - CO_{2OUT} - O_{2OUT})\} \times (1 - H / 100) + 18 \times H] / (22.4 \times 100) \quad (kg/Nm^3) \text{ --------- } (1)$$

$$g = \{g_0 \times 273/(273 + T_{OUT})\} \times \{(P_{Atm} \times 100/9.81 + SP_{OUT}) / (13.6 \times 760)\} \quad (kg/m^3) \text{ ---------- } (2)$$

$$V = 0.854 \times \sqrt{2 \times 9.81 \times DP_{OUT} / g} \quad (m/s) \text{ --------- } (3)$$

$$F_{OUT} = V \times p \times (1840 / 2000)^2 \times 60 \times \{273 / (273 + T_{OUT})\} \times (P_{Atm} \times 100 / 9.81 + SP_{OUT}) / (13.6 \times 760) \quad (Nm^3/min) \text{ ---------} (4)$$

$$F_{IN} = F_{OUT} \times (CO_{IN} + CO_{2IN}) / (CO_{OUT} + CO_{2OUT}) \quad (Nm^3/min) \text{ --------- } (5)$$

$$q_{IN} = F_{IN} \times T_{IN} \times \{q_{CO} \times CO_{IN} + q_{CO2} \times CO_{2IN} + q_{O2} \times O_{2IN} + q_{N2} \times (100 - CO_{IN} - CO_{2IN} - O_{2IN})\} / (4.186 \times 100)$$

$q_{CO} = 0.00013\ T \times T_{IN} + 1.28\ (kj / m^3N°C)$

$q_{CO2} = 0.000397\ T \times T_{IN} + 1.826\ (kj / m^3N°C)$

$q_{O2} = 0.000148\ T \times T_{IN} + 1.33\ (kj / m^3N°C)$

$q_{N2} = 0.000128\ T \times T_{IN} + 1.271\ (kj / m^3N℃)$ (kcal/min)---------(6)

Whereas;

g_0: Gas density at 0℃ and 1 atm. pressure. (kg/Nm³)

g: Gas density at actual state. (kg/m³)

V: Gas velocity at actual state. (m/s)

Note: Measurement was done using a Pitot tube, of coefficient 0.845.

F_{OUT}: Gas flow rate at C/C-outlet. (Nm³/min)

Note: Duct diameter is 1840 mm.

F_{IN}: Estimated gas flow rate at C/C-inlet. (Nm_3/min)

q_{IN}: Estimated gas heat content at C/C-inlet. (kcal/min)

DP_{OUT}: Gas dynamic pressure at C/C-outlet. (mmAq)

SP_{OUT}: Gas static pressure at C/C-outlet. (mmAq)

P_{atm}: Atmospheric pressure. (hPa)

T_{OUT}: Gas temperature at C/C-outlet. (℃)

CO_{OUT}: CO content of exhaust gas at C/C-outlet. (%)

CO_{2OUT}: CO_2 content of exhaust gas at C/C-outlet. (%)

O_{2OUT}: O_2 content of exhaust gas at C/C-outlet. (%)

N_{2OUT}: N_2 content of exhaust gas at C/C-outlet. (%)

T_{IN}: Gas temperature at C.C. outlet. (℃)

CO_{IN}: CO content of exhaust gas at C/C-inlet. (%)

CO_{2IN}: CO_2 content of exhaust gas at C/C-inlet. (%)

O_{2IN}: O_2 content of exhaust gas at C/C-inlet. (%)

N_{2IN}: N_2 content of exhaust gas at C/C-inlet. (%)

p: Pi, 3.14

H: Moisture (%)

Annex-5

An Example of Energy Saving Activities in Steel Works in Japan

1. Introduction

Energy saving is part of overall energy management, and to accomplish it requires organized effort. All employees (managers, engineers and workers) must cooperate in this effort.

Equipment must be well maintained in peak operating condition, and continuous effort made to improve it.

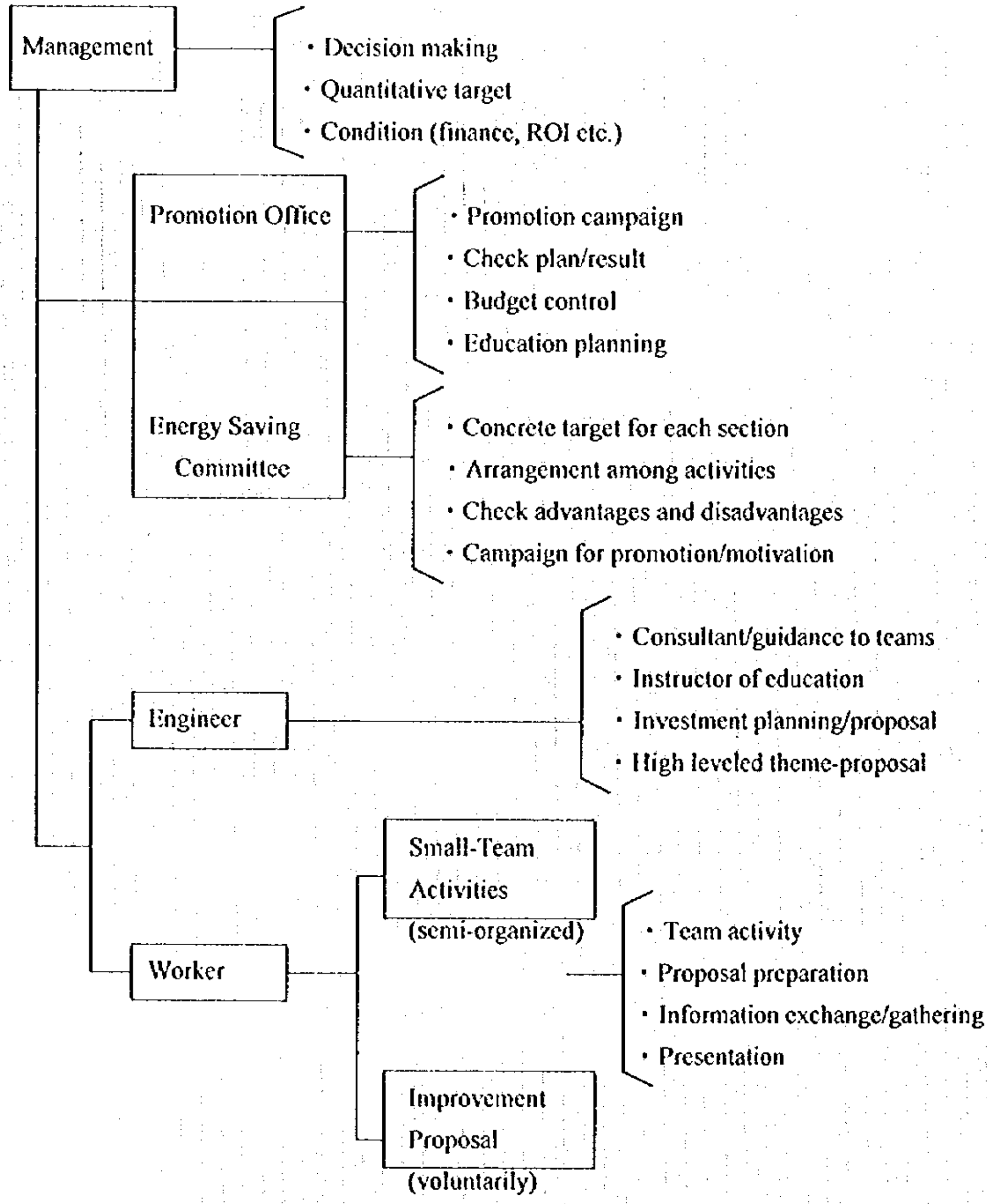
Energy saving activity includes:

(a) Employee education

(b) Investigation, data gathering, and to diagnose equipment

(c) Study of relevant literature to find hints for improvement

2. Organization for Energy Saving Activity



Notes: These activities shall be supported by the PDCA*-cycle, and spiral up to higher levels successively.

*Plan-Do-Check-Action

3. An Example of Small-Team Activity and Improvement-Proposal Awarding System.

1) Small-Team Activity (Semi-Organized)

- Participants: Worker class
- Organization: Central promotion office/Branch promotion office/Small-teams
- Yearly schedule: Fixed, including presentation and award ceremony once a year
- Award money

•Special	:	50,000 Yen/Team
•A	:	40,000 Yen/Team
•B	:	20,000 Yen/Team
•C	:	10,000 Yen/Team
•D	:	8,000 Yen/Team
•Other	:	Small token

- Activity time: Within working time
- Scope of Activity: From theme selection to solution proposal

2) Improvement-proposal Award System (voluntarily)

- Participants: All employees (individuals or groups)
- Organization: Promotion office/instructor, consultant
- Yearly schedule: Presentation and award ceremony once a year
- Award money and accumulation points

		(money)	(points)
•Diamond	:	10,000 Yen	100
•Gold	:	5,000 Yen	50
•Silver	:	3,000 Yen	30
•Bronze	:	1,000 Yen	10
•Encouragement	:	500 Yen	5
•Other	:	100 Yen	1

Highly accumulated points getter will be awarded at each designated points, say 1,000, 3,000 points, etc.

4. Some Results from the Activities

	1. Workers	2. Engineers
· Rotating Machines	· Impeller cut, pully change, pole number change · Pump number change, pump down sizing · Transportation by process pressure · Valve/damper control · Fly wheel installation · Mercury lamp voltage down	· VVVF application · Energy recovery by Hydraulic turbine/Expansion turbine /Pressure reduction turbine · Driving power change (electric→ steam) · Energy recovery by thermo compressor · DC power change (generator→ SCR) · Reduction of transformer number
· T/D	· Heat up by exhaust gas · Opening area closing by dolomite · Preheating pattern/time change	

(Source:JICA Report)

	1. Workers	2. Engineers
· Re-heating Furnance	· Heat pattern change, Heat time reduction · Insulation improvement · Fuel gas flow control, fuel/air ratio control · Charge pattern change (parallel → zigzag) · Walking beam pitch change · Double door · Preheater abolition · Transportation time reduction, hot charge ratio up	· Water cooling charge Equivalent target(per 1 ton steal) · Power/oil=2.4kwh/l.oil · Power/O_2=6.0kwh/$NM^3.O_2$ · Power/SPH=15.0kwh/100℃
· EAF	· Tap-tap time reduction by abolition of melt down operation · 〃 〃 of O_2/I · Heat leakage prevention by sand gasket · Dried scrap charge by use of previous day scrap · 〃 by use of residual heat of EAF · Reduction of cover opening by larger bucket · Damper control to exhaust duct · Air leakage reduction through molten steel door by dolomite · cover on transportation ladle · Abolition of water cooling electrode · Scrap mixture change (bulk density down) · Air tightening for electrode sleeve, slag door, molten door · etc.	· Basic atmosphere operation → Acidity atmosphere operation · Single slag operation · Abolition of intermittent analysis · Usage of digital load-cell · Residual heat usage by 2-furnace/1-power · Technique of electrode depth measurement (Refractory life prolong) · C/I operating for foaming · Automatic operation · Post combustion operation · J/B Installation at dead corner · etc.

(Source:JICA Report)

Chapter 13 Overall Conclusions and Recommendation

Chapter 13 Overall Conclusions and Recommendation

13-1 Laws and Regulation, Administrative Organization

13-1-1 Organizations and their functions

(1) Problem

1) Effectiveness

The single window system is very good but it is necessary to coordinate among governmental and private organizations to promote energy conservation. There should be effective interdepartmental coordination of conservation activities.

2) Commitment

In the government sector, acquisition of an additional budget for promoting an energy conservation program is difficult. As a measure to create a fund, expansion of the existing scheme or creation of new a monetary source is needed.

3) Planning

An overall energy conservation program with well-defined quantitative targets, strategy, budget is not formulated.

(2) Recommendation

1) Effectiveness

In the industrial sector, the Ministry of Industry and KOSGEB have functions such as access to informative means , adoption of technological developments and training. Coordination between EIE and NECC and that with the Ministry of Industry and KOSGEB are recommended to smoothly and effectively promote energy conservation in the industrial sector as well as enhancing awareness through the activities of ECCB.

2) Commitment

Strong political leadership and bureaucratic commitment are, however, the key to the success of government conservation activities. Strong political leadership with bureaucratic interest is expected to promote energy conservation in such a country that is highly dependent on a foreign supply of energy.

3) Planning

An overall action program is recommended to formulate.

13-1-2 Energy Conservation Laws and Regulations

(1) Problem

In order to promote energy conservation, there is a need for a law on which nation-wide energy conservation measures can be based. The existing regulation does not cover the whole range of the industrial sector nor other sectors

(2) Recommendations

1. To expand the scope of the Regulation to small energy consumers (500 TOE) in manufacturing industries. The obligation should be limited only to reporting their annual energy consumption.

2. To formulate an energy conservation law which, of course, covers the manufacturing sector. It is necessary for the government, government agencies, energy suppliers, energy equipment manufacturers and consumers to promote energy conservation from their respective standpoints, in an integrated way. Also, it is necessary for the government to express its commitment to energy conservation, and for it to formulate a law on which its various measures are to be based.

13-1-3 Preparation of Guidelines

(1) Problem

Various kinds of energy conservation non-compulsory standards, or guidelines, showing quantitative targets of measures for improving energy efficiency itemized in Article 6 of the Regulation should be prepared.

The guidelines may help factory staff implement appropriate measures for energy conservation and may help business operators make positive efforts for streamlining energy use in their factories, by choosing better solutions suited to the given conditions.

(2) Recommendation

EIE is strongly expected to take initiative for preparing these guidelines such as

1. To lower the intake air ratio, and excess oxygen content in exhaust gas to control fuel

combustion in furnaces

2. To raise the waste heat recovery rate up to the standard value for the purpose of effective recovery and utilization of waste heat recovery equipment
3. To prevent the loss of heat that occurs in the forms of radiation, convection and conduction, by applying heat insulation and so forth
4. To effectively control the operation of combined heat and power generation to achieve greater efficiency in the conversion of heat to power or the reverse
5. To prevent electricity loss due to resistance and other causes and to keep the power factor at an adequate level at the electricity receiving end, together with TSI and other experts concerned.

These guidelines should be reviewed periodically every 10 years to adjust to the development of technology and energy situations.

13-1-4 Incentives, Preferential Measures – Taxation and Loan

(1) Problem

Medium- and small- scale manufacturing industries in particular are suffering from a shortage of funds required for investment in equipment more efficient in energy consumption. Governmental assistance programs are urgently needed.

(2) Recommendation

Awareness of the existing measures such as tax reduction and a low interest finance with a system of endorsement for debt should be extended.

The incentive package scheme should be developed using the existing incentives such as tax incentives, soft loans, energy audit and training.

13-1-5 Energy Managed Factories

(1) Problems

Medium- and small-scale manufacturing industries are mostly small energy consumers and fall outside the class responsive to the Regulation. It is necessary to obtain accurate information on trends in energy consumption and conservation patterns of these small consumers.

(2) Recommendations

To revise the applicable scope of the Regulation downward to small- and medium-scale manufacturing industries which annually consume 500 TOE or more energy so that the Regulation may cover 90 percent or more of the energy consumption by the industrial sector. At the same time, MENR should be able to analyze energy data thus made available to it, and to use these data in formulating its policy for the industrial sector.

13-1-6 Qualification of Energy Managers

(1) Problems

The qualification system for an energy manager should be a socially authoritative one. Now, not all the energy-managed factories have enough qualified energy managers. Energy managers should be appointed at every energy-managed factory within these 3 years.

(2) Recommendations

1. Promotion and expansion of the energy management courses conducted by not only EIE but also by the authorized organizations, to train factory personnel to be assigned to energy managers.
2. To expedite deployment of energy managers in three years, it is advisable to introduce a state-approved qualification system for energy managers, by giving certificates to graduates of technology courses and to factory engineers with years of experiences in energy conservation.
3. Qualified energy managers should be registered after they are posted to energy-managed factories and EIE should provide them with updated information obtained by factory surveys and from foreign sources on energy conservation, as well as to communicate government measures and to give specialized technical education. They can perform as auditors or consultants for small-scale factories which are not designated.

13-1-7 Energy Conservation Training Center

(1) Problem

Management and engineers of medium- and small-scale manufacturing industries to not generally have good opportunities to be trained in the latest technology.

(2) Recommendation

To strengthen EIE/NECC, a training center equipped with a model plant able to carry out practical energy conservation operations there and an energy data base system, catering especially to engineers at medium- and small-scale industries, are effective measures.

EIE, through the activities of the training center, will become able to enlighten the engineers in the need for using energy efficiently and to educate them in energy conservation techniques. EIE should start these activities in the industrial sector where energy conservation effects may be promptly expected. The activities of the center should expand to the transportation and consumer sectors. In this way EIE can promote energy conservation on a nation-wide scale in a unified manner.

13-1-8 Organization and Role of EIE/NECC

(1) Problem

EIE and NECC's Industrial Energy Conservation Division are the main governmental organizations for promoting energy conservation to industries. EIE is not allowed to establish a new department nor division in NECC. The EIE/NECC's authority is weak as an organization, and it does not operate a factory; therefore, there is a limit to the technical information that can be accumulated. On the other hand, energy conservation is carried out by the factories that actually consume the energy. Private companies tend not to open their internal information and to avoid outside intervention.

(2) Recommendation

To promote officials of NECC to further continue their activities in energy conservation. One of the options is to extend the mandate and clearly define the responsibilities of any given positions.

The role of EIE/NECC as an administrative body should be considered, with one possible alternative being to enhance its authority by making it a management supervisory organization. It is also hoped that the current energy conservation activities, namely education and consulting, can be further developed and enhanced drawing upon international collaboration schemes.

13-1-9 EIE/NECC Activities, Energy Audit

(1) Problem

Analytic technology, engineers and equipment are not necessarily sufficiently available even in large-scale manufacturing industries. Small- and medium-scale industries are in much poorer conditions. EIE should use human resources available inside and outside itself to cope with the increasing needs for audits. More budget should be allocated to implementation of energy audits. In 1994 and 1995, only one energy audit was carried out, mainly because of government budget saving measures.

(2) Recommendation

1. To conduct simpler energy audits mainly at medium- and small-scale factories not designated as energy-managed factory in the Regulation, in order to make these factories interested in energy conservation. In this regard, the collaboration of KOSGEB is essential in selecting candidate plants worth auditing.

2. Introduction of paid energy audits at large energy-managed factory should also be studied where many human resources and costly experts including expatriates are needed, if precise and high-level diagnosis and guidance service are done. The managements of designated factories should conduct energy audits and identify potentials for energy saving and monetary savings.

13-1-10 Dissemination of Technical Information, EIE/NECC

(1) Problem

At present, factory managers and engineers are not provided with sufficient information on energy conservation. Provision of latest technical information will serve to upgrade the technical levels of factories and to stimulate them in their energy conservation activities.

(2) Recommendation

1. To continue the consulting activities of EIE/NECC and related organizations on one side, to intensify their activities on small- and medium-scale industries, on the other. To promote the latter and increase their awareness on energy conservation, collaboration of KOSGEB, with its nationwide network, should be utilized.

2. To issue a pocket-sized book, 'Energy Conservation Reference Book', illustrating related regulations, statistics, standards and technical data on heat management and electricity management, to enable factory staff to easily access the needed information while they are conducting energy conservation activities.

13-1-11 Establishment of Energy Data Base System, EIE/NECC

(1) Problem

Accurate information is not available on energy consumption and conservation in the whole range of manufacturing industries, by sectors/subsectors and by size groups. It is necessary to establish proper and wide channels of information gathering, and to increase public trust in it as a reliable source of information.

(2) Recommendation

1. To establish information service outlets, such as EIE's Industrial Data Base Evaluation Book

   In order to effectively provide factories with technical information on energy conservation, it is necessary to establish a system by which the present situation and future trends in technology in various areas can be grasped, and with which such information can be used effectively.
2. To strengthen the information gathering system, especially on smaller-scale industries, by expanding the scope of the Regulation to smaller energy consumers to oblige them to report their annual energy consumption. To broaden EIE's channels for the acquisition of international technical information on energy conservation by promoting cooperative relations with overseas organizations, then to make the information public.
3. To install an on-line information provision and retrieval system.

13-1-12 Energy Conservation Seminar, EIE/NECC

(1) Problem

There is a shortage of engineers and technology at medium- and small-scale factories. Factory managers and staff are not sufficiently aware of the need for energy conservation, because they are concerned more about production and cost.

(2) Recommendation

To hold seminars concerning successful examples of energy conservation in real factories and to give education in energy conservation to management and engineers of medium- and small-scale manufacturing industries, which are not designated as energy-managed factories. Publication of successful examples of energy conservation will be effective in leading those engineers to recognize the importance of energy conservation.

In this regard, the collaboration of KOSGEB is essential in holding joint seminars on energy conservation in order to improve awareness of energy saving among management and engineers. KOSGEB's Consulting and Quality Improvement Centers is responsible for providing consulting services, seminars to medium- and small-scale industries, aiming to improve their product competitiveness in such a manner as production cost reduction. The joint seminars would be thus operated, EIE sponsoring and providing specialists on energy savings, KOSGEB planning the seminar program and providing the seminar hall in its center office buildings throughout the country.

13-2 Factory Audit

13-2-1 Detergent, Oil and Fats Factory, Henkel-Turyag

The study team presents the following conclusions and recommendations.

(1) Improvement of Heat Balance around Boilers

The factory should measure lignite consumption rate directly, in order to control and manage thermal efficiency continuously around the boilers.

(2) Imbalance between Steam Consumption and Necessary Power Generation

This factory has excess steam and insufficient own-generated electric power. It is necessary increase steam consumption and decrease electricity consumption in a rational way. The following measures are recommended.

1. Introducing steam turbine drivers to replace large motors
2. Introducing condenser in steam turbine generator exhaust LP steam line
3. Introducing condenser in steam turbine outlet of FDF of boilers
4. Introducing air preheater utilizing LP steam for combustion air of air heater

(3) Improvement of Heat Balance around Spray Dryer and Air Heater

The heat balance around these facilities should be improved by the following measure.

1. Filling up leakage points of the spray dryer
2. Finding the relationship between water content of powder and maximum temperature
3. Inlet and outlet gas temperature control

(4) Improvement of Heat Balance in Sulfonation Process

There are five heat exchangers, often damaged by SO_2 or SO_3 gas, around the SO_3 converter. Among these, the BFW preheater is currently not in use due to heavy corrosion damage. Whenever treating SO_2 and SO_3, the materials of heat exchangers should be carefully selected. The most common materials of heat exchangers in this unit are as follows.

Shell and tube type:	Shell side- Carbon steel, Tube side - SUS 316
Plate type:	SUS 304

To improve the heat balance in this process, heat recovery from cooling air by reconstruction of the BFW preheater, once named 12 E8, is important. The conceptual specifications of the BFW preheater are basically the same as the original design of 12 E8 except for materials.

(5) Improvement in Steam Condensate Recovery System

The following measures are recommended to improve condensate recovery.

1. Separation of steam and condensate system from the line cleaning system
2. Introducing block and bleed valve systems in the line cleaning system
3. Introducing drain pots in the steam condensate system
4. Preparation of standard operation manual for line cleaning and education and training of the operating procedure
5. Identification of important valves to be opened or closed with special caution, introducing color management on lines and valves

(6) Decreasing Heat Loss in the Steam Trap System

The factory has as many as 500 steam traps, some of them are leaking and blowing. The scheduled management such as checking, maintenance and renewal is necessary.

(7) Decreasing Heat Loss in Thermal Insulation System

Heat loss from steam pipelines is significant. Therefore, thermal insulation of valves and flanges is necessary.

(8) Reduction of Electricity Consumption

The factory has six transformer stations and 992 motors. Reduction of electricity consumption of transformers and motors is necessary. Therefore, unification of transformers such as No. 1, No. 3 and No. 6 should be studied. Adoption of an inverter speed controlling system should be studied.

13-2-2 Brick Factory, Dev Blok

(1) Raw Materials and Molding

Selection of raw materials affects productivity and therefore thermal efficiency. From the standpoint of rationalization of energy use, control of the raw materials is the first step toward better productivity. Therefore, the raw materials clays must be carefully selected and blended. The content of the black clay should be carefully determined, because the black clay could cause heat shock in the kiln at temperature 573 degrees Centigrade.

(2) **Drying**

The study team recommends that one line be added to the dryer to increase the capacity.

(3) **Energy Balance of the Tunnel Kiln**

The study team recommends installation of a double door to the tunnel kiln to increase the thermal efficiency and production capacity. Dev Blok plans to calculate energy balances for themselves. The equipment necessary for measurement, a surface thermometer and gas analyzer, should be procured.

(4) **Coal**

It is recommended that one centrifugal separator as cyclone be added in the coal crusher to remove largest grains.

(5) **Electricity**

Systematic program for studying electricity consumption should be inaugurated. When problems are found with respect to energy consumption, the following measures should be taken.

	Items	Equipment	Measure
1	Small revamping	Motor	Pole change
		Pump	Impeller cutting
2	Model change	Motor	Reduction of capacity
		Pump	Reduction of capacity
3	rpm change	Pulley and gear	Ratio change
		Motor	Pole change
			Inverter control
4	Energy recovery	Turbine	Generator/pump

13-2-3 Textile Factory, IBF

IBF plans to construct a new dyeing factory in a suburb of Izmir. According to this plan, natural gas will be used instead of coal. The open width bleaching range, the mercerizing unit and the Max Goller washing range will be moved to the new factory. The existing utility supply facilities will be discarded. Against this background, recommendations for energy conservation measures are prepared for the new factory and the existing factory.

(1) **New Factory**

1) **CHP system**

Possibility of using a CHP system should be studied for the new factory to realize efficient use of steam.

2) **Package Boiler System**

As an alternative steam supply system for the CHP system, a package boiler system consisting of a few fully automated small-capacity boilers should be studied.

3) **Direct Heating System**

The direct heating system is recommended as a local heating device in the finishing unit for an alternative case for the hot oil system. Natural gas is very useful as fuel for this system.

4) **Establishment of Good Energy Management System**

A computer control system including measuring equipment for operation control and energy management is recommended.

(2) **Existing Factory**

1) **Heat Recovery from Waste Water from Open Width Bleaching Range**

Heat loss associated with waste water at higher temperatures represents the largest portion, 77.2 percent, and the following countermeasures are recommended.

1. Fundamentally, reduction of water use and lowering of the standard operation temperature should be tried, as far as product quality permits, in a careful and gradual manner.
2. Improvement of the system for water, such as installation of a high temperature waste water reservoir, automatic cold and hot water supply system, etc.
3. As a concrete countermeasure, installing a series waste heat recovery system in parallel to the existing waste heat recovery system is recommended.
4. The steam flow to higher temperature baths should be controlled automatically.

2) **Recommendations for the Max Goller Washing Range**

The Max Goller washing range of IBF is new and fully automated. Measurement of steam flow rate to the range and heat recovery from waste water is nonetheless recommended.

3) **Condensate Recovery**

To install a condensate recovery system is recommended in the drying unit and the open width bleaching range for effective use of steam traps.

4) Insulation on Hot Valves and Flanges

It is recommended to apply insulation on the valves and flanges in the hot oil system and the steam supply system.

5) Necessity of Measuring Equipment for Monitoring Energy Consumption

It is recommended to install a steam flow meter at the outlet of generated steam line of each boiler and also a hot oil flow meter for each hot oil heater. Each machine should have water, electric and steam flow meters.

6) Computerized Maintenance System

Use of personal computers is recommended to better manage maintenance of the facilities.

7) Adjustment of the Steam Boiler Load

It is recommended to operate two, instead of three, boilers in summer when the load is low.

13-2-4 Steel Mill, IDC

(1) 12-11-1 Modifications of Facilities and Operation

The study team recommends the following measures to improve the facilities and operation.

1. Modify the scrap preheaters (SPH) to accommodate a 3rd bucket for preheating.
   The following facilities should be installed to operate SPH's simultaneously and independently:
   A new 2nd hood and a new 2nd inlet duct to the existing 2nd chamber
   A new 2nd outlet duct from the existing 2nd chamber
   A new 2nd damper for a new 2nd outlet duct
   Two blowers for the existing 1st and a new 2nd outlet ducts.
2. Improve maintenance of oxy-fuel burners of EAF to keep the O_2/Oil ratio constant.
3. Standardize burnt lime addition into EAF.
4. Decrease flow rate of cooling water for EAF.
5. Introduce billet cooling system at higher temperature in front of the reheating furnace to prevent crack generation in cast billet.
   Pumping system, water piping, spray nozzles and control system should be installed.

6. Turn power on as immediately as possible to prevent the drop of hot heel temperature
7. Preheat scrap as longer as possible to raise it temperature.
8. Purchase as well calcined burnt lime as possible to prevent heat loss in decomposition of limestone.

(2) Measure for Enhancement of Morale

To streamline energy use, concerned people at all levels of management, engineers and workers should have their respective roles to play. These are detailed in the main report.

Chapter 14 Socio-economic Evaluation of the Recommendations

Chapter 14 Socio-economic Evaluation of the Recommendations

14-1 Evaluation of the Recommendations on Policy

The medium- and small-scale manufacturing industries that consume more than 2,000 TOE represent only less than 30 percent of the total consumption of energy by the manufacturing industries. If this borderline is reduced to 500 TOE as this study recommends, the medium- and small-scale manufacturing industries consume energy even less. On the other hand the number of medium- and small-scale manufacturing industries is very large and they are scattered throughout the nation. Naturally, effort towards the medium- and small-scale manufacturing industries is destined to be ineffective in terms of achieving energy saving and very laborious. It would take a great deal of work, time, manpower and expense of the government, yet the effects in terms of energy saving, ratio of energy saving on the total consumption would not be very great.

The question is whether it is right to spend the limited government resources on cost-ineffective energy saving on the medium- and small-scale manufacturing industries or the government should let the medium- and small-scale manufacturing industries alone for a while until energy saving in more important sectors have almost been achieved to satisfactory levels.

The study team must answer this question as long as this study recommends legal and administrative measures. The study team presents recommendations as enumerated in Chapter 7. The recommendations are all modest ones. In light of the small contribution to energy saving in the medium- and small-scale manufacturing industries, the policy and administrative measures should not be expensive in workload, time, and cost. The study team considers this feature of the medium- and small-scale manufacturing industries in formulating recommendations. Against such a socio-economic background of the medium- and small-scale industries, the policy recommendation are based on the following ten basic principles so that the recommendations may be well balanced with the expected benefits. The study team exercised extreme caution not to make grand and expensive recommendations. Under such conditions new policy measures to this cost ineffective area may be justified.

Basic Concept for Recommendation

The recommendations for the study of policy towards the medium- and small-scale manufacturing industries are based on the following basic concepts. The recommendations intend:

1. To promote rational use of energy in the manufacturing sector in a manner that will contribute to environmental conservation,
2. To enhance awareness of the importance of promoting rational use of energy among those who are associated with manufacturing and administration,
3. To improve the organizational setup of the government so that the roles of the responsible organizations may be clearly defined and so authorized as to implement their roles,
4. To organize an effective system of collecting and processing information of manufacturing industries, the medium- and small-scale manufacturing industries in particular, so that the government may adequately promote rational use of energy,
5. To identify and develop human resources, both in the public and private sectors, that will be needed to promote rational use of energy,
6. To prepare an effective and easy-to-access package of incentives and finance to encourage medium- and small-scale manufacturing industries to promote rational use of energy,
7. To pursue inexpensive but effective strategies and methods in policy implementation,
8. To seek policy measures which the industries will accept and cooperate with willingly,
9. To facilitate development and introduction of technologies that promote rational use of energy, and
10. To establish a legal structure under which rational use of energy in the manufacturing sector may be effectively implemented.

Another important consideration is the fact a large number of people is involved in the medium- and small-scale manufacturing industries. As a matter of fact the number of people working for medium- and small-scale industries far exceeds that of those working for industries consuming more than 2,000 TOE per year. Enhancement of awareness of the importance of energy saving is very important among all conceivable policy measures. This could not be achieved if this large portion of people in the medium- and small-scale manufacturing industries is neglected. Education and training of those who actually work in the medium- and small-scale manufacturing industries are important in the sense that improper management of energy, combustion of fuel in particular, could lead to environmental hazards, generation of soot, smoke, or even more carbon monoxide for example.

In implementation of this study, the study team put environmental consideration ahead of energy saving, or to harmonized these two issues. For this reason the study team wishes to leave the standards for guidelines non-compulsory, because it is up to every installation to achieve energy saving without causing environmental disruption rather than obey the standards simple-mindedly without regard to their effects upon the environment and energy saving. Detailed operating conditions of manufacturing facilities are an area the government should not step in, unless the facilities evidently cause damages to the environment and people. It should be recognized that people who actually operate the facilities know more about their facilities than the government officers or any other organization. As far as the operating conditions are concerned, the role of the government should be limited to provision of information about new technology and good examples, and extension of energy audit service.

The effect of the recommended policies would not be very prompt and large in terms of energy saved, because the consumption of energy by the medium- and small-scale industries is not very large. More energy would be saved in the large-scale manufacturing industries and the transportation sectors. It does not mean in the least that the medium- and small-scale manufacturing industries can be neglected. Efforts should be made to save energy in the medium- and small-scale manufacturing industries along with large-scale manufacturing industries and other sectors, but in a cost effective manner. The medium- and small-scale manufacturing industries are particularly important from the standpoint of enhancing awareness of the importance of energy saving among the whole population.

14-2 Summary of the Costs and Benefits of the Recommended Measures for Factories

Table 14-1 summarizes estimated investments in the recommended modifications for the factories. The estimated costs in TL are based on the prices of August 1996 and are converted into US Dollar at the then prevailing rate of 86,500 TL per one US Dollar.

Table 14-1 Incremental Investment and Incremental Profit

Modification	Incremental investment	Incremental investment, US$	Incremental profit by energy saving, US$/y
Henkel-Turyag			
Steam turbine driver for FDF of a boiler	800,000 DM		
Condenser in steam turbine outlet of FDF for a boiler	50,000 DM		
Air preheater for combustion air of air heater	4,500 DM		
Filling up leaks of the spray dryer	7,000 DM		
Inlet and outlet gas temperature control of the spray dryer	10,500 DM		
Dev Blok			
Double door		810,730	171,000
MONO gas analyzer			
Surface thermometer			
Increase of dryer			
IBF			
Heat recovery from the open width bleaching range	1,175 million TL	13,584	19,457
Heat recovery from the Max Goller washing range	2,509 million TL	29,006	13,734
Condensate recovery plan	489 million TL	5,653	8,775
Insulation on 6 inch valve	25 million TL	289	305
IDC			
Modification of the scrap preheater		200,000	214,800
Introduction of billet cooling system		21,300	604,800

Note: 1 US$ is equivalent to 86,500 TL. Eleven month operation per year is assumed for IBF.

14-3 Evaluation of Recommendation for Factories

14-3-1 Premises for Financial Internal Rates of Return

Chapters 9 to 12 present evaluations of the recommended modifications by the methods acceptable to each factory. Here, the internationally accepted method for calculating internal rate of return, or rate of return of the discounted cash flow on investment, is used to assess some of the proposed modifications.

The calculation assumes the following basic premises.

1.	Project year	10
2.	Discount rate, percent/year	To be obtained
3.	Construction period, year	Within 1
4.	Operation period, year	9
5.	Depreciation, year	5
6.	Depreciation, method	Straight line without residual value
7.	Other capital related cost, percent on investment	5
8.	Income tax, percent on net income	30
9.	Currency	United States Dollars

14-3-2 Premises for Economic Internal Rates of Return

The results of the study indicate that the prices of inputs to calculation are not significantly deviated from their true economic values. The prices of coal and electricity are close to those in the OECD member nations. For practical purposes elimination of "incremental income tax" from the financial IRR calculation is all that is required to obtain their economic internal rates of return.

14-3-3 Financial and Economic Internal Rates of Return

Table 14-2 gives the calculated financial and economic internal rates of return for selected recommended modifications. The incremental variable operating costs can be neglected for these calculations.

Table 14-2 Calculated Financial and Economic Internal Rates of Return

Modification	Financial internal rate of return, percent	Economic internal rate of return, percent
Dev Blok		
Double door	6.48	8.14
MONO gas analyzer		
Surface thermometer		
Increase of dryer		
IBF		
Heat recovery from the open width bleaching range	102.42	138.18
Heat recovery from the Max Goller washing range	31.63	40.34
IDC		
Modification of the scrap preheater	76.91	102.22

Tables 14-3 to 14-6 show the calculation of financial internal rates of return and Tables 14-7 to 14-10 show the calculation of economic internal rates of return.

14-3-4 Evaluation of the Calculated Results

The obtained financial and economic internal rates of return indicate that all investment projects except for that in Dev Blok are financially and economically justifiable.

The investment project in Dev Blok could be justifiable if the investment cost is reduced to 502,000 US Dollars as indicated by the calculation on Table 14-11. At this investment cost the financial internal rate of return is 20 percent. Dev Blok should reduce the investment cost to this level by using domestic inputs instead of foreign inputs before actually embarking on the project.

Table 14-3 Financial IRR of the Modification Recommended for Dev Blok

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of Dev Blok

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	810,730									
Incremental Pre-operation Cost	0									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		162,146	162,146	162,146	162,146	162,146				
Incremental Operation Cost		40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537
Incremental Variable Cost		0	0	0	0	0	0	0	0	0
Incremental Fixed Cost		40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537
Incremental Profit by Energy Saving		171,000	171,000	171,000	171,000	171,000	171,000	171,000	171,000	171,000
Incremental Taxable Income		-31,683	-31,683	-31,683	-31,683	-31,683	130,464	130,464	130,464	130,464
Incremental Income Tax		-9,505	-9,505	-9,505	-9,505	-9,505	39,139	39,139	39,139	39,139
Incremental Income after Tax		-22,178	-22,178	-22,178	-22,178	-22,178	91,324	91,324	91,324	91,324
Cash Flow	-810,730	139,968	139,968	139,968	139,968	139,968	91,324	91,324	91,324	91,324
Internal Rate of Return	0.0648									

Table 14-4 Financial IRR of the Modification Recommended for IBF (Heat Recovery from the Open Width Bleaching Range)

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of IBF

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	13,584									
Incremental Pre-operation Cost	0									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		2,717	2,717	2,717	2,717	2,717				
Incremental Operation Cost		679	679	679	679	679	679	679	679	679
Incremental Variable Cost		0	0	0	0	0	0	0	0	0
Incremental Fixed Cost		679	679	679	679	679	679	679	679	679
Incremental Profit by Energy Saving		19,457	19,457	19,457	19,457	19,457	19,457	19,457	19,457	19,457
Incremental Taxable Income		16,061	16,061	16,061	16,061	16,061	18,778	18,778	18,778	18,778
Incremental Income Tax		4,818	4,818	4,818	4,818	4,818	5,633	5,633	5,633	5,633
Incremental Income after Tax		11,243	11,243	11,243	11,243	11,243	13,144	13,144	13,144	13,144
Cash Flow	-13,584	13,960	13,960	13,960	13,960	13,960	13,144	13,144	13,144	13,144
Internal Rate of Return	1.0242									

Table 14-5 Financial IRR of the Modification Recommended for IBF (Heat Recovery from the Max Goller Washing Range)

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of IBF

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	29,006									
Incremental Pre-operation Cost	0									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		5,801	5,801	5,801	5,801	5,801				
Incremental Operation Cost		**1,450**	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450
Incremental Variable Cost		**0**	0	0	0	0	0	0	0	0
Incremental Fixed Cost		**1,450**	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450
Incremental Profit by Energy Saving		**13,734**	13,734	13,734	13,734	13,734	13,734	13,734	13,734	13,734
Incremental Taxable Income		6,483	6,483	6,483	6,483	6,483	12,284	12,284	12,284	12,284
Incremental Income Tax		1,945	1,945	1,945	1,945	1,945	3,685	3,685	3,685	3,685
Incremental Income after Tax		4,538	4,538	4,538	4,538	4,538	8,599	8,599	8,599	8,599
Cash Flow	-29,006	10,339	10,339	10,339	10,339	10,339	8,599	8,599	8,599	8,599
Internal Rate of Return	0.3163									

Table 14-6 Financial IRR of the Modification Recommended for IDC (Modification of the Scrap Preheater)

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of IDC

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	**200,000**									
Incremental Pre-operation Cost	**0**									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		40,000	40,000	40,000	40,000	40,000				
Incremental Operation Cost		**10,000**	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Incremental Variable Cost		**0**	0	0	0	0	0	0	0	0
Incremental Fixed Cost		**10,000**	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Incremental Profit by Energy Saving		**214,800**	214,800	214,800	214,800	214,800	214,800	214,800	214,800	214,800
Incremental Taxable Income		164,800	164,800	164,800	164,800	164,800	204,800	204,800	204,800	204,800
Incremental Income Tax		49,440	49,440	49,440	49,440	49,440	61,440	61,440	61,440	61,440
Incremental Income after Tax		115,360	115,360	115,360	115,360	115,360	143,360	143,360	143,360	143,360
Cash Flow	-200,000	155,360	155,360	155,360	155,360	155,360	143,360	143,360	143,360	143,360
Internal Rate of Return	0.7691									

Table 14-7 Economic IRR of the Modification Recommended for Dev Blok

Evaluation of Modification for Rationalization of Energy Use (Unit: USS)

Internal Rate of Return, Modification of Dev Blok

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	810,730									
Incremental Pre-operation Cost	0									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		162,146	162,146	162,146	162,146	162,146				
Incremental Operation Cost		40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537
Incremental Variable Cost		0	0	0	0	0	0	0	0	0
Incremental Fixed Cost		40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537	40,537
Incremental Profit by Energy Saving		171,000	171,000	171,000	171,000	171,000	171,000	171,000	171,000	171,000
Incremental Taxable Income		-31,683	-31,683	-31,683	-31,683	-31,683	130,464	130,464	130,464	130,464
Incremental Income Tax		0	0	0	0	0	0	0	0	0
Incremental Income after Tax		-31,683	-31,683	-31,683	-31,683	-31,683	130,464	130,464	130,464	130,464
Cash Flow	-810,730	130,464	130,464	130,464	130,464	130,464	130,464	130,464	130,464	130,464
Internal Rate of Return	0.0813									

Table 14-8 Economic IRR of the Modification Recommended for IBF (Heat Recovery from the Open Width Bleaching Range)

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of IBF

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	13,584									
Incremental Pre-operation Cost	0									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		2,717	2,717	2,717	2,717	2,717				
Incremental Operation Cost		679	679	679	679	679	679	679	679	679
Incremental Variable Cost		0	0	0	0	0	0	0	0	0
Incremental Fixed Cost		679	679	679	679	679	679	679	679	679
Incremental Profit by Energy Saving		19,457	19,457	19,457	19,457	19,457	19,457	19,457	19,457	19,457
Incremental Taxable Income		16,061	16,061	16,061	16,061	16,061	18,778	18,778	18,778	18,778
Incremental Income Tax		0	0	0	0	0	0	0	0	0
Incremental Income after Tax		16,061	16,061	16,061	16,061	16,061	18,778	18,778	18,778	18,778
Cash Flow	-13,584	18,778	18,778	18,778	18,778	18,778	18,778	18,778	18,778	18,778
Internal Rate of Return	1.3818									

Table 14-9 Economic IRR of the Modification Recommended for IBF (Heat Recovery from the Max Goller Washing Range)

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of IBF

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	29,006									
Incremental Pre-operation Cost	0									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		5,801	5,801	5,801	5,801	5,801				
Incremental Operation Cost		1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450
Incremental Variable Cost		0	0	0	0	0	0	0	0	0
Incremental Fixed Cost		1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450
Incremental Profit by Energy Saving		13,734	13,734	13,734	13,734	13,734	13,734	13,734	13,734	13,734
Incremental Taxable Income		6,483	6,483	6,483	6,483	6,483	12,284	12,284	12,284	12,284
Incremental Income Tax		0	0	0	0	0	0	0	0	0
Incremental Income after Tax		6,483	6,483	6,483	6,483	6,483	12,284	12,284	12,284	12,284
Cash Flow	-29,006	12,284	12,284	12,284	12,284	12,284	12,284	12,284	12,284	12,284
Internal Rate of Return	0.4034									

Table 14-10 Economic IRR of the Modification Recommended for IDC (Modification of the Scrap Preheater)

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of IDC

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	**200,000**									
Incremental Pre-operation Cost	**0**									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		40,000	40,000	40,000	40,000	40,000				
Incremental Operation Cost		**10,000**	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Incremental Variable Cost		**0**	0	0	0	0	0	0	0	0
Incremental Fixed Cost		**10,000**	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Incremental Profit by Energy Saving		**214,800**	214,800	214,800	214,800	214,800	214,800	214,800	214,800	214,800
Incremental Taxable Income		164,800	164,800	164,800	164,800	164,800	204,800	204,800	204,800	204,800
Incremental Income Tax		0	0	0	0	0	0	0	0	0
Incremental Income after Tax		164,800	164,800	164,800	164,800	164,800	204,800	204,800	204,800	204,800
Cash Flow	-200,000	204,800	204,800	204,800	204,800	204,800	204,800	204,800	204,800	204,800
Internal Rate of Return	1.0222									

Table 14-11 Financial IRR of the Modification Recommended for Dev Blok (Investment to make 20 percent Financial IRR)

Evaluation of Modification for Rationalization of Energy Use (Unit: US$)

Internal Rate of Return, Modification of Dev Blok

Year	1	2	3	4	5	6	7	8	9	10
Incremental Investment	**502,000**									
Incremental Pre-operation Cost	0									
Incremental Interest during Const.	N.A.									
Repayment Statement										
Outstanding Debt	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Repayment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Interest Payment	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Working Capital										
Depreciation		100,400	100,400	100,400	100,400	100,400				
Incremental Operation Cost		**25,100**	25,100	25,100	25,100	25,100	25,100	25,100	25,100	25,100
Incremental Variable Cost		**0**	0	0	0	0	0	0	0	0
Incremental Fixed Cost		**25,100**	25,100	25,100	25,100	25,100	25,100	25,100	25,100	25,100
Incremental Profit by Energy Saving		**171,000**	171,000	171,000	171,000	171,000	171,000	171,000	171,000	171,000
Incremental Taxable Income		45,500	45,500	45,500	45,500	45,500	145,900	145,900	145,900	145,900
Incremental Income Tax		13,650	13,650	13,650	13,650	13,650	43,770	43,770	43,770	43,770
Incremental Income after Tax		31,850	31,850	31,850	31,850	31,850	102,130	102,130	102,130	102,130
Cash Flow	-502,000	132,250	132,250	132,250	132,250	132,250	102,130	102,130	102,130	102,130
Internal Rate of Return	0.1998									

Attachment-I

SCOPE OF THE STUDY

This SCOPE OF THE STUDY forms part of the Scope of Work agreed between EIE and JICA on June 30, 1995.

In order to achieve the above objectives, the Study will cover the following items;

1. Study on the energy situation in Turkey

1-1 Government policy on energy

1-2 Present energy situation in Turkey

1-3 Situation of energy use in the field of industrial sector in Turkey

2. Study on the promotion of the rational use of energy int he selected small and medium size industrial sectors

2-1 Relevant laws and regulations

2-2 Current program for the rational use of energy

2-3 To study and evaluate the activities of the authorities concerned

(1) Current activities for the promotion of the rational use of energy

(2) Achievements of past activities

(3) Future plan/program for the promotion of the rational use of energy

3. Study on the situation of energy use in the selected factory of each industrial sector

3-1 Situation of energy use in each factory

(1) Outline of the factory

(2) Situation of energy management

(3) Energy flow chart and production process

(4) Situation of major energy consuming equipment

(5) Problems in each factory and countermeasures that do not involve changing the existing production process

(6) Estimated effects of the countermeasures

4. Recommendation for the promotion of the rational use of energy in Turkey

4-1 Government policy, law and regulation

4-2 Executing organization to promote the rational use of energy

4-3 Activities for the promotion of the rational use of energy

4-4 Measures to promote the rational use of energy in the selected small and medium size industrial sectors

4-5 Countermeasures to solve the problems that do not involve changing the existing production process

4-6 Expected effects after the implementation of the Master Plan

5. Preparation of reference material to be used in technical guidelines for the promotion of the rational use of energy in the selected small and medium size industrial sectors

The objective of the study referred to in the fourth line is stated as follows:

OBJECTIVE OF THE STUDY

The objective of the Study is to contribute to the promotion and strengthening of the rational use of energy in the fields of industries in the field of industries in the Republic of Turkey (hereinafter referred to as "Turkey") by studying the technical and managerial applicability of the rational use of energy and formulating the report for the promotion of the rational use of energy in the industrial sectors stated below:

1. Brick
2. Textile
3. Metallurgy (Steel rolling mil, Arc furnaces)
4. Food (Vegetable oils)
5. Cleaning material

JICA