THE INTERIM REPORT
FOR
THE FEASIBILITY STUDY
ON
EFFECTIVE UTILIZATION OF BANKO COAL
IN
THE REPUBLIC OF INDONESIA

(Basic Design on Coal Gasification Test Facilities)

May, 1985

JAPAN INTERNATIONAL
COOPERATION AGENCY

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1. Plan for Coal Gasification Experiments

1-1. Coal gasification experiment plan

1-1-1. Principle and features of coal gasification process using a molten iron bath

A number of coal gasification processes have been developed from diverse ideas of reactor structures for coal gasification and for the use of gases produced. Those processes can be classified into four groups by characteristics of reactions taken place in a reactor; the fixed bed, the fluidized bed, the entrained flow and the molten bath. The coal gasification process using a molten iron bath is classified into a group of molten bath method.

Schematic drawing of this process is shown in Fig. 1. It has been developed by applying a highly refined technology of steelmaking converter and consists of a gasification reactor storing high-temperature molten iron which acts an important role in acceleration of gasification reaction.

Process of oxidation reaction in a top-blown converter is schematized in Fig. 2. In the early stage of blowing, an amount of oxygen consumed for oxidation of Si, Mn and P is greater than that for decarburization. In the middle stage, most part of the oxygen is used for decarburization. More than 98% of gases produced in this period is carbon monoxide, which suggests

that decarburizing efficiency of oxygen is almost 100%. In the late stage of blowing, since the amount of carbon in molten iron bath has already reduced, oxygen is increasingly consumed for oxidation of iron and generation of carbon dioxide and, as a result, reduces generation of carbon monoxide.

In molten iron coal gasification process, an adequate amount of coal is added to a molten iron bath during the middle stage of blowing, where decarburization reaction proceeds at the highest rate, in such a way as to compensate the reducing carbon content in the molten iron and to maintain its level at about 1% or higher, and coal is thus gasified continuously.

Coal is blown through a non-submersion-type lance onto the surface of this molten iron at a high speed together with gasification agents (oxygen gas and steam). Only a small amount of coal is gasified before it arrives the molten iron surface, but most amount of coal is efficiently gasified in the molten iron bath which provides the following benefits;

(1) The molten iron bath completely cracks the blown coal in a short period of time and not only generates hydrogen gas but dissolves and absorbs the carbon produced by cracking.

(2) The molten iron reacts with blown oxygen and with carbon dioxide generated in the bath and becomes FeO, but this FeO is immediately reduced by carbon contained in the molten iron and becomes Fe while generating carbon monoxide gas.

(3) Even if an excessive amount of coal is fed into the molten iron bath, the molten iron dissolves and absorbs an excessive amount of carbon preventing unoxidized carbon to escape from the gasifier.

(4) Even if an excessive amount of oxygen is supplied, carbon contained in the molten iron bath reacts with excess oxygen preventing the generation of carbon dioxide gas.

(5) Coal ash is melted in the molten iron bath and floats on the surface due to its low specific-gravity characteristic.

(6) The molten iron dissolves and absorbs the sulfur contained in the coal and then transform into the molten slag.

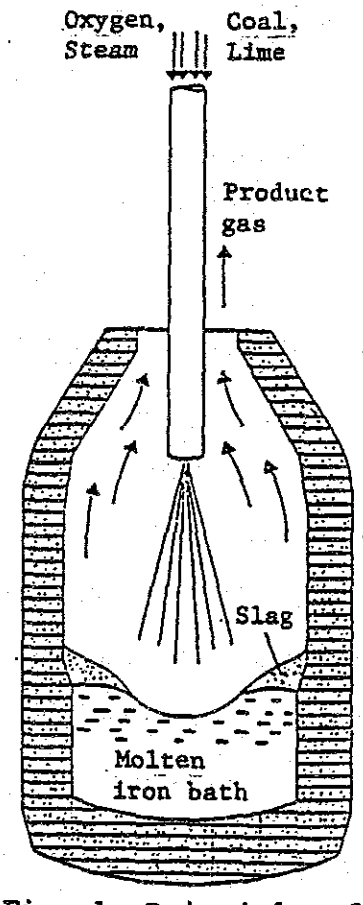


Fig. 1 Principle of molten iron coal gasification process

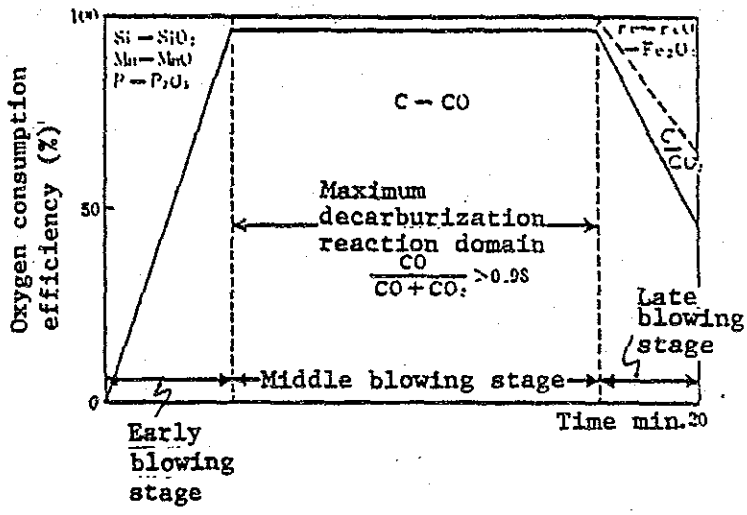


Fig. 2 Process of oxidation reaction in a top-blown converter

1-1-2 Purpose of experiments

In gasification of coal, characteristics of gasification operation (amount of product gas, components, contents of impurities, characteristics of slag, etc.) vary with properties of coal (moisture, ash, C,H,O,S contents, etc.).

Especially, coal reserved in the district of Banko, Indonesia, has a wide variety of qualities depending on area and coal seam. Therefore, before working out a plan for Banko coal gasification project, it is necessary to have a good knowledge of the properties of each coal produced in this district from the viewpoint of gasification.

Therefore, the purpose of experiments are;

(1) Different kinds of brown coal produced in Banko district in Indonesia are gasified in a molten iron coal gasification testing plant to obtain necessary information about them for understanding each aspect of gasification operation.

(2) The data obtained through conduction of gasification experiments are analyzed and studied by referring to our accumulated information by basic researches and experiments on pilot plants, and are summarized into a basic information needed for further feasibility study of coal gasification. Accordingly, the purpose of this experiment is

not for development of new technology nor collection of engineering data.

1-1-3. Plan for installation of experimental equipment

The basic idea in making plan for installation of experimental equipment is as follows;

(1) The experimental equipment must have a proper scale and function for understanding and evaluation of characteristics of coal gasification operation.

a) In order to make an accurate analysis of product gas components by minimizing the external disturbances (such as inclusion of N_2 gas used for sealing), the experimental equipment must have a capacity to generate about 40 Nm^3/h of product gas (Feeding rate of coal: about 20 kg/h).

b) The experimental equipment must be capable of producing a necessary amount of slag for analysis of components. A sufficient amount of slag for analysis will be produced when the coal is blown at a rate of about 20 kg/h.

(2) The equipment must be capable of keeping the molten iron bath at a constant temperature.

A small-scale experimental equipment has a greater heat loss causing the molten iron temperature to drop. To compensate such heat loss by giving heat from outside, this experimental equipment has an induction coil surrounding

a gasifier to maintain the molten iron bath at a constant temperature.

(3) The molten iron required for coal gasification is produced by a medium-frequency induction furnace from iron scraps.

The basic specifications and the main components of the experimental equipment for coal gasification process designed on the basis of above-mentioned idea are indicated in Table 1 and Fig. 3.

Table 1 Basic specifications required for the experimental equipment

Item	Amount required	Remarks
Molten iron bath	300 kg	
Coal feeding rate	20 kg/h	Dry coal
Blowing oxygen	575 Nm^3/coal-t, 12 Nm^3/h	Standard value, varies with kind of coal.
Carrier gas	150 Nm^3/coal-t, 3 Nm^3/h	N_2
Product gas	2000 Nm^3/coal-t, 40 Nm^3/h	Standard value, varies with kind of coal.
Calcined lime	30 kg/coal-t, 0.6 kg/h	Standard value, varies with kind of coal.
Slag production	78 kg/coal-t, 1.6 kg/h	

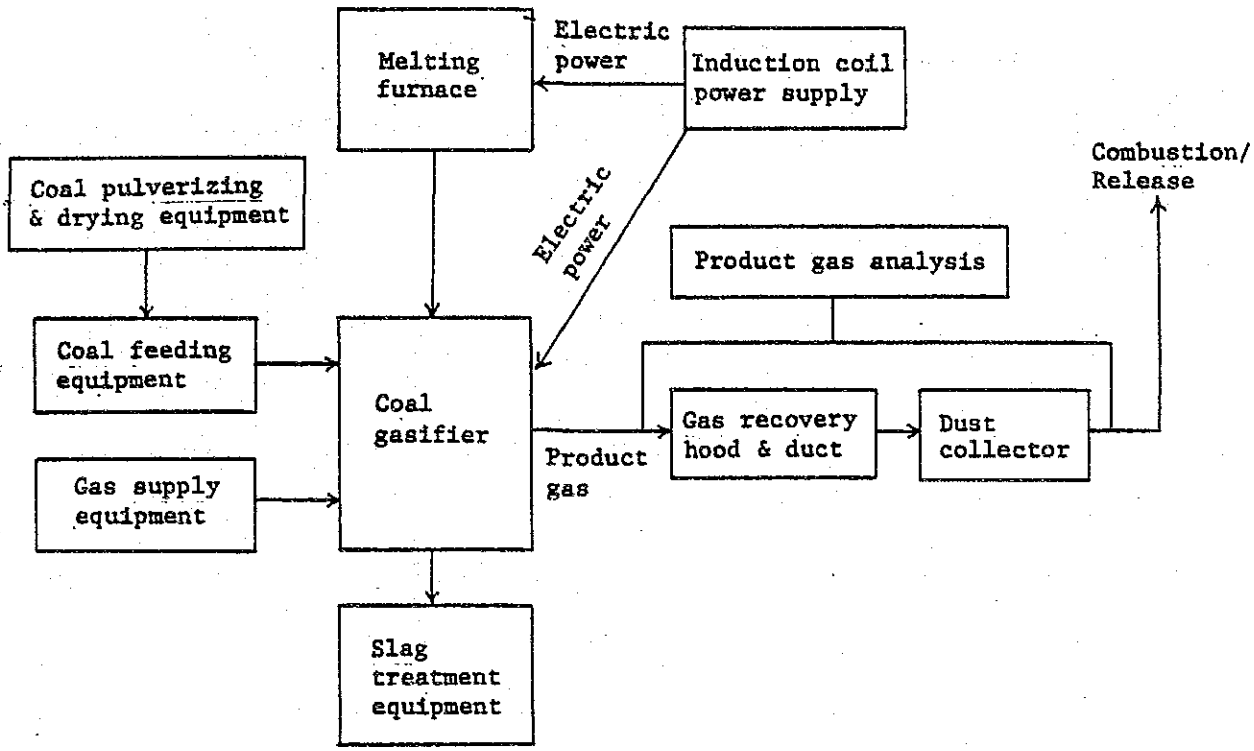


Fig. 3 Main components of experimental equipment

1-1-4. Considerations on experimental method

As a result of preliminary investigations made on Banko coal in 1984, common properties of Banko coal have been reported as follow;

(1) Total moisture is as high as 28 to 38%.

(2) Ash content is generally low but fluctuates between 4% and 16% depending on coal seam.

(3) Oxygen content is as high as 23 to 26% according to the result of ultimate analysis.

(4) Total content of sulfur is 0.2 to 1.8% and a large amount of sodium oxide (Na_2O) is included in ash.

A large fluctuation is recognized in the above-mentioned values among locations of coal area from NW Banko to Central Banko and also among depths of seam. Accordingly, the experimental method was so designed that the characteristics of coal gasification could be distinguished by properties of coal under the constant experimental conditions (proper values of the results obtained from past experiments) such as reaction temperature, feeding and blowing conditions of coal and oxygen, particle size of pulverized coal and basicity of slag, etc.

1) Experimental conditions

The experimental conditions were discussed considering the results of past experiments. The main items of the experimental conditions are as follow;

Temperature of molten iron bath:

In a large-sized reactor, coal gasification can be performed to almost 100% of decarburizing efficiency when the molten iron temperature is 1400°C or higher. But, in a small-seze reactor, a little higher temperature of the molten iron bath is needed for decarburization. Therefore, we took a range of 1500 to 1550°C for the target of molten iron temperature.

Carbon content in molten iron bath:

In order to maintain the carbon content in the molten iron bath at a level of 1% or higher, the ratio of coal to oxygen to be blown onto the molten iron bath is adjusted. The target of carbon content for practical operation is usually 2 to 3%.

Slag basicity:

For maintaining the basicity of slag (CaO/SiO_2) between 1.5 to 2.0, an adding amount of calcined lime is controlled in consideration of fluidity, reaction with refractory bricks and desulfurization reaction of slag.

Pulverized coal feeding method:

Both pulverized coal and oxygen are blown onto a hot spot on the surface of molten iron bath through a non-submersion type lance.

Particle size of pulverized coal:

Pulverized coal of -200 mesh (more than 70%) is used, considering the efficiency of gasification.

2) Sampling of Banko coal for gasification experiments

After examining the results of proximate and ultimate analyses conducted on samples of coal collected from each area and each seam of area spread over from NW Banko to Central Banko districts, some kinds of coal which are particularly

characterized by total moisture, ash content, O content, S content and sodium content in ash are selected out of them and used for the coal gasification experiment.

3) Time and procedure of experiment

Taking the following points into consideration that it was predicted to take 20 to 30 minutes for stabilization of gasification and one more hour for normalization of the process from which the reliable samples could be collected for analysis, a maximum period of time for one experiment was decided to be two hours. Table 2 indicates the standard time schedule for one experiment.

A 300 kg molten iron is prepared in a melting furnace (medium-frequency induction furnace)

In the morning, a 300 kgs of molten iron is produced from iron scraps in a medium-frequency induction furnace (melting furnace). In the afternoon of the same day, the molten iron is transferred into a gasifier in which a 2-hours gasification experiment is conducted at a prescribed temperature. Considering the necessary jobs to be done before and after an experiment including the arrangement of collected data, a cycle of two experiments in a week will be suitable.

Table 2 Standard time schedule for an experiment

Hour	9	10	11	12	1	2	3	4	5
Melting furnace	Molten iron preparation				Tapping				
Gasifier	Gasifier preparation & preheating				Charg-ing	Experiment			Finishing job

1-1-5. Schedule

Table 3 indicates an overall schedule of Banko coal gasification experiment.

Table 3 Overall schedule of Banko coal gasification experiment

	Fiscal 1986							Fiscal 1987										
	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Installation of equipment																			
Trial run & commissioning																			
Test (Camp.1)								Camp.I											
Test (Camp.2)									Camp.II										
Analysis of data												(Japan)							
Test (Camp.3)															Camp.III				
Completion of reports																		(Japan)	

It is so scheduled that installation, trial run and commissioning of the experimental equipment and also a cold test (drying, pulverizing and feeding of the actual Banko coal) are to be completed at or before the end of March, 1987. The gasi-

fication experiment is to be conducted in a period of one year, from April, 1987 to March, 1988, and is divided into 3 steps of Campaign I to Campaign III by the purposes of experiment as indicated in Table 4.

During Campaign I, preparatory experiment is conducted to examine and understand the characteristics of the experimental equipment.

During Campaign II, essential experiment is conducted to understand the characteristics of Banko coal being a raw coal for gasification.

During Campaign III, supplementary experiment is conducted in consideration of the results of analyzed data.

Table 4 Experiment by 3-step Campaign

	Main purpose
Trial run and commissioning	1. Non-load test of the equipment 2. Drying, pulverizing and feeding tests using the actual Banko coal
Campaign I	1. Experiments to understand the characteristics of equipment 1) Heat loss of gasifier 2) Examination of gasifier temperature holding condition that can keep the molten iron bath at a constant temperature 3) Study of furnace repair intervals 4) Establishment of an optimum testing condition 2. Number of heats for experiment: About 8 heats
Campaign II	1. Experiment to understand the characteristics of Banko brown coal being a raw material for gasification 1) Influence of moisture and ash 2) Influence of C, H, O and S contents 2. Number of heats for experiment: About 15 heats
Campaign III	Supplementary tests to the results of analyzed data collected during Campaign II

1-2. Measuring and analyzing items

The main measuring and analyzing items needed to understand the characteristics of coal gasification are summarized in Fig. 4 and Tables 5-1 and 5-2.

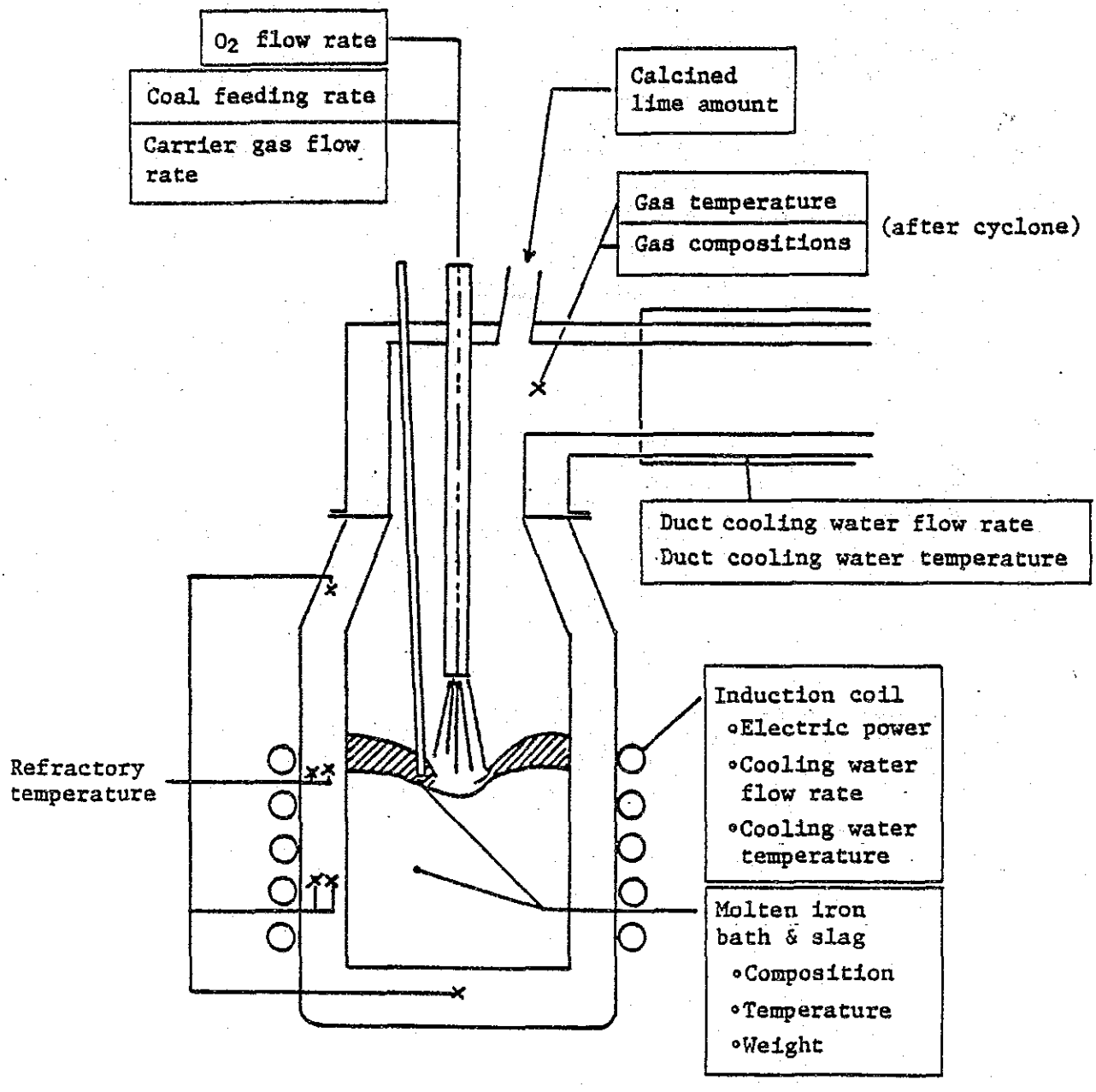


Fig. 4 Main measuring and analyzing items

Table 5-1 Methods for measurement and analyses

	Item	Method	Frequency
Molten iron bath	◦Chemical compositions (C,S,Si,P, etc.)	◦Sampling by spoon Use also a sub-lance for measuring of "C".	◦Before and after experiment Every 10 to 15 min.
	◦Temperature	◦Sub-lance	◦Every 10 to 15 min.
	◦Weight	◦Weighing machine	◦Before and after experiment
Slag	◦Chemical compositions (Cao, SiO_2, FeO, Al_2O_3, T.S, etc.)	◦Adhesion	◦Every 15 to 30 min.
	◦Temperature	◦Sub-lance	◦Every 10 to 15 min.
	◦Weight	◦Weighing machine	◦After experiment
Product gas (at the exit of gasifier)	◦Main compositions (CO, CO_2, H_2, O_2)	◦Continuous analyzer	◦Continuous measurement
	◦Trace compositions (H_2S, COS)	◦Gas chromatography	◦Every 10 min.
	◦Temperature at exit of gasifier	◦PR thermocouple	◦Continuous
Product gas (Before cyclone)	◦Temperature	◦CA thermocouple	◦Continuous
Refractory	◦Furnace bottom (2 positions)	◦CA thermocouple	◦Continuous
	◦Furnace wall (2 positions below iron bath level, 2 positions at slag level, 2 positions above slag level)	◦CA thermocouple	◦Continuous
Dust	◦Quantity	◦Weighing the dust collected by cyclone dust collector	◦After experiment
	◦Components (T.Fe, C, T.S, CaO, SiO_2, etc.)	◦Analyze the above	◦After experiment

Table 5-2 Methods for measurement and analyses

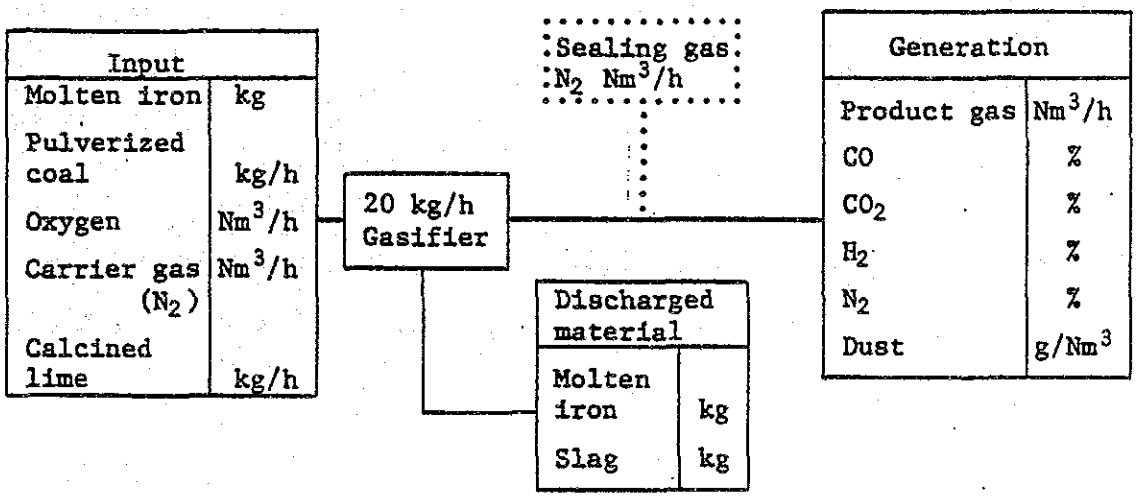
	Item	Method	Frequency
Pulverized coal	∘Feeding rate	∘Load cell	∘Continuous
	∘Chemical compositions (Proximate analysis, Ultimate analysis and ash analysis)	∘Raw coal and pulverized & dried samples	∘Before experiment
	∘Particle size	∘Pulverized & dried sample	∘Before experiment
Supply gases	∘O_2 gas flow rate	∘Orifice flowmeter	∘Continuous
	∘Carrier gas flow rate	∘Orifice flowmeter	∘Continuous
	∘Purge gas N_2 flow rate	∘Orifice flowmeter	∘Continuous
Calcined lime	∘Quantity	∘Weighing machine	∘Every 20 to 30 min.
	∘Chemical composition	∘Spot sampling	∘Arbitrarily
Duct cooling water	∘Temperature	∘CA thermocouple (or alcohol thermometer)	∘Continuous
	∘Flow rate	∘Float-type flowmeter	∘Set before experiment
Induction coil	∘Electric power		∘Continuous
	∘Cooling water flow rate	∘Flowmeter	∘Continuous
	∘Cooling water temperature	∘CA thermocouple	∘Continuous

1-3. Methods of data analysis and evaluation

To evaluate the characteristics of gasification of Banko brown coal by area and by seam, the collected data during the experiments are arranged, analyzed and evaluated as described hereunder;

1-3-1. Mass balance and heat balance

(1) Mass balance



- The amount of product gas is calculated from gas compositions by continuous gas analysis, oxygen amount, etc.
- The amount of product gas is calculated from the actual result of measurements considering inclusion of other gases like carrier gas (N_2) and sealing gas (N_2).
- Molten iron, slag and dust are measured in weight and also analyzed for their main components.

- Amount of product gas, useful components (CO, H_2) in the product gas and heating value are compared by kind of coal.
- As to carbon balance, a rate of contribution of carbon contained in coal to gasification (CO, CO_2) is calculated (gasification efficiency of carbon in coal) and compared by kind of coal.

$$\text{Gasification efficiency of carbon} = \frac{\text{Gasified carbon (CO, } CO_2\text{)} + \text{Carbon transferred to molten iron bath}}{\text{Carbon contained in coal}}$$

- As to S (Sulfur) balance, the amount of sulfur transferred to product gas, slag, dust and molten iron from total contents of sulfur in coal is obtained and used for estimation of desulfurizing effect of slag and dust.

Sulfur contained in coal
- S transferred to product gas
- S transferred to slag
- S transferred to molten iron
- S transferred to dust

However, it should be noted that the analyzed results of mass balance obtained from a small-sized experimental equipment tend to show a distinctive characteristic originated from the experimental scale. Therefore, those data must be corrected by the test results having been

obtained from pilot plants and also by theoretical values when preparing a fundamental information for execution of feasibility study. Especially, carbon and sulfur balances should be regarded merely as reference data.

(2) Heat balance

A heat balance table, as shown below, is made for every experiment and used for evaluation of the results.

	Item	Heating value
Heat input	Reaction heat for gasification	kcal/h
	Electric power consumption	kcal/h
	Sub total	kcal/h
Heat output	Product gas sensible heat	kcal/h
	Slag sensible heat	kcal/h
	Change of metal sensible heat	kcal/h
	Dust sensible heat	kcal/h
	Change of refractory sensible heat	kcal/h
	Heat loss	kcal/h
	(Heat loss in cooling water)	kcal/h
	(Dissipation of electric energy from coil, etc.)	kcal/h
	(Dissipated energy from furnace body)	kcal/h
	Sub total	kcal/h

- A heat loss, out of heat outputs (especially, dissipated energy from furnace body), depends largely on the scale

of equipment and its operating characteristics. A small-sized equipment, in particular, has relatively a large heat loss and must be compensated from outside for maintaining a heat balance. A level of heat loss in a commercial-size equipment will be estimated from the measured results on a pilot plant and practically-operated converters of equivalent size.

- Moisture and ash content in the coal influence greatly on the heat balance. When gasifying the coal having a high percentage of moisture like brown coal, the coal must be dehydrated to a certain level prior to feeding into a gasifier for maintaining the heat balance. Determination of a permissible limit of moisture content (dehydration limit) and evaluation of each kind of coal for ash content will be made using the data to be obtained from this experiment and also an estimated heat loss incurred in commercial-size gasification reactors.

1-3-2. Evaluation of slag

- Fluidity of slag is examined using the results of chemical analysis for determination of operating conditions such as a temperature at which the slag can be smoothly discharged out of a gasifier in operation.

- Prevention of environmental pollution (yellowish water, expansion and degradation of slag) is studied by comparing the various conditions of experimental site with the actual results already obtained from the fundamental experiment.

1-4. Procedures for preparation of basic information required for execution of feasibility study

By utilizing the collected data from this experiment, preparation of basic information required for execution of feasibility study will be made in the way as mentioned below in consideration of the characteristics of small-sized experimental equipment and the test results having been obtained from pilot plants.

1-4-1. Raw material and sub material specifications

1) Coal

- Proximate Analysis (Moisture, Ash, Volatile Matter, Fixed Carbon)
- Ultimate Analysis (C, H, N, O, S, others)
- Ash Chemical Composition (CaO, SiO_2, $A\ell_2O_3$, Fe_2O_3, MgO, etc.)
- Size Distributions
- Hardgrove Grindability Index
- Heating Value (LHV, HHV)

2) Scrap Iron

- Chemical Composition (Metallic Fe, Fe_2O_3, others)
- Size Distribution

3) Calcined Lime

- Chemical Composition (CaO, CO_2, SiO_2)
- Size Distribution

1-4-2. Gasification Agents

1) Oxygen

- Pressure
- Temperature
- Purity

2) Carrier Gas

- Kinds
- Pressure
- Temperature

3) Process Steam

- Pressure
- Temperature

1-4-3. Utilities

1) Electric Power

- Voltage
- Frequency

2) Industrial Water

- Pressure
- Temperature
- pH

3) Boiler Feed Water

- Pressure
- Temperature
- $CaCO_3$ Content
- pH

4) Compressed Air

- Pressure
- Temperature

5) Nitrogen

- Pressure
- Temperature

1-4-4. Product and waste material specifications

1) Product Gas (after cleaning)

- Production Rate
- Chemical Composition (CO, CO_2, H_2, N_2, T.S, etc.)
- Dust Content
- Temperature
- Pressure
- Heating Value (LHV, HHV)

2) Steam

- Production Rate
- Pressure
- Temperature

3) Slag

- Production Rate
- Chemical Composition (CaO, SiO_2, S, etc.)
- Temperature

4) Dust

- Production Rate
- Chemical Composition
- Size Distribution
- Properties

5) Waste Water

- Quantity
- Contents (COD, SS, DEA, pH, etc.)

2. Process Design

2-1. Basic design data

2-1-1. System of measurement

(1) Metric system shall be generally used for the plant as follows;

Measurement	Unit
Length	m, cm, mm and μm
Area	m^2 and cm^2
Volume	m^3, cm^3 and ℓ

Mass		Ton, kg and g
Flow rate	Liquid	m^3/hr
	Steam	kg/hr
	Gas	Nm^3/hr
	Solid	kg/hr
Pressure		$kg/cm^2g.$, $kg/cm^2abs.$ and mm Aq.
Temperature		°C
Heat energy		kcal
Voltage		V
Electrical current		A
Electrical resistance		Ω
Electrical power		kVA
Frequency		Hz

(2) Pipe diameters, nozzle size and valve size shall be specified in "A" system of JIS.

2-1-2. Applied codes and standards

All construction shall conform to or refer to the following Japanese codes and standards;

Building Standard Act

Design Standard for Steel Structures

Japan Petroleum Institute Standards

Design Specifications for Pressure Gas Cylinders

Regulations for Security of Gas Cylinders

Regulations for Security of Liquefied Petroleum Gas

Regulations for Security of Other Pressured Gas

Japanese Industrial Standard

The Japanese Electrotechnical Committee

The Japan Electrical Manufacturer's Association

Technical Standard for Electric Equipments

The other codes and standards considered necessary by the engineers.

2-1-3. Site information

(1) Location

The plant will be constructed in the pilot plant Building Stage 1 in PUSPIPTEK, Serpong, Jakarta, the Republic of Indonesia.

(2) Climate data (Indonesian data)

1) Ambient temperature

Daily maximum temperature	33°C
Yearly maximum temperature	31.5°C
Daily minimum temperature	21°C
Yearly minimum temperature	22.5°C
Daily normal/average temperature	24°C (at 07:00)
Daily normal/average temperature	30°C (at 13:00)

Daily normal/average temperature	26.5°C (at 18:00)

2) Relative humidity

Daily maximum humidity	96% (24°C at 07:00)
Daily minimum humidity	47% (32°C at 13:00)
Daily normal humidity	92% (at 07:00)
Daily normal humidity	62% (at 13:00)
Daily normal humidity	79% (at 18:00)

(3) Seismic design

Fe = kw

where, Fe: horizontal shear force

k : seismic coefficient

w : weight of the components

The "k" value is 0.2, as all the equipments are smaller than 16 m and their specific period are shorter than 0.4 second.

2-1-4. Raw materials

(1) Coal

Moisture	max. 35%
Consumption rate	about 60 kg/heat

(2) Calcined lime

Component	CaO 90% over
Grain size	30 mm under

Consumption rate	about 0.6 kg/hr (1.2 kg/heat)
(3) Scrapped steel	
Size	about 110ø for starter block
Consumption rate	about 300 kg/heat

2-1-5. Wastes

(1) Cooling water (outlet)	
Temperature	inlet temperature + max. 10°C
Pressure	This will be informed at detailed engineering stage
Flow rate	max. 30 t/hr
(2) Dust	
Component	Total Fe 40∿50%, C 10∿25%
Flow rate	about 2 kg/hr (4 kg/heat)
(3) Slag	
Basicity	CaO/SiO_2 = about 1.5
Flow rate	about 1.6 kg/hr (3.2 kg/heat)
(4) Produced gas	
Flow rate	about 40 Nm^3/hr

2-1-6. Utilities

(1) Oxygen	as cylinders
Purity	99% over

	Temperature	ambient temperature
	Pressure	about 20 kg/cm^2g
	Flow rate	about 12 Nm^3/hr
(2)	Nitrogen	as cylinders
	Purity	99% over
	Temperature	ambient temperature
	Pressure	about 6 kg/cm^2g
	Flow rate	about 6 Nm^3/hr
(3)	Electrical power	
	Frequency	50 Hz 3ø
	Voltage	380V ± 10%
	Electrical power	max. 350 kVA
(4)	Compressed air	
	Temperature	ambient temperature
	Pressure	min. 6 kg/cm^2g
	Flow rate	max. 60 Nm^3/hr
(5)	Air for instrumentation	
	Temperature	ambient temperature
	Dew point	0°C
	Pressure	min. 6 kg/cm^2g
	Flow rate	max. 10 Nm^3/hr

(6) Cooling water

1) Water analysis (Indonesian data)

Color	20 Pt.Co
Turbidity	-
Odor	No
Taste	No
PH	6.5
Solid content	4.1 ppm
Conductivity	-
Organic content	4.4 ppm $KMnO_4$
Free CO_2 content	No
Alkalinity	
Phenol phtalein	0 ppm $CaCO_3$
Methyl orange	40.0 ppm $CaCO_3$
Carbonate	0 ppm $CaCO_3$
Hydroxide	0 ppm $CaCO_3$
Bicarbonate	40.0 ppm $CaCO_3$
Hardness	
Calcium	4.28 ppm Ca^{++}
Magnesium	1.72 ppm Mg^{++}
Iron content	negative
Manganese content	negative
Sulfate content	negative
Phosphate content	negative

Ammonium content	negative
Nitrate content	negative
Silica content	-
Chloride content	7.10 ppm Cl^-
Residual chlorine	0.30 Cl_2

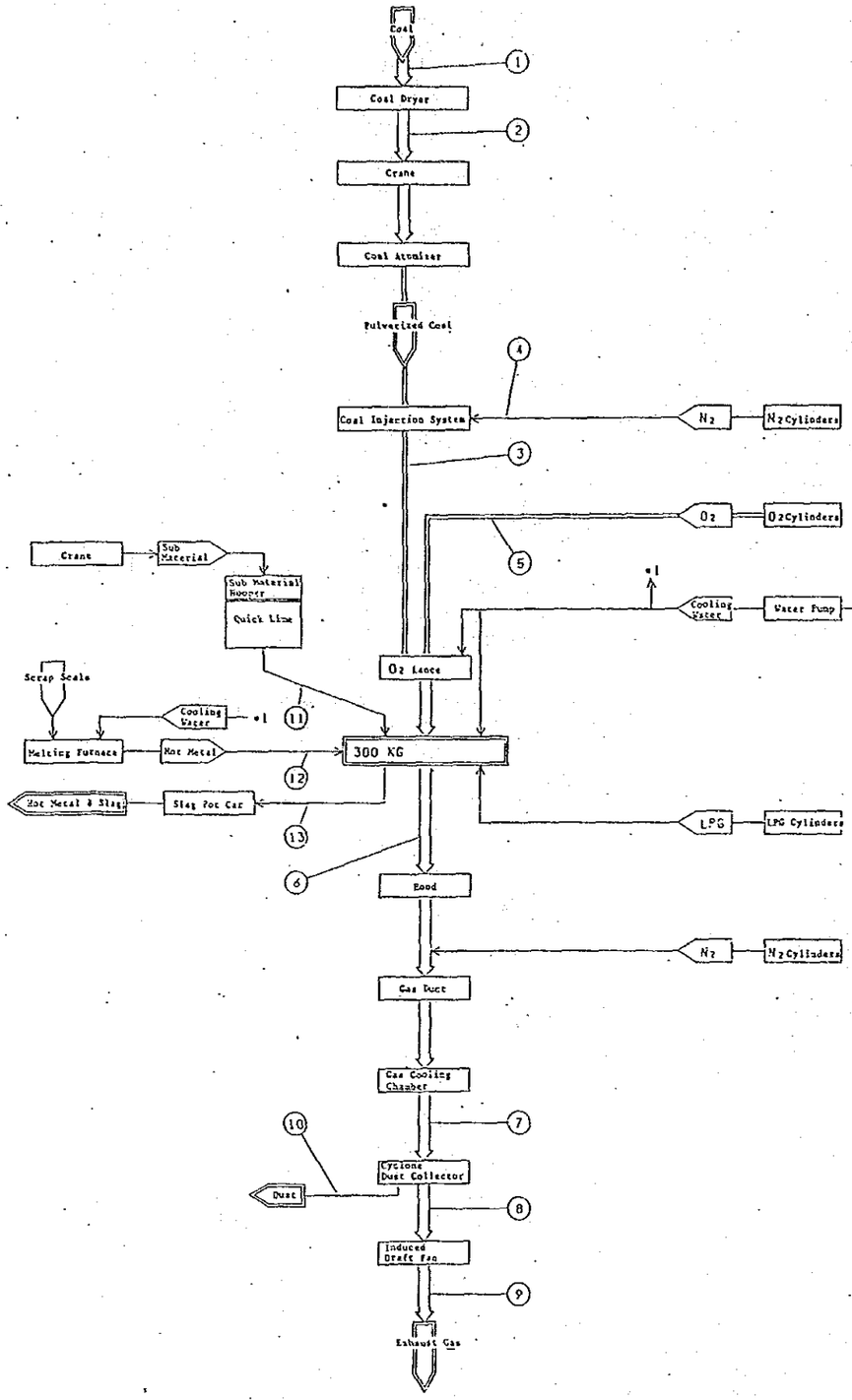
2) Temperature (Indonesian data) 25∿27°C

3) Pressure min. 10 kg/cm^2g

4) Flow rate max. 30 t/hr

(7) Liquefied petroleum gas as cylinders

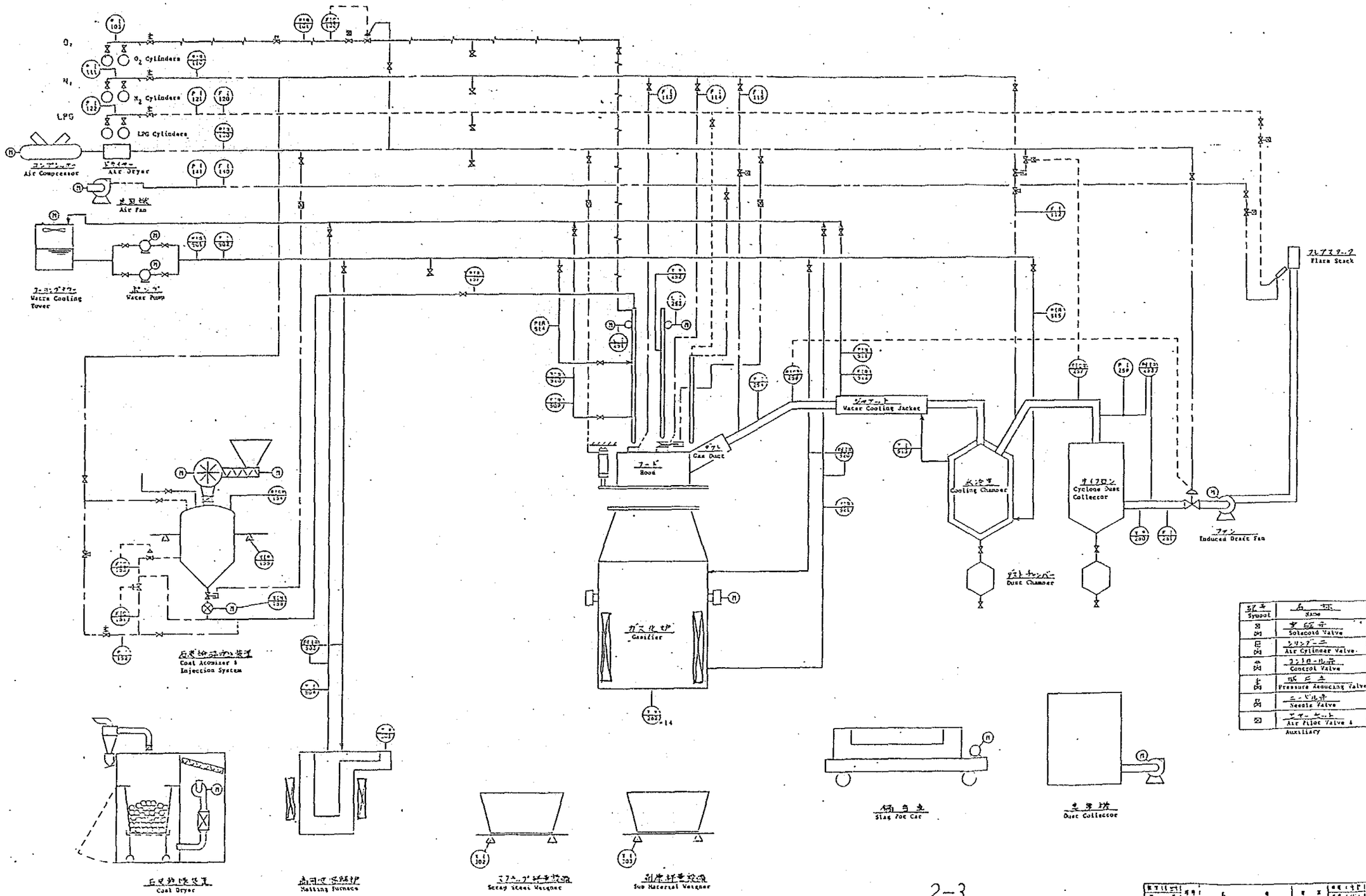
Calorific value	over 24,000 $kcal/Nm^3$
Temperature	ambient temperature
Pressure	about 2 kg/cm^2g
Flow rate	max. 3 Nm^3/hr



Item		FRG. NO. / Materials	Unit	(1) Coal	(2) Coal	(3) Coal	(4) Nitrogen	(5) Oxygen	(6) Produced Gas	(7) Produced Gas	(8) Produced Gas	(9) Produced Gas	(10) Produced Dust	(11) Quick Lime	(12) Hot Metal	(13) Slag	Remarks
Molten Iron Process	Solidity	Flow Rate	Kg/H	80 Kg/ch	40 Kg/ch	20							2	0.8	300 Kg/heat	1.6	
		Temperature	°C	Ambient Temp	100	100							150	Ambient Temp	1500°1600	1600°1650	
		Water Content	%	35	5	5							—	—	—	—	
		Grain Size	—	-25 mm	-25 mm	-74μm >70 %							-63 μm 100%	-30 mm	—	—	
	Gaseity	Flow Rate	Nm^3/H				3	12	40	40	40	40					
		Temperature	°C				Ambient Temp	Ambient Temp	1300°1500	150	150	150					
		Pressure	Kg/cm² G				4~4.5 k	10~12 K	±100 M	-300~-100M	-500~-300M	100~300 M					kg/cm² G M mmAq
		Dust Content	g/Nm^3				—	—	50	50	0.05	0.05					

REVISION		
NO	DATE	DESCRIPTION

DATE Feb 20 '75	MANAGER OF DEP.	BANKO COAL GASIFICATION TEST PLANT P. F. D.
SCALE	MANAGER	WORK NO
	CHIEF	DRAWING NO
	CHECKED BY	
	DRAWN BY	



Symbol	Name
S	Solecord Valve
C	Air Cylinder Valve
	Control Valve
	Pressure Reducing Valve
N	Needle Valve
P	Air Pilot Valve & Auxiliary

2-3

BANKO COAL GASIFICATION TEST PLANT

P.I.D

アンモニア バンコ炉 ガス化 試験装置 P.I.D 計画図

P3066

2-4. Mechanical equipment list

2-4-1. Coal preparation system

(1) Coal dryer — 1 set

1)	Type	Multi tray type
2)	Heater	Electric heater
3)	Raw coal/Drying time	117 kg/1.5 hr
4)	Raw coal moisture/ Dry coal moisture	35%/5%
5)	Electrical accessories	Motor for fan and Electric heater

(2) Coal atomizer — 1 set

1)	Type	Special Hammer Mill
2)	Coal/Atomizing time	80 kg/1.5 hr
3)	Inlet grain size/ Outlet grain size	- 25 mm/ - 74 μm over 70%
4)	Electrical accessories	Motor for screw feeder and atomizer

(3) Coal injection system — 1 set

1)	Type	Rotary feeder feeding with Rock hopper
2)	Flow rate x time	40 kg/hr x 2 hrs
3)	Electrical accessories	Motor for rotary feeder

2-4-2. Gasifier system

(1) Gasifier vessel		1 set
1) Type	Molten iron process gasifier	
2) Inner size	400ø x 950 mm H	
3) Molten iron	300 kg	
4) Refractories	Electrical fused MgO-Cr bricks and MgO stump refractories	
5) Electrical accessories	Induction heating coil	
(2) Vessel tilter		1 set
1) Electrical accessories	Gear motor	
(3) Structure, deck and stairs		1 set
(4) Calcined lime feeder		
1) Type	Double seal valves with rock hopper	
2) Feed rate	300 g/one time/0.5 hr	
(5) Melting furnace		1 set
1) Type	Crucible shaped middle frequency induction melting furnace	
2) Melting rate/ Melting time	300 kg/2 hrs	
3) Refractories	Mg-O stump refractories	
4) Electrical accessories	Induction heating coil	

(6) Slag pan and car — 1 set

1) Pan	Steel made with castable refractories
2) Car	Driven with gear motor

(7) Lance and driving unit — 1 set

1) Lance	water cooled lance
2) Driving Unit	Gear motor drive

(8) Sub-lance and driving unit — 1 set

1) Sub-lance	non water cooled lance
2) Driving Unit	Gear motor drive

2-4-3. Gas treatment system

(1) Hood and duct — 1 set

1) Hood	Vessel mouth seal type with rise and fall mechanics
2) Duct	Duct with water cooled jacket

(2) Cooling chamber — 1 set

Chamber with water cooled jacket

(3) Dust collector — 1 set

1) Type	Linden type cyclone
2) Gas flow rate	80 Nm^3/h
3) Outlet dust content	- 50 mmg/Nm^3 (not guaranteed)

(4) Induced draft fan 1 set

1) Flow rate x pressure 80 Nm^3/h x 600 mm Aq.

(5) Flare stack 1 set

1) Ignition torch LPG by compressed air

2-4-4. Dust collection for gasifier mouth and others

(1) Hood, duct and dampers 1 set

(2) Bag filter 1 set

1) Flow rate 1000 m^3/hr

2) Outlet dust content 50 mmg/Nm^3 under

3) Electrical accessories Motor for fan

2-4-5. Utility equipments

(1) Oxygen line 1 set

Initial cylinder set, pressure reducing valve and pipings necessary for pilot plant

(2) Nitrogen line 1 set

Initial cylinder set, pressure reducing valve and pipings necessary for pilot plant

(3) Compressed air line 1 set

All pipings in battery limit which boundary will be prescribed on another print

(4) Cooling water line 1 set

All pipings in battery limit which boundary will be prescribed on another print

(5) Liquefied petroleum gas 1 set

Initial cylinder set, pressure reducing valve and pipings necessary for pilot plant

(6) Air line for burner 1 set

1) Fan 90 m^3/hr

2) Pipings and valves

2-4-6. Spare parts 1 set

2-4-7. Expendables 1 set

2-4-8. Portable fire extinguisher 1 set

2-5. Electrical equipment list

2-5-1. Induction gasification furnace and induction melting furnace

(1)	Transformer		1
1)	Oil-filled, self cooling, indoor use		
2)	Capacity	260 kVA	
3)	Input	3 phase, 380V, 50 Hz	
4)	Output	3 phase, 480V, 50 Hz	
(2)	Thyristor inverter		1
1)	Indoor use, self-supporting		
2)	Input	3 phase, 480V, 50 Hz	
3)	Output	single phase, 1000V, 300 Hz	
4)	Capacity	200 kW (Maximum continuous rating)	
(3)	Operating console		1
1)	Desk type		
2)	Devices	Display lamps, push-button switches, voltage meter, ampere meter, command switches	

2-5-2. Auxiliary AC equipment

(1)	Distributing panel	
1)	for 380V (indoor use, self-supporting)	1
2)	for 220V (indoor use, wall-mounting)	1
3)	for 110V (indoor use, wall-mounting)	1

(2) Transformer

1) 50 kVA, 380V/220V, 3 phase, 50 Hz 1

2) 10 kVA, 380V/110V, single phase, 50 Hz 1

(3) Control panel

1) Indoor use, self-supporting

2) Controlled equipment

i) Induction motors 12

ii) Electric heater 1

iii) Solenoid valves 4

3) Operation

Manual operation

(4) Operation console (installed in the pulpit) 1

1) Desk type

2) Controlled equipment

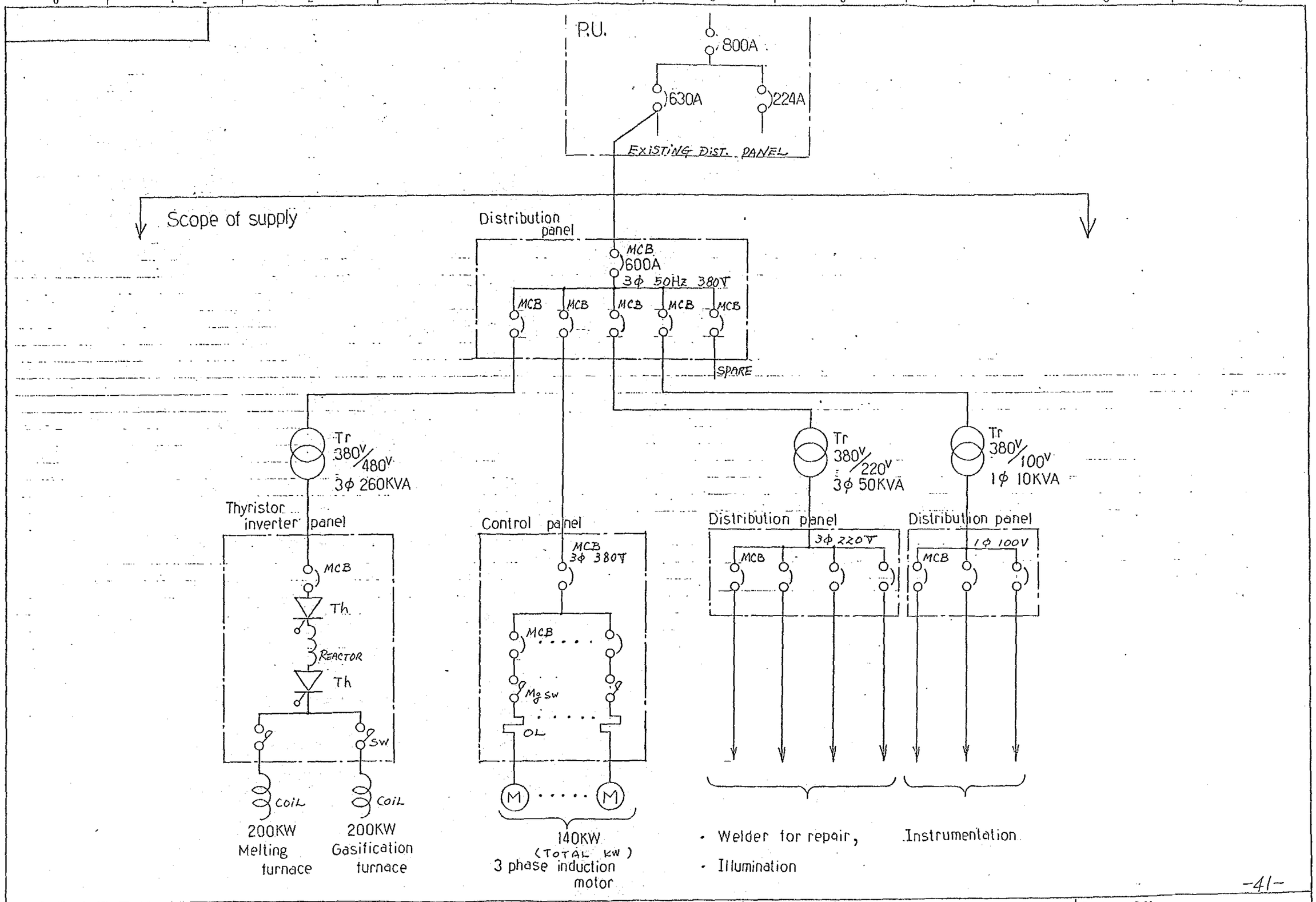
Rotary feeder, gasification furnace, induced draft fan

(5) Operation boxes (installed around machines) 1

1) Indoor use, wall-mount type

2) Controlled equipment

All machines except for item (4) listed above



APPROVED BY	TITLE	DRAWING No.
CHECKED BY	2-6 SINGLE LINE DIAGRAM	
DRAWN BY Komeda		

2-7. Instrument list

2-7-1. Instrument panel (center) — 1 side

(1) Self-standing indoor type

(2) Panel flash
- Controller
- Indicator
- Recorder
- Annunciator
- Push button switch

(3) Panel rack
- Distributor
- Auxiliary relay
- Converter

2-7-2. O_2 line

(1)	PIA-101	Pressure transmitter & indicator with alarm	1 set
(2)	FIC-102	Diff. pressure transmitter, controller & control valve	1 set
(3)	PI-103	Local type pressure indicator for bombe	1 set

2-7-3. N_2 line

(1)	PIA-110	Pressure transmitter & indicator with alarm	1 set
(2)	PI-111	Local type pressure indicator for bombe	1 set
(3)	FI-112	Diff. pressure transmitter & indicator for cyclone	1 set

(4)	FI-113	Local type flow meter for main lance food	1 set
(5)	FI-114	Local type flow meter for sub-lance food	1 set
(6)	FI-115	Local type flow meter for duct	1 set

2-7-4. LPG line

(1)	FI-120	Local type flow meter	1 set
(2)	PI-121	Local type pressure indicator for supply pressure	1 set
(3)	PI-122	Local type pressure indicator for bombe	1 set

2-7-5. Air line

(1)	PIA-130	Pressure transmitter & indicator with alarm for high press. air	1 set
(2)	FI-140	Local type flow meter for burner	1 set
(3)	PI-141	Local type pressure indicator for burner	1 set

2-7-6. PC

(1)	FIC-151	Diff. pressure transmitter controller & control valve for PC carrier N_2	1 set
(2)	PI-152	Local type pressure indicator for PC carrier N_2	1 set
(3)	FIC-153	Diff. pressure transmitter, controller & control valve for PC airration	1 set
(4)	PIAR-154	Pressure transmitter, indicator with alarm & recorder for feed hopper	1 set
(5)	XIR-155	Weight detector & indicating recorder for PC feed hopper	1 set
(6)	PIA-157	Pressure transmitter & indicator with alarm for PC injection	1 set

(7) XIA-158 Indicator with alarm for PC rotary feeder — 1 set

2-7-7. Gasifier

(1) LI-251 Indicator for main lance position — 1 set

(2) TR-252 Thermocouple & recorder for sub-lance metal — 1 set

(3) LI-253 Indicator for sub-lance position — 1 set

(4) TI-254 Thermocouple & indicator for gasifier out — 1 set

(5) PICR-256 Pressure transmitter, controller, recorder & control valve for gasifier — 1 set

(6) TR-262 Thermocouple & recorder for gasifier refractory — 1 set

(7) TICA-257 Thermocouple, controller & control valve for cyclone — 1 set

(8) PIA-258 Pressure transmitter & indicator with alarm for cyclone — 1 set

(9) PI-259 Local type pressure indicator for cyclone — 1 set

(10) XR-260 Gas analyzer — 1 set

1) CO/CO_2 (Infrared analyzer)

2) H_2 (Thermal conductivity analyzer)

3) O_2 (Magnetic oxygen analyzer)

4) N_2 (Gas chro.)

5) COS/H_2S (Gas chro.)

(11) FI-261 Diff. pressure transmitter & indicator for gasifier — 1 set

2-7-8. Utility

(1)	TR-301	Thermocouple & recorder for melting plant	1 set
(2)	XI-302	Local type indicator for scrap weight	1 set
(3)	XI-303	Local type indicator for sub-material weight	1 set
(4)	-	Instrument air & drier	1 set

2-7-9. Water line

(1)	PIA-501	Pressure transmitter & indicator with alarm for supply water	1 set
(2)	TI-502	Resistance bulb & indicator for supply water	1 set
(3)	FIA-503	Diff. pressure transmitter & indicator with alarm for melting diff. water	1 set
(4)	TI-504	Resistance bulb & indicator for melting water	1 set
(5)	FIA-509	Diff. pressure transmitter & indicator with alarm for main lance water	1 set
(6)	TIA-510	Resistance bulb & indicator with alarm for main lance water	1 set
(7)	TIA-511	Resistance bulb & indicator with alarm for gas jacket water	1 set
(8)	FIA-512	Diff. pressure transmitter & indicator with alarm for gas jacket water	1 set
(9)	TI-513	Local type temp. indicator for gas cooler	1 set
(10)	PI-514	Local type press. indicator for main lance water	1 set
(11)	PI-515	Local type press. indicator for gas cooler	1 set

(12) FIA-520 Diff. press. transmitter & indicator with alarm for gasifier water 1 set

(13) TIA-521 Resistance bulb & indicator with alarm for gasifier 1 set

2-7-10. Off-line analyzer

(1) Slag analyzer 1 set

1) Analyzer

CaO, SiO_2, Al_2O_3, MgO, Fe_2O_3

2) Accessory

(2) Melting plant analyzer 1 set

1) Analyzer

C or (C, S)

(3) Off-line common parts 1 set

1) Desiccator

2) Magnetic bowl

3) Spoon, scale, saucer

4) Sieve

5) Tongs

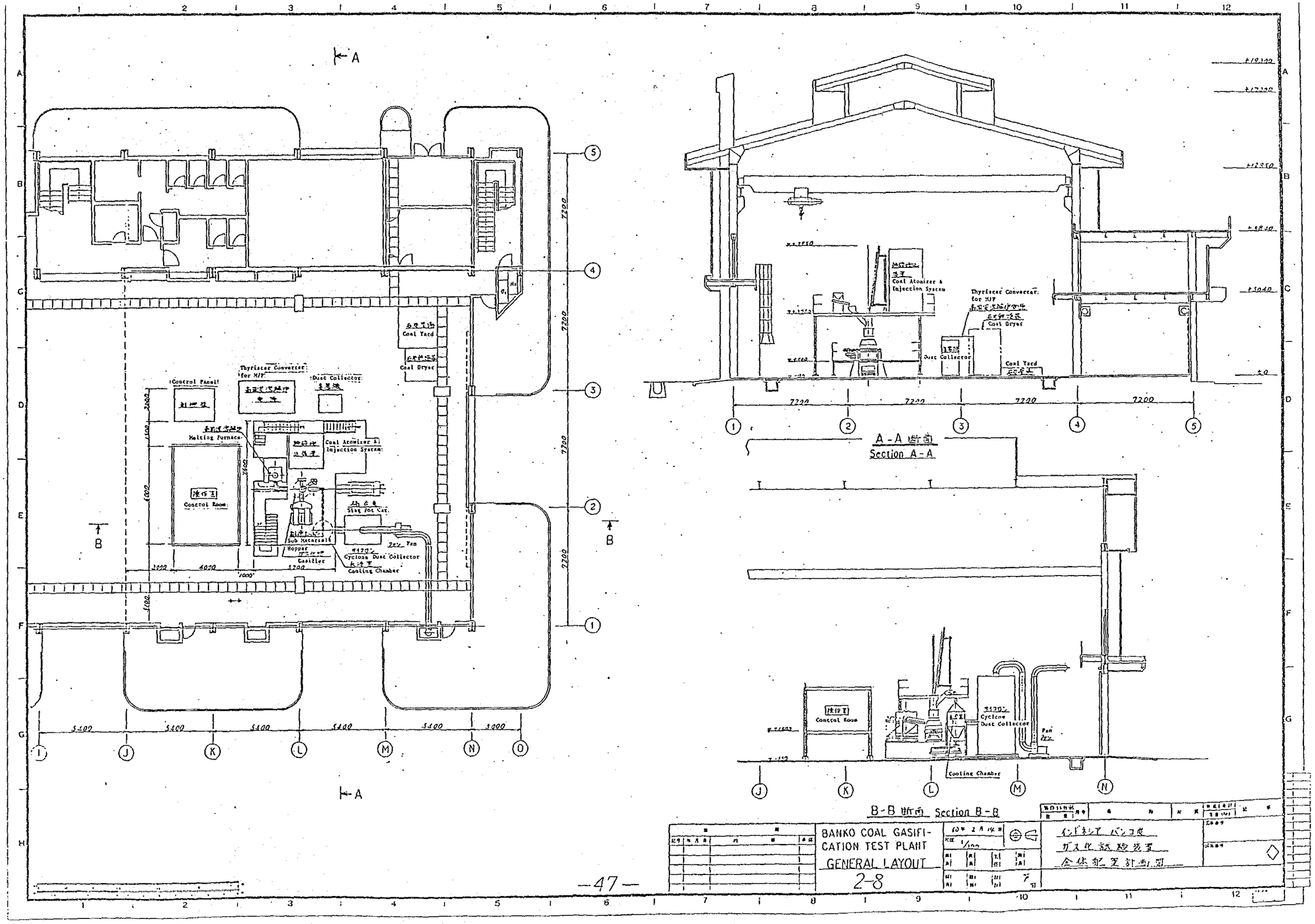
6) Sample keeping case

7) Precision spring balance

8) Sample bottle

2-7-11. Spare parts

2-7-12. Expendables

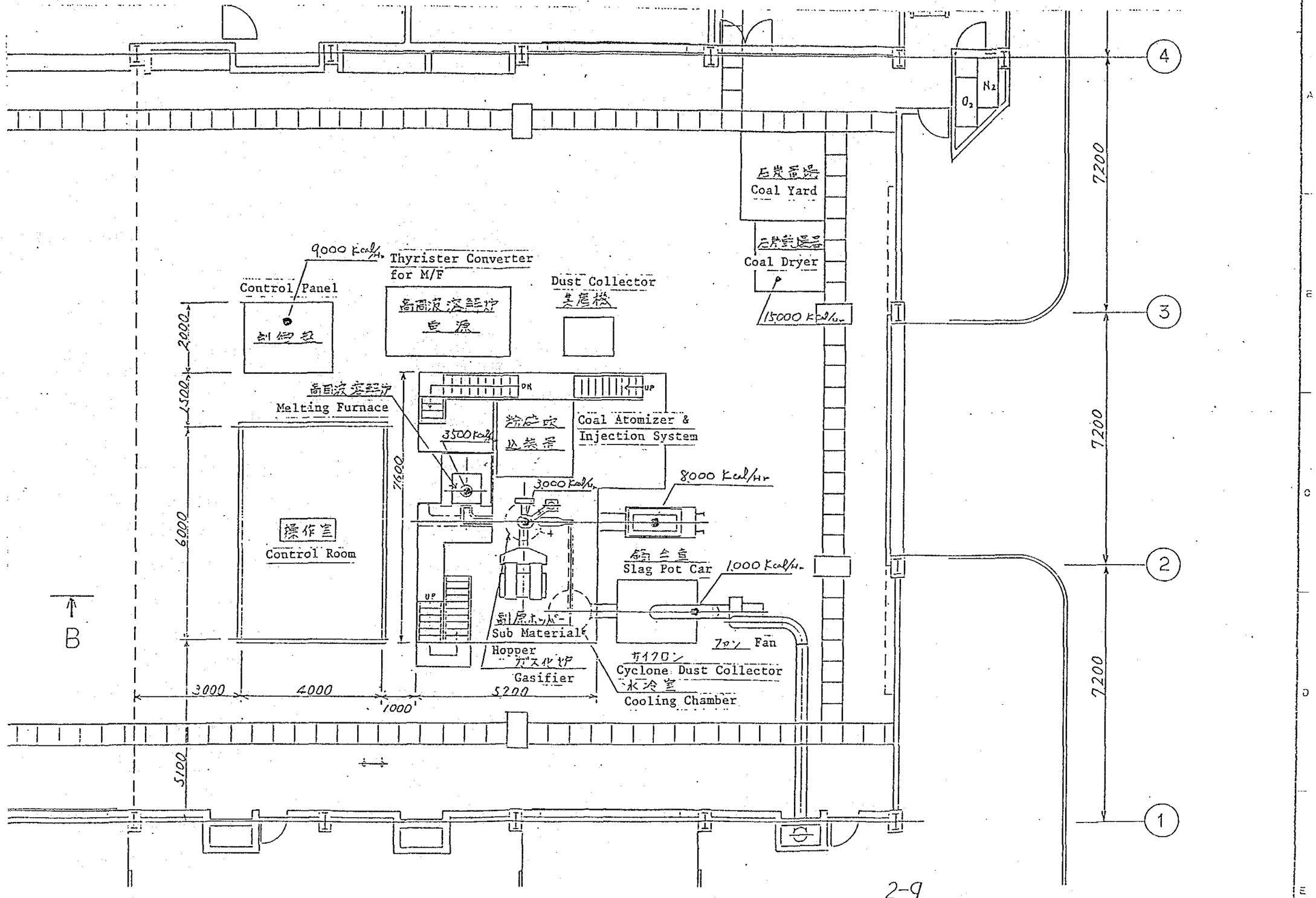


BANKO COAL GASIFICATION TEST PLANT

GENERAL LAYOUT

2-8

インドネシア バンコ炭 ガス化試験発電 全体配置計画図



2-9

DATE	MANAGER OF DEPT.	BANKO COAL GASIFICATION TEST PLANT
SCALE	MANAGER	HEAT GENERATIVE EQUIPMENTS
	CHIEF	
	CHECK	
	DRAWN	

2-10. Descriptions of coal gasification process

The coal gasification equipment is composed of a coal drying and pulverizing unit, a coal blowing unit, a molten iron production unit, a gasifier and a product gas dedusting unit.

(1) Coal drying and pulverizing unit

Raw coal is dried in a drying unit until its moisture content is reduced down to a prescribed level and pulverized into a particle size of about 74 μm in a pulverizing unit.

(2) Coal blowing unit

The pulverized coal is gathered in a rock hopper, pressurized, fed out in a predetermined amount by a rotary feeder and then transported pneumatically to a coal blowing lance by means of a carrier gas (N_2).

(3) Molten iron production unit

The molten iron required for operation of gasifier is produced in a medium-frequency induction furnace from iron scraps. The molten iron produced in this furnace is carried to the gasifier after being adjusted for its chemical composition (mainly carbon content) and for temperature.

(4) The gasifier is lined with refractory bricks on internal walls and equipped with a lance through which both coal and oxygen are blown and an induction coil to maintain the

temperature of molten iron constant. The gasifier stores molten iron and instantaneously gasifies the coal blown at a high speed with oxygen on to the surface of molten iron bath. Through a sub-lance, temperature and carbon content of the molten iron bath in the gasifier is measured.

(5) Product gas filtration unit

The gas produced in the gasifier is recovered through a hood directly connected to the gasifier and a joining duct. The recovered product gas is cooled, dedusted, burnt and released.

3. Job Assignment Program with Counterpart

3-1. Materials & sub-materials

3-1-1. Coal

(1) Properties	various coals
(2) Size	-50 mm
(3) Total consumption	6 tons

3-1-2. Scrap

(1) Chemical compositions	Fe 93∿96%
	C 3∿3.5%
	Si 1∿2%
(2) Size	about 110ø
(3) Total consumption	15 tons

3-1-3. Calcined lime

(1) Chemical compositions	CaO over 90%
	CO_2 4∿8%
(2) Size	-30 mm
(3) Total consumption	150 kgs

3-2. Utilities

3-2-1. Oxygen

(1) Supply condition	cylinders (Inner volume 46.7ℓ)
	(Pressure 150 kg/cm^2g)
(2) Supply rate	10 cylinders/heat

3-2-2. Nitrogen

(1) Supply condition	Same as oxygen
(2) Supply rate	8 cylinders/heat

3-2-3. Electrical power

(1) Frequency	50 Hz 3ø
(2) Voltage	380V ± 10%
(3) Electrical power	max. 350 kVA

3-2-4. Compressed air

(1) Supply condition	Flange contact Contact point and size will be prescribed on another print.
(2) Supply temperature	Ambient temperature
(3) Supply pressure	min. 6 kg/cm^2g
(4) Supply rate	max. 60 Nm^3/h

3-2-5. Cooling water (Supply water/waste water)

(1) Supply condition	Flange contact Contact point and size will be prescribed on another print.
(2) Water analysis	Ref. 2-1-6 (1) 1) (Indonesian Data) There will be no quality change between supply water and waste water.

(3) Supply temperature/waste temperature 25∿27°C/35∿37°C

(4) Supply pressure/waste pressure min. 10 kg/cm^{2}g/This will be decided at detailed engineering stage.

(5) Supply rate/waste rate max. 30 t/h / max. 30 t/h

3-2-6. Liquefied petroleum gas

(1) Supply condition Same as oxygen

(2) Supply rate 5 cylinders/heat

3-3. Consumables for chemical analysis

Standard gas

Reagent

Others (consumables for gas chromatography, etc.)

3-4. Safety and first aid equipment

Stretchers

3-5. Maintenance tools and materials

- Steel materials for general maintenance (Steel sheets, pipe)
- Valves for general maintenance
- Piping materials for general maintenance (Flanges, Unions, Elbows, etc.)
- Bolts and nuts for general maintenance
- Paint, brushes, brooms

3-6. Transfer and storage containers

Drums, Cans containable 4.765 U.S. gallon, Desiccator, Sample sorting cases, Cart

3-7. Administration requisites

Sink, Hot water facility, Thermal pots, Kitchen cabinet, Cups and spoons, etc., Waste baskets, Electric washing machines, Electric refrigerators, VTR, Office desks and chairs, Conference table and chairs, Blackboard, etc.