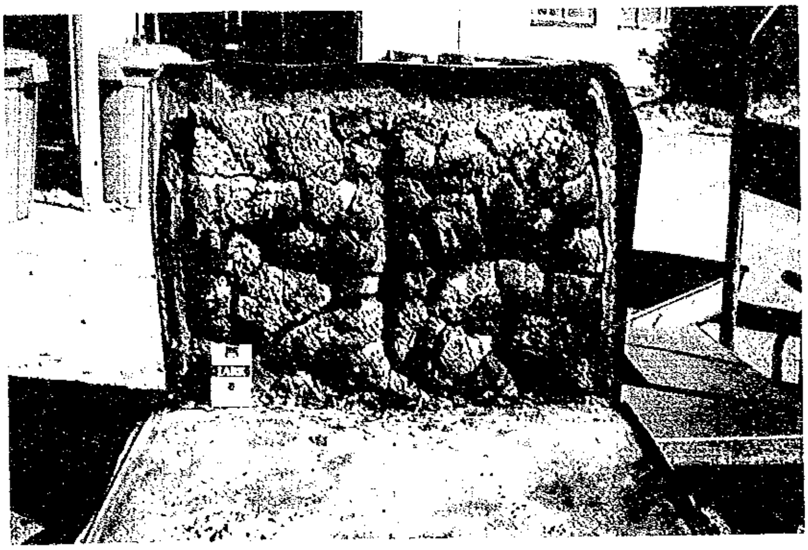
1) Heated surface of SCO container



2) Cokes produces

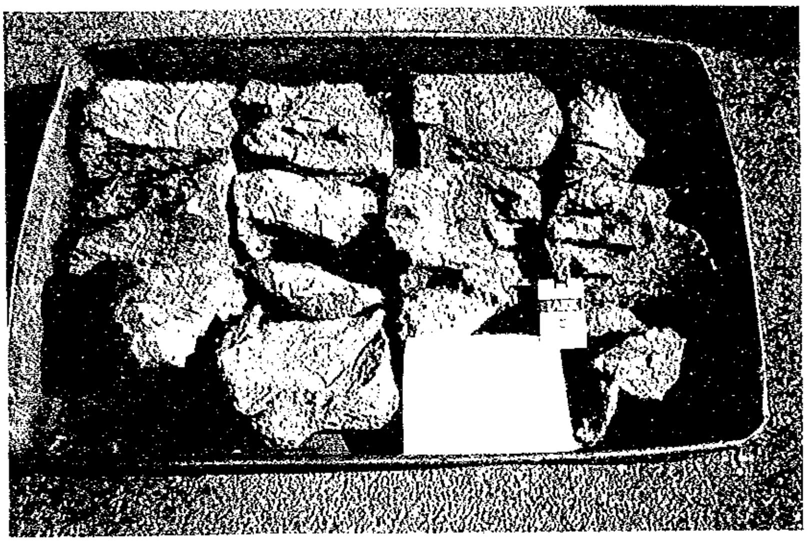
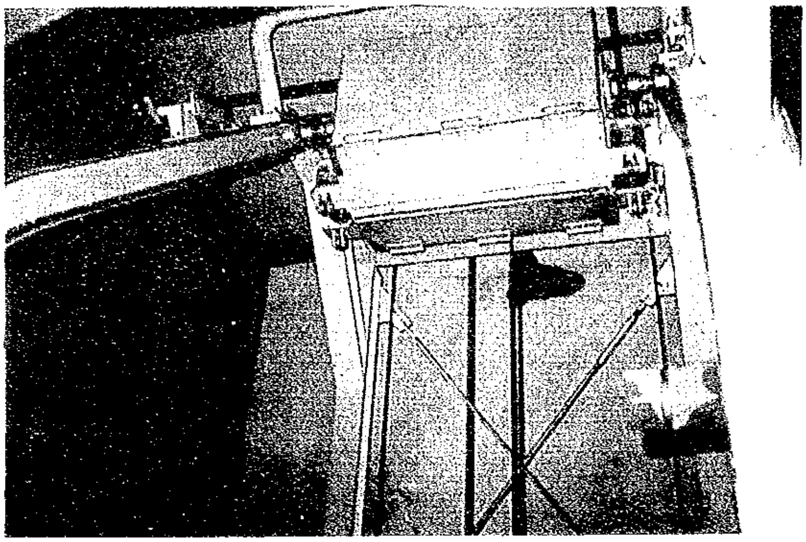


Photo 5-10 COKES CARBONIZED IN THE SCO

1) The bucket lifted 2m high



2) Cokes dropped from 2m above

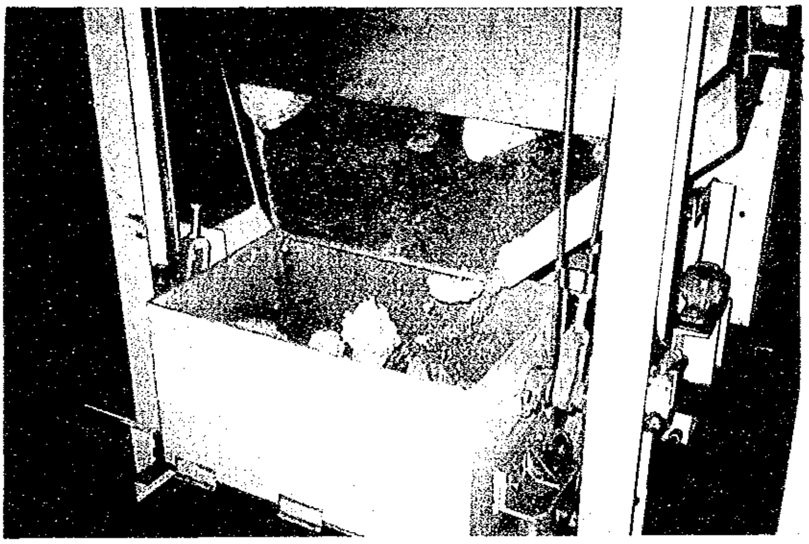


Photo 5-11 ADJUSTMENT OF COKES GRAIN SIZE BY USING SHUTTER TESTING MACHINE

(3) Coke quality

Cokes discharged from the SCO are in large lumps, as shown in Photo 5–10–2. This is because, unlike coke in the actual coke oven, cokes made in the SCO are subject to very small load while coking or shock when pushed from the coke oven. To obtain grain sizes similar to cokes made in an actual oven, SCO cokes are dropped three times by using a shutter testing machine shown in Photo 5–11.

Property analysis of cokes after grain size adjustment was conducted in accordance with the test flow in Fig.5–17.

The results of the property analysis are shown in Table 5–47 (Grain Size Distribution), Table 5–48 (Proximate Analysis, Total Sulfur, Apparent Relative Density, True Relative Density, and Porosity), Table 5–49 (Anisotropic Texture Analysis), Table 5–50 (Reactivity, Coke Strength after Reaction, and Coke Drum Strength).

The result indicates that the coke is low in ash content 8.90 (%, d.) and in total sulfur 0.64 (%, d.), thus considered to be high quality blast–furnace coke. Porosity is relatively high at 52%, but it seems to come from small load during the coking process, thus does not present a problem.

Anisotropic texture analysis of cokes is dominated by fine mosaic, coarse mosaic, and fibrous, which together account for 73.4 (%, vol.), considered to be coke with high resistance to CO_2 reaction.

Coke drum strength and coke strength after reaction are DI_{150-15}81.2, TI_{25}59.7, and CSR 50.5. as shown in Table 5–50. These coke strengths are obtained on the SCO basis and need to be converted to those made in the actual oven. That was done by using the following equations (a), (b) and (c). The result is shown in Table 5–51.

DI_{150-15} (actual oven) = 0.884 X DI_{150-15}(SCO) + 11.9 (a)

TI_{25} (actual oven) = 0.728 X TI_{25}(SCO) + 18.8 (b)

CSR (actual oven) = 0.753 X CSR(SCO) + 21.4 (c)

Table 5-47 GRAIN SIZE DISTRIBUTION OF COKE FROM COAL BLEND

Sample No.	Grain size distribution (mm, %)					
	125-100	100-75	75-50	50-25	25-15	-15
SCO test-1	2.7	29.6	39.9	24.2	1.6	2.0

Table 5-48 PROXIMATE ANALYSIS, TOTAL SULFUR AND POROSITY OF COKE FROM COAL BLEND

Sample No.	Proximate analysis (%, d)			Total sulfur (%, d)	Apparent specific gravity (-)	True specific gravity (-)	Porosity (%)
	Ash	Volatile matter	Fixed carbon				
SCO test-1	8.90	0.77	90.33	0.64	0.96	2.00	52

Table 5-49 ANISOTROPIC TEXTURE ANALYSIS OF COKE FROM COAL BLEND

Sample No.	Isotropic	Fine Mosaic	Coarse Mosaic	Fibrous	Leaflet	Inert
SCO test-1	3.7	23.6	22.7	27.1	1.5	21.4

Table 5-50 REACTIVITY AND COKE STRENGTH OF COKE FROM COAL BLEND

Sample No.	Reactivity (%)	Coke strength after reaction		Coke strength			
				Drum indx		Tumbler indx	
		CRI	CSR	DI_{30-15}	DI_{150-50}	TI_{25}	TI_6
SCO test-1	17	31.3	50.5	94.3	81.2	59.7	65.7

Table 5-51 COKE STRENGTH CONVENTED UNDER ACTUAL OVEN

Sample No.	CSR	DI_{150-50}	TI_{25}
SCO test-1	59.4	83.7	62.3

CSR and coke strength of coal blend made in the SCO, on an actual oven basis (converted), are 59.4, DI_{150-15}83.7, and TI_{25}62.3, showing excellent properties for blast-furnace coke.

Trace constituents in coke, P and alkali contents (K_2O + Na_2O), are calculated from ash composition in Table 5-47 and ash content in coke in Table 5-49, 0.032 (% on a coke basis) and 0.15% (on a coke basis) respectively. These contents do not present any problem related to the use of blast-furnace coke.

(4) Conclusion

As shown in Table 5-52, coke made in the SCO under coking coal blending conditions required for annual coke production of 1 million tons satisfies quality requirements for blast-furnace coke.

Table 5-52 COMPARISON OF TARGET COKE QUALITIES FOR COMMERCIAL PRODUCTION FOR COMMERCIAL PRODUCTION AND SCO COKE QUALITY

	Target	Target of Quality for Qualities	SCO Coke
Standard Quality			
Ash (%)	10.5 (Max.)	10.3	8.90
Volatile matter (%, d.)	1.0 (Max.)		0.77
Fixed carbon (%, d.)	88.5 (Min.)		90.33
Total sulfur (%, d.)	0.8 (Max.)	0.76	0.64
TI25	59 (Min.)	61	62.30
Others, important properties			
CSR	53 - 60	58	59.40
P (%, coke basis)	0.04		0.02
K20 + Na20 (%, coke basis)	0.25 (Max.)		0.15

5.4 Blending Design of Coking Coals

Based on the results of the box test and the SCO coking test, preliminary blending design of coking coals was developed.

5.4.1 Blending Design Using Tachira, Colombian, and Imported Coals

Based on known production amounts, the optimum blending conditions of Tachira, Colombian, and imported coals are derived from theoretical calculation of coke strength in Table 5–30, the result of the box test in Fig.5–14, and the result of the SCO coking test in Tables 5–52, and are presented in Table 5–53 below.

Table 5-53 OPTIMUM BLENDING CONDITIONS USING TACHIRA, COLOMBIAN, AND IMPORTED COALS

Kind of Coal	Blending proportion	Remarks
FNO Coal	5% or more	Imports of medium volatile matter coal can be , reduced if production of FNO coal increases significantly.
LAS Coal	46% or less	Blending amounts of LAS coal be increased if production of low volatile matter coal (equivalent to Boyaca coal) increases. HAT and LOB coals can be used if the sulfur problem is solved.
Boyaca Coal	3% or more	Development of coal reserves equivalent to Boyaca is desirable. If happens, imports of low volatile matter coal can be reduced.
Low Volatile matter Imported Coal	16% or more	Required to maintain coke strength.
Medium Volatile matter Imported Coal	24% or more	Required to maintain coke strength and CSR.

Blending conditions of coking coals required to produce high quality coke merchandisable to the international market at production of 1 million tons/year are as follows:

FNO coal : 5%
LAS coal : 27%
Boyaca coal : 3%
Imported low volatile matter coal : 25%
Imported medium volatile matter coal : 40%

5.4.2 Blending Design Using Tachira and Colombian Coal

The result of the box test revealed that coke merchandisable to the international market could not be produced by blending Tachira and Colombian coals in proportion according to their present production amounts. Major reasons are excess caking property and an insufficient level of coalification.

If high grade blast-furnace coke is to be produced on the basis of currently production amounts of coal, the following blending ratio is conceivable from the result of the coke quality calculation in Table 5-30 and the result of the box test in Fig. 5-14, provided that annual coke production limited to 100,000 tons:

FNO coal : 50%
LAS coal : 30%
Boyaca coal : 20%

Thus, the combination of Tachira and Colombia coals can produce a very small amount of coke, at a rate of 100,000 tons per year. To increase coke production under this setting, it is essential to develop coal fields equivalent to Boyaca coal (low volatile matter) and FNO coal (medium volatile matter).

5.4.3 Blending Design for Use of Guasare Coal

Although a coking test using Guasare coal has not been conducted, theoretical calculation indicates that the increased use of Guasare coal would deteriorate CSR and coke strength TI_{25}), shown in Table 5-31 and maximum blending of Guasare coal is 5%[1] as shown below.

1) Based on the analytical data (1993), blending design is conducted and detail are described in Annex-1.

FNO coal	: 5%
LAS coal	: 27%
Boyaca coal	: 3%
Imported low volatile matter coal	: 25%
Imported medium volatile matter coal	: 35%
Guasare coal	: 5%

5.5 Blending Plan of Coking Coal

Since heavy coking coal of low volatile matter and heavy coking coal of medium volatile matter coals are not available in large quantities in Venezuela and Colombia, production of high grade coke acceptable to the international market at a rate of 1 million tons per year will have to heavily depend upon imported coals.

It is most economical to purchase imported coals from the U.S.A., which is one of the prominent countries of producing coal and closest to Venezuela.

5.6 Consideration of Coking Coal Prices

The project is designed to use coals produced in Tachira, Colombia, and the U.S. for coke making. Coking coal prices assumed in financial and economic analysis are as follows:

Tachira coal :Based on the estimation caluculated below, coal price at the plant is assumed as US$24/ton

Colombian coal :Mining cost: US$14.0 Transportation cost: US$26.5
Total cost: US$40.5

Imported coal (U.S.) :The average FOB price of coals produced in the eastern part of the U.S. in 1993 is US$52/tons. Assuming that transportation cost is US$7, the purchase price at the coke making plant is assumed to be US$60.

Reference Data

Preliminary estimation of raw coal prices

LAS :		
[1992-F/S]Base	Currently applied rate	: 1US$→95Bs
Mining Coast : 1,265,55Bs/ton	Mining cost	: 13.32US$/ton
	Transportation cost	: 14.5 US$/ton
	Total cost	: 27.82US$/ton
FNO:	Mining cost	: 12.0 US$/ton
	Transportation cost	: 11.6 US$/ton
	Total cost	: 23.7 US$/ton
Boyaca(Colombia) :		
Mining cost : 14.0US$/t		
(locally estimated)	Mining cost	: 14.0 US$/t
	Transportation cost	: 12.0 + 14.5 = 26.5US$/t
	Total cost	: 40.5 US$

U.S. coal (1993 basis)

Pinnacle	: FOB 51.0, Freight 7.0	Total 58.0 US$
Blue Creek	: FOB 52.9, Freight 7.0	Total 59.9 US$

Chapter 6 Project Planning Framework

Chapter 6 Project Planning Framework

6.1 Planning Parameters

6.1.1 Plant Capacity

In establishing the plant capacity for the project, it is assumed that Venezuelan coals will be used as far as practicable.
As discussed in Chapter 5, preliminary findings on availability and prospect for existing coking coal sources are as follows:

(1) The blending of domestic coals (FNO and LAS) alone does not satisfy all the quality requirements for blast-furnace coke, particularly the required coke strength (TI_{25}, CSR) if FNO coals are 50% or less.
(2) The blending of domestic coals (FNO and LAS) and Colombian coals (Boyaca) can maintain the required coke strength for blast-furnace, but limited production results in annual coke production capacity of only 100,000 tons.

The above analysis suggests that, to maintain blast-furnace coke with the required strength in the project, low and medium volatile matter coals need to be imported, at least 46% (Boyaca 67%, U.S. coals 40%) of total coal requirements. The blending is translated into annual coke production capacity of 570,000 tons, which is thus the minimum production capacity required to satisfy quality requirements. Since the coke making plant is capital intensive in nature, however, it is desirable to increase the production capacity as much as possible by increasing the amount of coking coal, thereby to reduce the average production cost. At the same time, the increase in coking coal consumption will lead to the increase in use of imported coals which are relatively costly.
Availability of domestic coal reserves indicates that the production capacity can be increased to 1 million tons annually, which obviously offers a major advantage in economy of scale. Thus, the plant capacity is assumed to be 1 million tons per year. Imported coals will account for 68% (U.S. coals 65%, Colombian coals 3%) of total coal consumption and can be replaced with domestic coals if production increases.

6.1.2 Environmental Considerations

With a rapid rise in public concern about the environment and its preservation worldwide, environmental issues have been extended to a global scale beyond the conventional framework

of regulating air and water qualities, such as global warming.
Venezuela is no exception to this, and public awareness of environmental preservation heightens and is translated to the control of air pollution and water pollution in the form of the Environmental Organization Law and Environmental Penal Code. Under these circumstances, the project, as well as industrial plants which consume large amounts of fuel, becomes a source of air pollution and water pollution, if waste gas and waste water are discharged without proper treatment. Thus, appropriate facilities and equipment to reduce pollutants should be included as an integral part of the proposed plant.
In fact, the project plan proposes pollution control measures which can meet strict environmental standards in Venezuela and Japan, whichever applicable and lower. As a result, water pollution control will conform to effluent standards applied to Lake Maracaibo along which the proposed plant site is located, and air pollution control including soot and dust discharge will meet more strict standards enforced in Japan. To meet the applicable effluent standards, the drainage containing ammonia discharged from the proposed coke oven (referred to as ammonia liquor) will be first treated in the stripping process to remove ammonia that is harmful to bacteria. Remaining ammonia liquor will be subjected to the activated sludge treatment process in order to remove harmful substances. Finally, it will go through the advanced treatment system using activated carbon to reduce concentration of harmful matters to the minimum practicable level. On the other hand, rainwater and other waste water from the coal and coke yards will be discharged after adjustment of SS and pH. As for air pollution control, appropriate facilities and equipment will be provided to purify and burn COG in such manner to control SOx and NOx discharge below Japanese emission standards. Dust will be controlled by installing dust collecting equipment, which can satisfy strict Japanese installing regulations, in the coke oven, coal preparation and coke handling facilities.

As for safety and health to workers, all plant facilities and equipment will be installed to satisfy requirements in the Clean Air Act of the U.S., which is scheduled to be enacted in 1993, in particular, with provisions to prevent workers from exposure to tar and dust.

6.1.3 Selection of Coke Oven Facility

The coke oven needs to have solid and stable structure with design consideration to ensure uniform heating of the coking chamber and minimum practicable consumption of heat energy. For this purpose, various innovations have been made, such as the arrangement of the combustion chamber and the regenerator, construction of the flue, and the gas supply system, and various types of coke oven have been developed. Widely used chamber type coke ovens are Koppers, Nippon Steel, Carl Still, and Otto.

The study team evaluated the coal charging system using the stamping method. It has been developed for the chamber type coke oven and is used in Europe. It consists of a device to compact coals and to charge them from the pusher side. Effect of compaction results in increased coke strength to allow some of heavy coking coal to be replaced with the non-caking or slightly coking type. However, the system has been installed in relatively small ovens having height of around 4m, and the stamping equipment for taller ovens doesn't have been developed yet. Furthermore, when inert substances such as PC and breeze are added, coke strength after reaction (CSR) declines to necessitate the blending of expensive pitch for compensation, increasing raw materials cost.

New coke making processes, other than the chamber type, already commercialized or under development, are described as follows.

(1) Non-recovery coke oven

Commercial plants are operated in the U.S. and Australia. The process completely burns gas and tar produced in the oven during carbonization and does not need a gas purification plant. On the other hand, it requires relatively long time for carbonization (24 - 96 hours) due to a wide oven (2 - 4m), resulting in relatively poor productivity. Also, heavy coking coal is essential to secure the required coke strength. Finally, it burns sulfur and ammonia contained in by-products to produce air pollutants, so that stack gas desulphurization and denitrification equipment need to be added to meet environmental standards.

(2) Formed coke process (FCP)

In Japan, a FCP-based pilot plant (200 tons/day) was operated for 2 years, starting in 1984, to verify coke quality. The FCP is a continuous coke making process in which briquetted raw coals are charged into an enclosed oven for carbonization under direct heating and cooling. It can use non-coking or slightly coking coal up to around 70%. However, produced cokes are round in shape and are subject to closet packing in blast furnaces, reportedly capable of replacing only 20% - 30% of cokes produced from the chamber type oven.

(3) Jumbo Coking Reactor (JCR)

The JCR has been tested at a verification plant in Prosper, Germany, since April 1993. It is designed to control environmental pollution by reducing the number of pushing by using a large carbonization chamber (its volume is 250m^3 which is seven times as much as conventional chamber type of ovens), and the pushing of coke to a enclosed container. However, a wide oven size (more than twice that of conventional chamber type of ovens) requires longer carbonization time, necessitating the change of preheating coal to reduce carbonization time. Therefore the installation cost is relatively high.

Available coke oven types including the new processes were evaluated and compared in consideration to suitability for types of coal to be used, coke quality requirements, pollution control measures including treatment of waste gas, and plant economy. As a result, the by-product recovery coke oven of chamber type which is most widely used for production of blast-furnace coke has been selected. Its advantages are summarized as follows:

- The ability to produce uniform and high quality coke
- Solid structure and long life of coke oven facilities
- Ease of operation
- Heat regenerator to ensure high thermal efficiency
- High yield and quality of by-product

At the coke making plant, one team can operate 100 to 120 of pushing. Thus, the proposed plant is assumed to have 100 - 120 ovens (chamber/battery) with oven height of 6.5m or more.

6.1.4 Selection of Coal Preparation and Coke Handling Facilities

A number of new coal preparation and coke handling processes have been developed for quality improvement and energy saving, including the coal preparation control process (CPCP), the briquette blend coking process (BBCP), the preheated coal charging method(Precarbon), and the coal moisture control process (CMC). They are generally capable of improving coke quality (increased coke strength), thereby to replace heavy coking coal with less costly non-caking coke (5% - 10%). However, given the narrowed price differential between heavy coking coal and non-coking or slightly coking coal due to the increased use of PCI in blast furnaces, and massive capital investment requirements for any of these processes, neither process would offer significant economic advantages. Also, a small amount of production of heavy coking coal

(FNO class) in Venezuela (70,000 tons per year) does not produce much advantage for replacement with non-coking coal. Thus, the blending after crushing of coal method – the basic coal preparation method in coke making – will be used for the proposed plant.
As for treatment of coke, the coke wet quenching method has been selected in place of the coke dry quenching (CDQ) method which does not provide significant economic advantages due to large capital investment and low energy price in Venezuela.

6.1.5 Selection of Gas Purification Plant

The gas purification plant removes hydrogen sulfide, ammonia, naphthalene, BTX, and tar from crude gas produced from the coke oven to a level not having an adverse effect in terms of pollution control and transportation. Ammonia is converted into ammonium sulfate which can be forwarded to domestic markets. Hydrogen sulfide is converted to sulfuric acid, which can be used as a raw material for ammonium sulfate in the ammonia removal plant. BTX and naphthalene are recovered as crude light oil, and tar as crude tar, which are assumed to be all exported. Because there is little demand for these derivatives within the country, construction of a new refining and distillation plant cannot be justified economically.

6.1.6 Other Considerations

To ensure a sufficient level of productivity, the plant will be automated and mechanized to an extent widely introduced in Japan. At the same time, spare equipment and route will be provided for important equipment.

6.2 Major Considerations in Individual Processes

Based on key process designs selected in 6.1 above, important considerations to be made in each process are described below. The entire coke making process from coal receiving to processing and transportation is presented in a block diagram, shown in Fig.6-1.

6.2.1 Coal Receiving and Preparation Facilities

(1) The coal receiving facility will consist of two parts, one for receiving coals transported by ships (imported coals) and another for receiving coals transported on land (domestic and Colombian coals).
(2) The coal yard will have an area enough to hold 60 days of inventory.
(3) The coal yard will be provided with facilities to prevent coals from dispersing and to protect issue of them from rain, together with pollution control measures to prevent air pollution and water contamination.
(4) Pollution control facilities for openings between belt conveyers, and the inside of the building, will be provided according to local conditions, such as the dust collector, water sprinkler, and wind shield cover.

6.2.2 Coke Oven Facilities and Equipment

(1) Annual production capacity: 1 million tons
(2) A large chamber-type oven, 6.5m high, in consideration to productivity, ease of operation, and pollution control.
(3) The number of chambers: 100 in total, 50 at 1A battery and 50 at 1B battery
(4) Coke quenching method: Wet quenching
(5) Combusting equipment and other plant equipment will be automated and mechanized to a level achieved in Japan.
(6) The dust collector and similar equipment will be used during the charging, pushing, and quenching operations to prevent air pollution.
(7) To prevent gas leakage from the coke oven, charging hole lids will be mortar sealed, and top covers and bends of ascension pipes will be water sealed.
(8) To prevent gas leakage from the oven door during carbonization, the air-cooling door will be used. In addition, door and seat cleaners will be provided for machinery to operate the door.

6.2.3 Coke Handling and Shipping Facilities

(1) The produced coke will be adjusted its size and screened to meet user requirements and will be transported to a coke yard by conveyors.
(2) The storage capacity of coke yard will be 2 Panamax ships (40,000 tons per ship).
(3) The produced coke will be entirely exported, and a ship loading facility will be provided for the purpose.
(4) The samplers and conveyor weighers will be provided for quality control of coal and coke.

6.2.4 Gas Purification Plant

(1) Sulfur, ammonia, and BTX contained in coke oven gas will be removed through a scrubber. Purified COG will be used as clean gas at the coke oven and other plant facilities, and any surplus will be exhausted to a nearby thermal power plant.
(2) Sulfur content removed from COG will be converted to sulfuric acid, which will be used as a raw material for ammonium sulfate.
(3) Ammonia will be removed at the ammonium sulfate plant, and ammonium sulfate produced will be sold domestically.
(4) Crude light oil and tar will be all exported through the plant's own shipping facility.
(5) Surplus ammonia liquor will be steam distilled to remove ammonia, and after the activated sludge treatment process and the activated carbon absorption process, it will be discharged as an effluent.

6.2.5 Others

(1) An administrative office, a maintenance center, and a testing laboratory related to operation of the plant will be provided.
(2) Utilities consumed at the plant (electricity and water) will be received collectively and distributed to each facility.
(3) Steam, nitrogen, and compressed air will be generated within the plant and distributed to each facility.
(4) Green belts will be provided along the battery limit to clearly separate the plant from the outside.

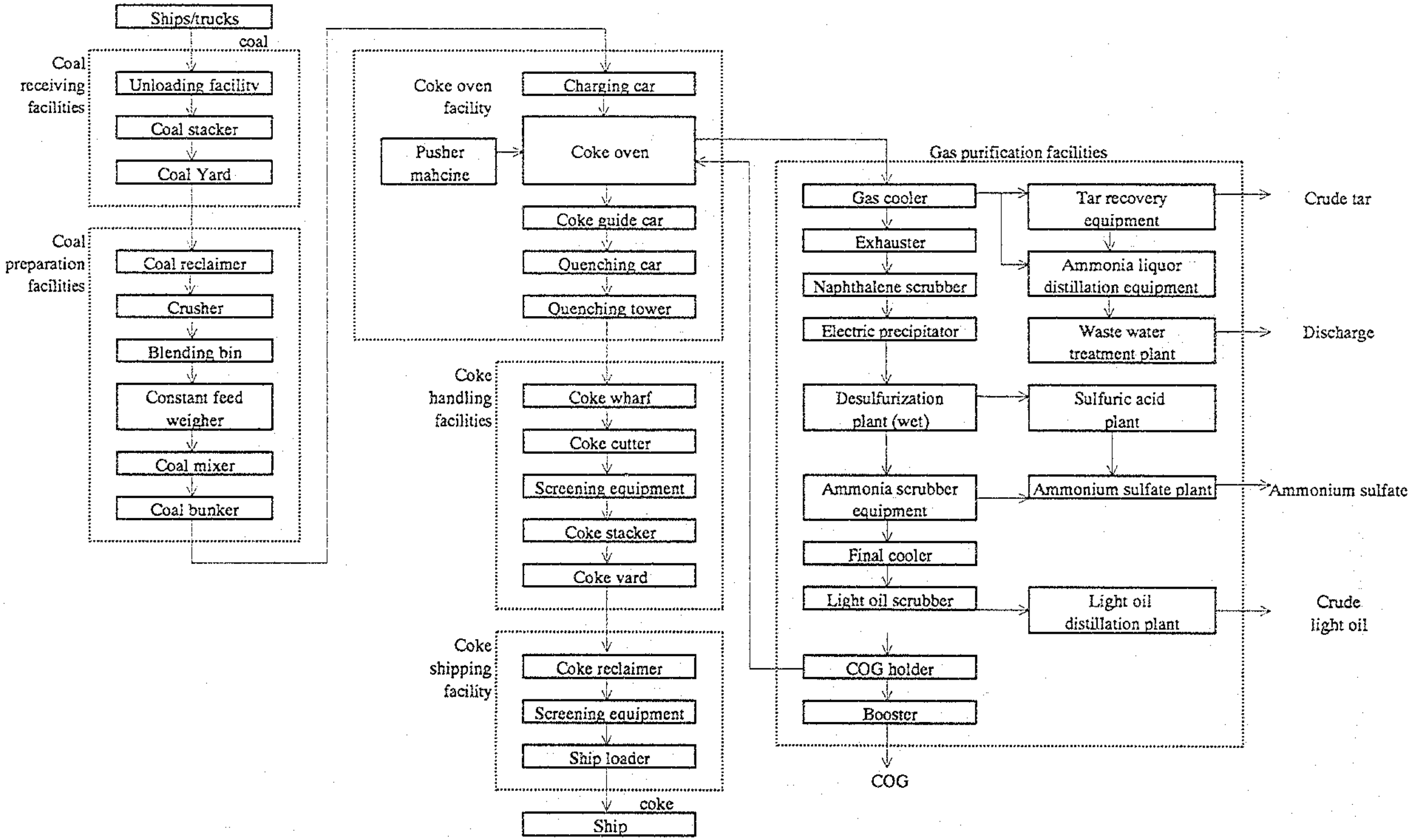


Fig.6-1 BLOCK DIAGRAM OF THE PROPOSED COKE MAKING PLANT

6.3 Coke and By-Product Production Plan

6.3.1 Production (Design Basis)

Production data and material balance of product assumed for plant design are summarized in Table 6-1. Also, properties of coal charge and product yields are shown in Table 6-2. As a basis of estimating the above data, properties of coking coals and blending ratio are assumed from the result of analysis in Chapter 5 and are presented in Tables 6-6 and 6-5, respectively. Coke quality targets are also assumed as listed in Table 6-3.

Table 6-1 PRODUCTION AND MATERIAL BALANCE OF PRODUCT COMPOSITION

Item	Production/Amount Handled		Remarks
	Daily	Annually	
Raw coal (wet)	4,020 ton	1,465 x 10^3 ton	
Coal charge (dry)	3,650 ton	1,333 x 10^3 ton	
Coke in total	2,740 ton	1,000 x 10^3 ton	
Lump coke	2,330 ton	850 x 10^3 ton	
Coke breeze	410 ton	150 x 10^3 ton	-25mm or less
COG	1,210 x 10^3Nm^3	441 x 10^6 Nm^3	4,500 Kcal/Nm^3
Tar	110 ton	40 x 10^3 ton	
Light oil	36 ton	13 x 10^3 ton	
Ammonium sulfate	44 ton	16 x 10^3 ton	
Sulfuric acid (by-product)	17 ton	6.2 x 10^3 ton	Raw material for ammonium sulfate

Table 6-2 BASIC ASSUMPTIONS FOR PRODUCTION PLAN

Item	Yield	Remarks
Moisture content of coal charge	9%	
Volatile matter of coal charge	26.5%	
Coke yield	75%	Coal basis
Lump coke yield	85%	Coke basis
COG yield	330Nm^3/t-coal	4,500kcal/Nm^3
Proportion of COG sold	55%	
Tar yield	3.0%	Coal basis
Light oil yield	1.0%	Coal basis
Ammonium sulfate yield	1.2%	Coal basis
By-product sulfuric acid yield	0.5%	Coal basis, captive private

6.3.2 Coke Production Flow (Based on Average Design Production Capacity)

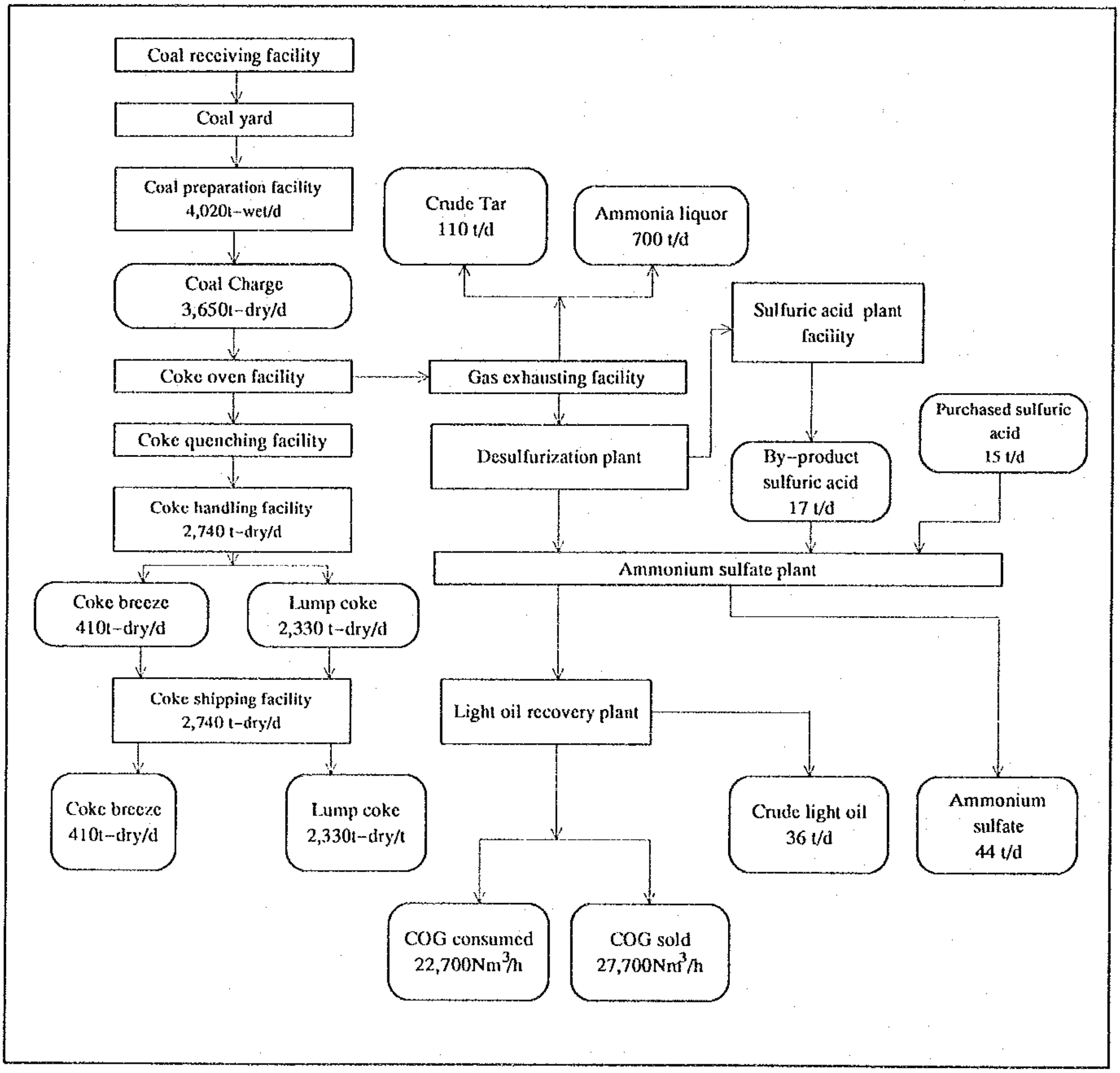


Fig.6-2 COKE PRODUCTION FLOW

6.4 Quality Targets

6.4.1 Coke

Coke to be produced at the proposed plant is assumed to meet quality requirements in U.S.A. shown in Table 6-3.

Table 6-3 TARGET QUALITIES OF COKE

Item	Target value	Remarks
Moisture content	4 - 5%	Standard quality
Ash	10.5 % (Max.)	Ditto
V.M.	1.0 % (Max.)	Ditto
Fixed carbon	88.5 % (Min.)	Ditto
Total sulfur	0.8 % (Max.)	Ditto
TI_{25}(Stability index)	59.0 % (Min.)	Ditto
-25mm	5.0 % (Max.)	Ditto
CSR	53 - 60	Important characteristic value
P (%, d.)	0.04	
Alkali (%, d.)	0.20 - 0.25	
Mean size (Inch)	2	

6.4.2 By Products

Standard quality targets of by-products are shown in Table 6-4.

Table 6-4 TARGET QUALITIES OF BY PRODUCTS

COG	Calorific Value	Density	H_2S	T-S	HCN	NH_3	BTX	Naphthaline
	4,500 kcal/Nm^3	0.47 kg/Nm^3	0.2 g/Nm^3	0.25 g/Nm^3	0.15 g/Nm^3	0.1 g/Nm^3	5 g/Nm^3	0.3 g/Nm^3
Tar	Water	T-S						
	3.50%	0.7%						
Crude light oil	180 fraction							
	90%							
Ammonium Sulfate	Ammoniacal Nitrogen	Free Sulfuric Acid	Thiocyanate		Arsenic			
	20.5%	0.5%	1.0%		0.50%			

6.5 Using Plan of Raw Materials

6.5.1 Amounts of Use

Based on properties of Venezuelan, Colombian and imported coals, and the result of the blending test, their typical using amounts for the project is estimated as follows.

Table 6-5 STANDARD COAL BLENDING RATIO AND ANNUAL USING .TB1.21"AMOUNTS

	Ratio	Amounts of use [t-wet/y]	Producing Area
Domestic			
LAS	27 %	400,000	Tachira State
FNO	5 %	70,000	Tachira State
Imported			
Boyaca	3 %	50,000	Colombia
Low volatile matter, U.S.	25 %	366,000	U.S.
Medium volatile matter, U.S.	40 %	586,000	U.S.

6.5.2 Properties of Coking Coals

Properties of coking coal to be used for the project are summarized in Table 6-6.

Table 6-6 PROPERTIES OF CLEAN COALS FOR BLENDING

Sample	LAS	FNO	Boyaca	U.S. low volatile matter	U.S. medium volatile matter
Ash (%, d.)	3.94	7.55	7.45	5.61	8.91
V.M. (%, d)	37.91	23.21	21.37	16.74	25.44
F.C. (%, d.)	58.15	69.24	71.18	77.65	65.65
T.S. (%, d.)	0.59	0.85	0.95	0.76	0.85
SI	2.86	5.06	6.91	7.28	4.60
CBI	0.85	2.39	4.91	5.66	0.63
FSI	7	9	8	9	9
M.F. (logDDPM)	4.10	2.96	1.04	0.60	3.60
T.D. (%)	203	124	41	42	239
CRI	33.6	23.0	21.4	33.0	32.6
CSR	41.4	70.0	69.9	47.0	59.7

6.5.3 Properties of Coal Charge

Based on estimated coal use in 6.5.1, typical properties of coal to be charged into the coke oven are summarized in Table 6-7.

Table 6-7 PROPERTIES OF COAL CHARGE

Item	Characteristic Value	Factors Affected
V.M.	26.5 %	Yields and properties of coke, COG, tar, and light oil
T - S	0.76 %	Yield of by-product sulfuric acid
N	1.6 %	Yield of ammonium sulfate

6.6 Unit Cost Consumption of Utilities

6.6.1 COG

As shown in Table 6-8, 45% of COG produced at the plant will be consumed internally at the coke oven, boiler, and light oil heating furnace, and remaining 55% will be sold to a thermal power plant near the site.

Table 6-8 COG CONSUMPTION

Application	Consumption (Nm^3/hour)	Remarks
Coke oven boiler,heating furnace value	20,000 2,700	Heat consumption 590kcal/kg-coal
Internal consumption in total	22,700	
Sales	27,700	
Total production	50,400	

6.6.2 Electricity Consumption

Electricity consumption at the entire plant is estimated in Table 6-9. The average consumption is assumed to be 7,000KWH/hour, and peak consumption (instantaneous) when unloading of imported coal and crushing are carried out simultaneously 10,500KWH/hour.

Table 6-9 ELECTRICITY CONSUMPTION

	Unit Consumption	Average Consumption	Remarks
Electricity	61KWH/ton-coke	7,000KWH/hour	10,500KWH/hour (instantaneous)

6.6.3 Consumption of Other Utilities

Consumption of steam, nitrogen, compressed air, industrial water, and portable water is estimated in Table 6-10.

Table 6-10 CONSUMPTION OF OTHER UTILITIES

	Supply Capacity (Average)	Consumption	Remarks
Steam	13 tons/hour	310 tons/day	Internal production
Nitrogen	100 Nm^3/hour	2,400 Nm^3/day	Ditto
Compressed air	14 Nm^3/minute	20,000 Nm^3/day	Ditto
Industrial water	375 m^3/hour	9,000 m^3/day	Purchase
Portable water		400 m^3/day	Ditto

6.6.4 Consumption of Chemicals

Consumption of major chemicals is estimated as shown in Table 6-11.

Table 6-11 CONSUMPTION OF CHEMICALS

	Consumption	Remarks
Wash oil	5.4 tons/day	Purchase
Sulfuric acid	15 tons/day	Ditto
Caustic soda	0.6 tons/day	Ditto

6.7 Plant Layout and Production Flow

6.7.1 Site Location

The proposed plant site shown in Fig.6-3 and Fig.6-4 is located within the La Cañada industrial park, more precisely a new port construction site suitable for ship loading. The site is convenient for coal and coke handling, the receiving of electricity and industrial water, and exhausting of COG to the thermal power plant.

6.7.2 Plant Layout Plan

Assuming that imported coals will account for 68% of total coal uses and produced coke will be all exported, the major factor to be considered in plant layout design is to reduce costs related to imports and exports. Fortunately, the La Cañada port plans to construct a port facility capable of accommodating Panamax class ships, which can be used for efficient use of ships and berths. Thus, the port facility for the plant is designed to accommodate Panamax class ships, with handling capacity on the basis of general demurrage contract at international ports. The coal yard's storage capacity will be 60 days of inventory in consideration to possible variation of coal quality and shipping schedule, while the coke yard's storage capacity will be a full load of 2 Panamax class ships in consideration to fluctuation of production and shipment.

Fig.6-5 shows the proposed plant layout. The priority is placed on streamlined process flow from coal receiving, preparation, to the coke oven and coke treatment. The gas purifying section is arranged to ensure smooth flow of gas. Also, wide green belts and roads will be provided within the site to separate facilities into blocks for safety and environmental consideration.

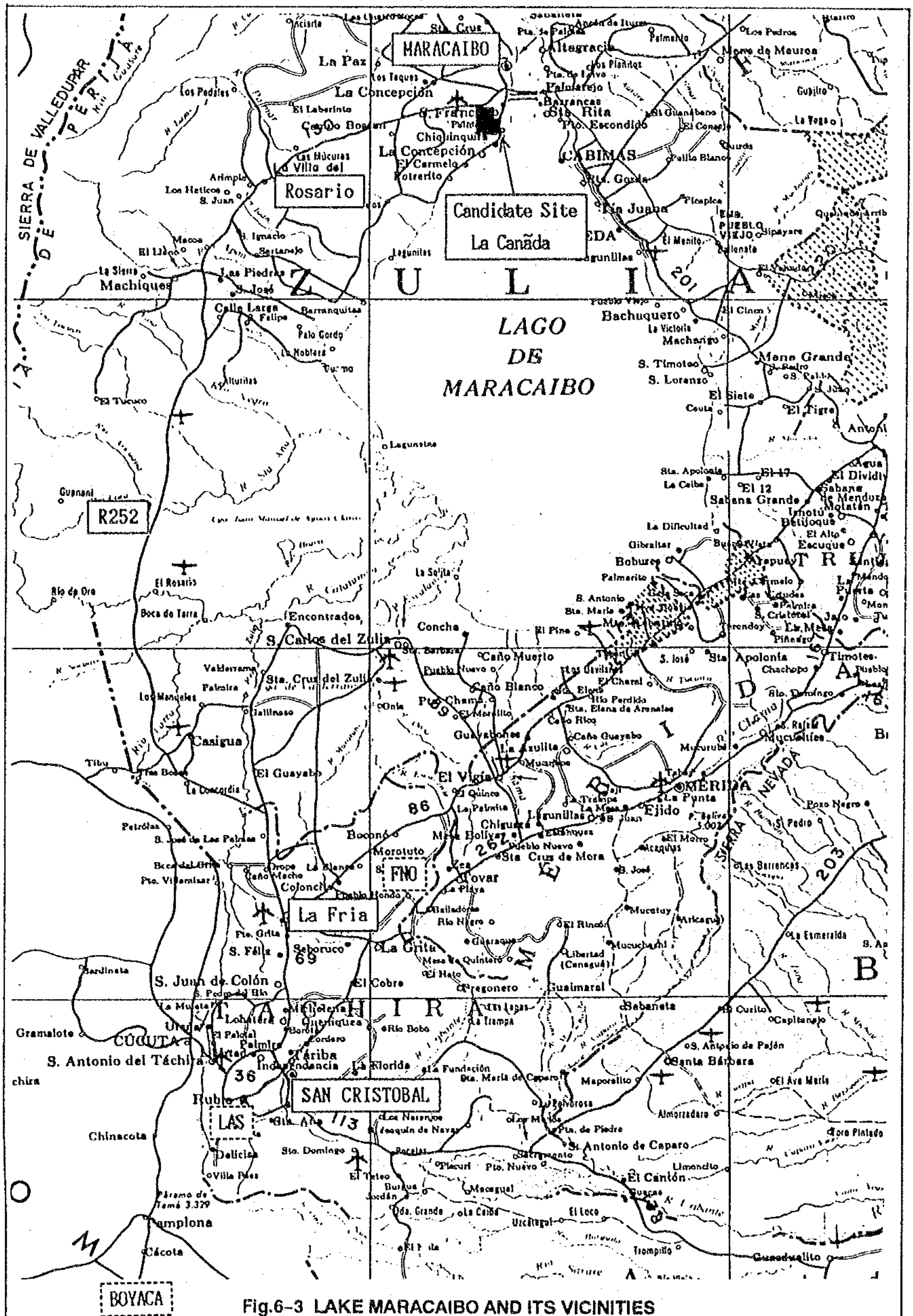


Fig.6-3 LAKE MARACAIBO AND ITS VICINITIES

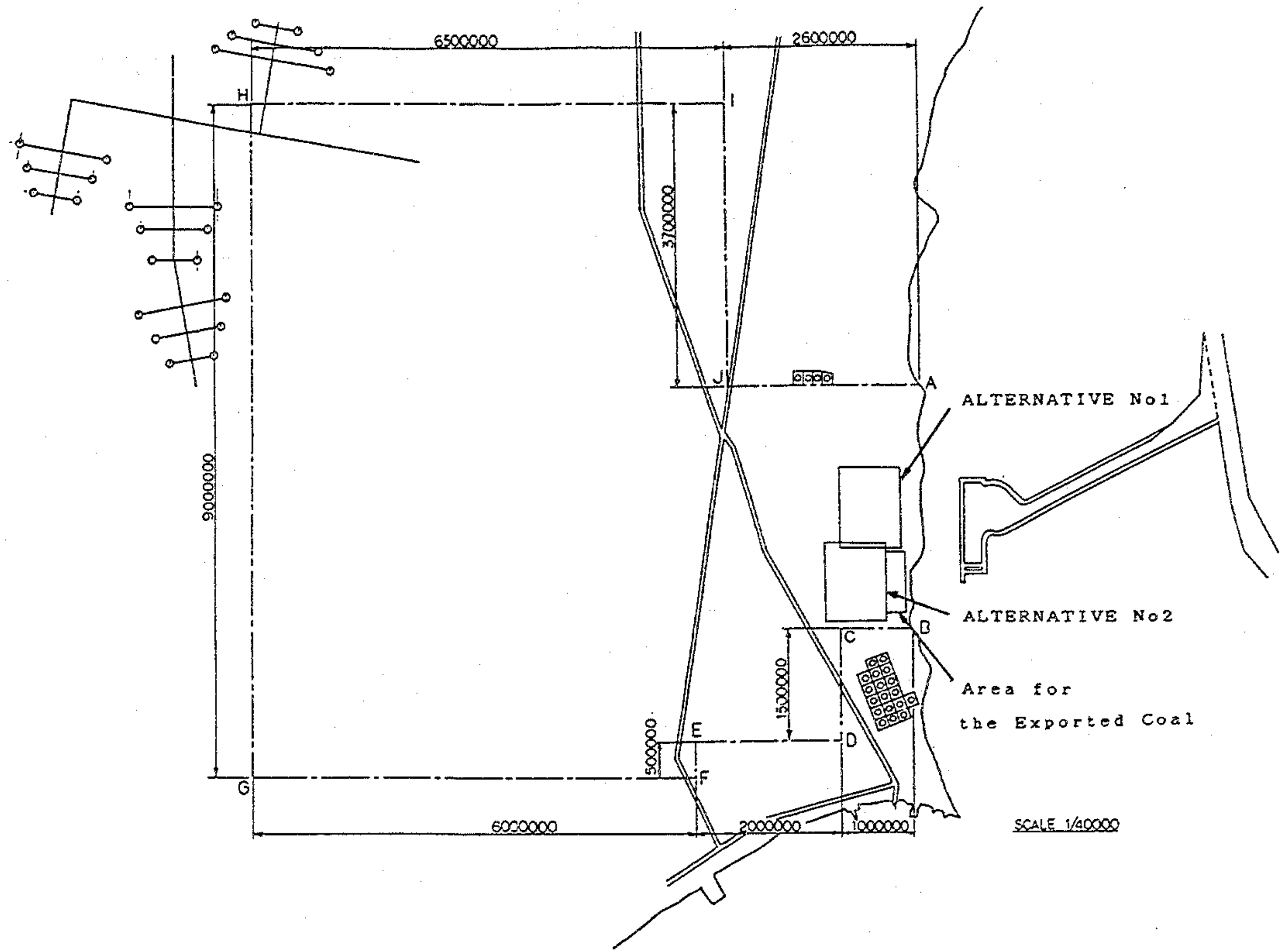


Fig.6-4 PROPOSED PLANT SITE

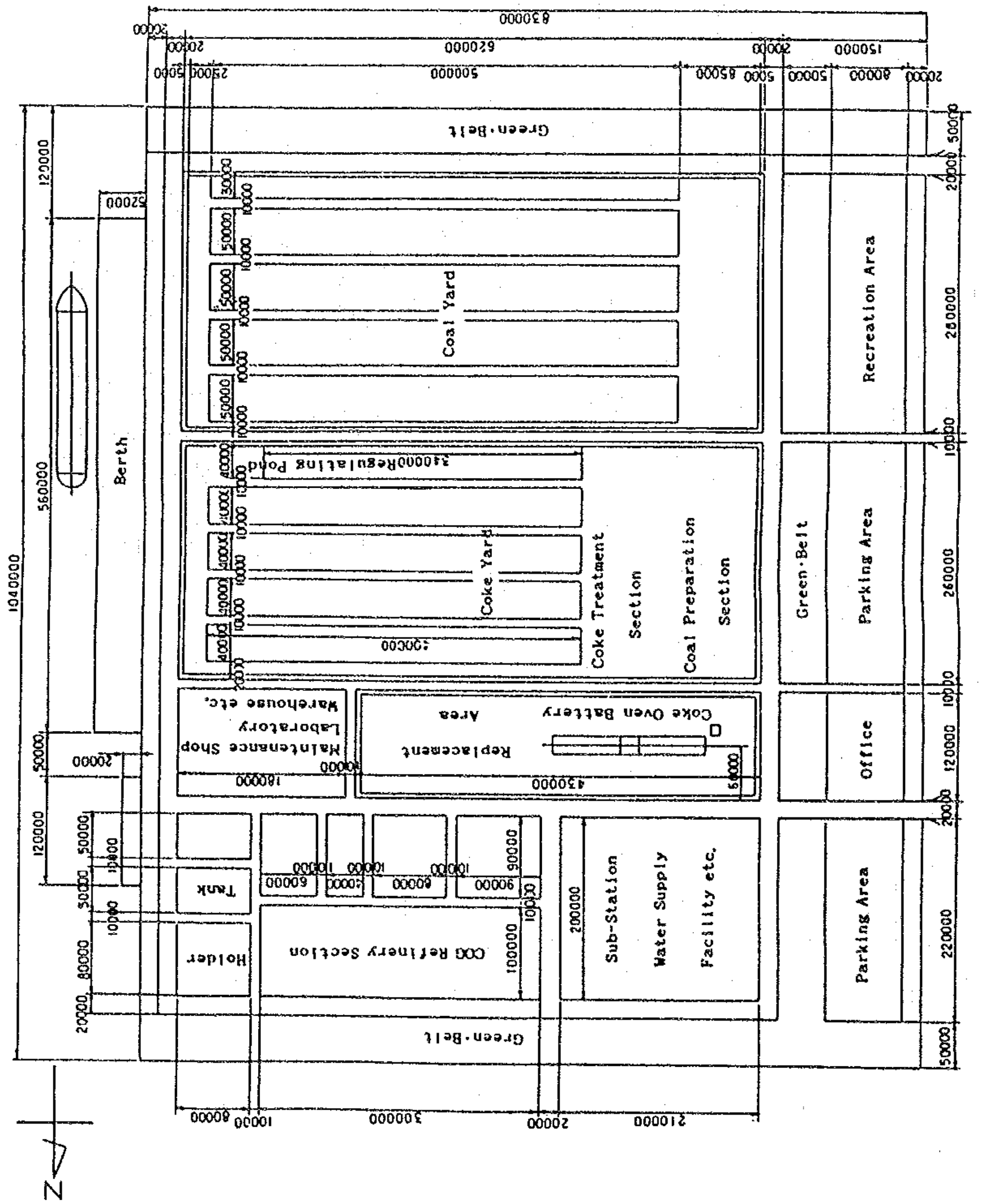


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Fig.6-5 GENERAL PLANT LAYOUT

6.8 Infrastructure

6.8.1 Road

Domestic and Colombian coals will be transported by truck via National Highway Route 252 on the west side of Lake Maracaibo (460km long). From the coal mining to La Fria, 20-ton trucks will carry coals via ordinary roads (including mountain roads) and a partially completed highway. 50-ton trucks will be used from La Fria to La Cañada. Fig.6-6 shows the transportation route. The road between La Fria and Rosario has 2 lanes, and the road between Rosario and La Cañada 4 lanes. While traffic is heavy during the daytime, these roads are generally flat to ensure smooth operation of large trucks. Traffic demand forecast between La Fria and Maracaibo made by a university in Maracaibo is summarized in Table 6-12.

Table 6-12 TRAFFIC DEMAND FORECAST BETWEEN LA FRIA AND MARACAIBO

Year	1991	1995	2000	2005	2010	2015	2020
Traffic Volume (vehicles/day/lane)	360	450	550	620	710	790	850
Degree of congestion (%)	38	47	58	65	75	83	89

(Maximum traffic capacity: 950 vehicles/hour/lane)

Assuming that 520,000 tons of domestic and Colombian coals which can be produced annually are transported by 50-ton trucks, traffic demand on the road will increase 33 vehicles per day. If imported coals are all replaced with domestic coals (1.47 million tons), road traffic will increase 94 vehicles daily. This means, the proposed route can be used until 2020. Note that large trucks are not operated on Sundays and holidays in Venezuela.

Within the La Cañada industrial park (6,800ha), a principal road (2 lanes, paved) runs in a north-south direction, 1.5km west of the lake share. From the road, an access road needs to be constructed to the site. (See Fig.6-4)

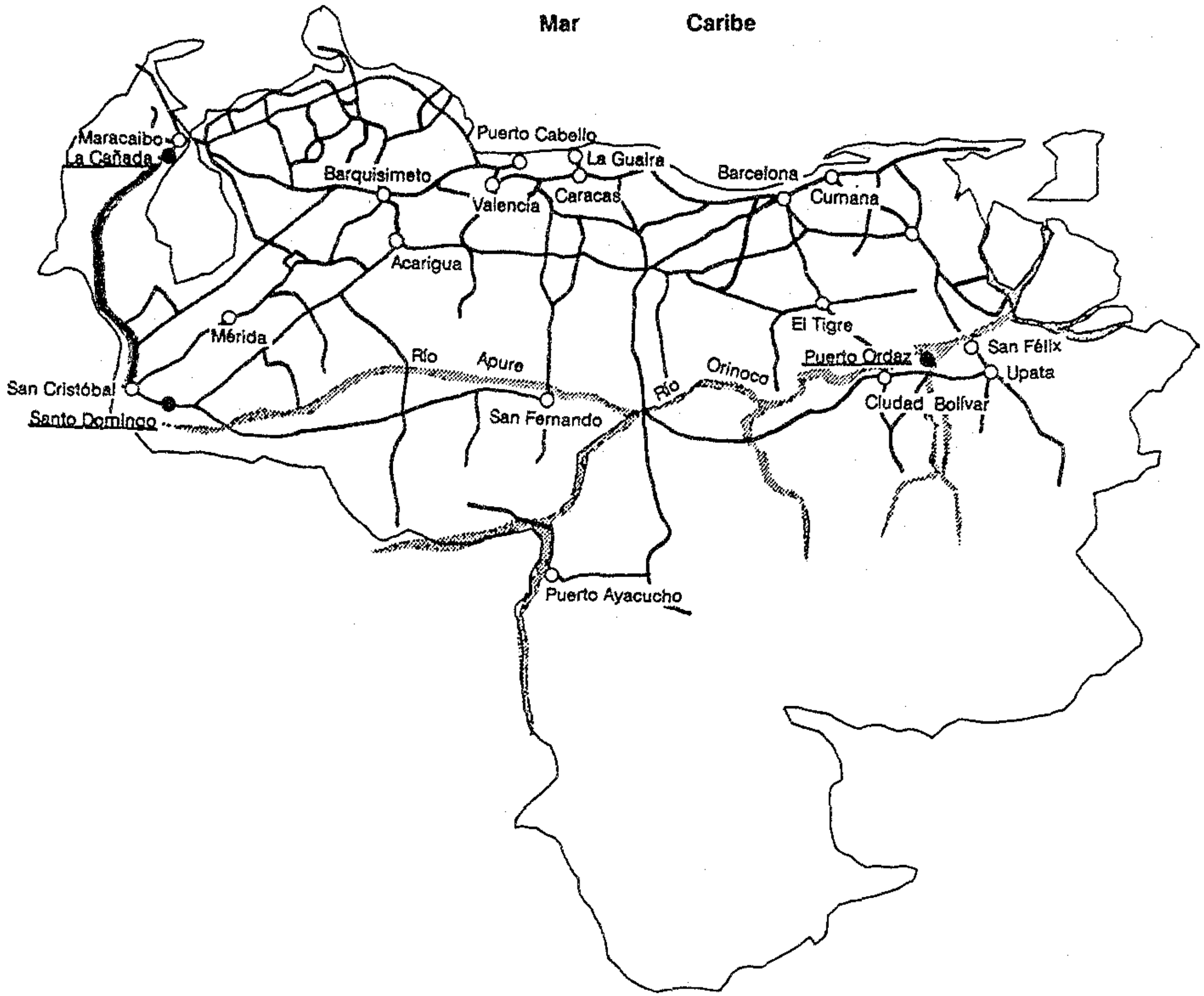


Fig.6-6 COAL TRANSPORT ROUTE FROM COAL PRODUCING AREA TO LA CAÑADA

6.8.2 Port Facilities

Within the La Cañada industrial park, Puerto Siderurgico port (243m : length of wharf) is located along Lake Maracaibo. Water depth at the wharf is 3m and the harbor area is dredged to 5m – 12m. At present, Tachira and Colombian coals are shipped to 2,000–ton barges and then transshipped to Panamax class ships (60,000 tons) anchoring off shore. Construction of a new port facility where panamax ships can be directly berthed is under way on the north side of the existing facility. The government's concession is scheduled to be obtained in 1993, and Transporte Coal Sea company will start construction in 1994. A wharf will be constructed 300m – 500m off the lake shore, and the channel between here and an existing navigation channel (water depth : 13m) located 4,500m off the shore will be dredged to 13m. The new facility will be used for unloading of imported coal and shipping of produced coke.

6.8.3 Electricity

Electricity can be obtained from ENELVEN's thermal power plant (installed capacity of 380MW) located 2km north to the site, or a nearby substation. ENELVEN will construct transmission and distribution facilities to the site at the expense of the user.

6.8.4 Water

There are unused wells 10km west to the site, which have been used to supply portable water to the city of Maracaibo and industrial water to factories. Their pumping capacity is estimated to be 1.8 tons/second (160,000 tons/day), sufficient for water consumption requirements at the proposed plant. The water resource corporation will construct the water pipeline to the site at the expense of the user.

6.8.5 Gas

Natural gas required during construction and heating up of the coke oven will be obtained from ENELVEN's thermal power plant by constructing a pipeline, which will in turn be used to supply surplus COG produced from the coke oven to the power plant.

6.8.6 Other Utilities

Since there are no supply facilities of steam, nitrogen, and compressed air near the proposed site, exclusive (private) production facilities will be provided within the plant site.

6.9 Design Conditions

6.9.1 Operating Rate

The coke making plant must be operated day and night throughout the year because most of bricks forming the cove oven are made of silica, which expands significantly in the temperature range between normal temperature and 350°C, followed by gradual expansion between 350°C and 900°C, and little change above 900°C. Thus, the coke oven needs to be operated in the high temperature range causing little expansion and contraction of bricks, after thorough drying in advance. As a result, coke handling and gas purification processes will be operated continuously throughout the year.

6.9.2 Applicable Laws and Standards

The plant will be designed in accordance with applicable laws and generally accepted standards in Venezuela, as well as the following international and foreign standards.

(1) Laws

Ley Orgánica del Ambiente
Ley Penal del Ambiente
Ley Orgánica para la Ordenación del Territorio
Ley Orgánica de Ordenación Urbanista
Ley Orgánica de Decentralización, Delimitación y Transferencia de Competencias del Poder Público

(2) Standards

1) General
National Fire Protection Association (NFPA)
American Occupational Health Safety (AOHS)
Occupational Safety and Health Administration

2) Heating furnace
American Society of Mechanical Engineers (ASME)
American Petroleum Institute (API)
Japanese Industrial Standards (JIS)
American National Standard Institute (ANSI)

3) Pressure vessel
American Society of Mechanical Engineers (ASME)
American National Standard Institute (ANSI)
American Society for Testing and Materials (ASTM)
Japanese Industrial Standards (JIS)
American Petroleum Institute (API)
Japan Petroleum Institute (JPI)

4) Tank
American Petroleum Institute (API)
Japan Petroleum Institute (JPI)
Japanese Industrial Standards (JIS)

5) Heat exchanger
American Society of Mechanical Engineers (ASME)
Tubular Exchanger Manufactures Association (TEMA)
American National Standard Institute (ANSI)
American Society for Testing and Materials (ASTM)
Japanese Industrial Standards (JIS)
American Petroleum Institute (API)
Japanese Petroleum Institute (JPI)

6) Pump and compressor
American Petroleum Institute (API)
Japanese Industrial Standards (JIS)
American National Standard Institute (ANSI)
Manufacturer's standards

7) Other equipment
Japan Petroleum Institute (JPI)
Japanese Industrial Standards (JIS)
Manufacturer's standards
Contractor's standards

8) Piping
American Petroleum Institute (API)
Japan Petroleum Institute (JPI)
Japanese Industrial Standards (JIS)

9) Electricity

National Electrical Manufacture's Association (NEMA)
International Electro Technical Commission (IEC)
National Electrical Code (NEC)
Japan Electrical Manufacture's Association (JEM)
Institute of Electrical & Electronic Engineers (IEEE)
American Petroleum Institute (API)
Japanese Industrial Standards (JIS)

10) Instrumentation

International Electro Technical Commission (IEC)
Japan Electro Technical Committee (JEC)
Institute of Electrical & Electronic Engineers (IEEE)
American Petroleum Institute (API)
Japanese Industrial Standards (JIS)

11) Architecture and civil engineering

American Institute of Steel Construction, Manual of Steel Structure (AISC)
American Society of Heating, Refrigerating and Air Conditioning Engineer (ASHRAE)
American Occupational Health and Safety (AOHS)
Japanese Industrial Standards (JIS)

6.9.3 Weather Conditions

Weather conditions assumed for plant design are summarized as follows.

(1) Temperature and humidity

Maximum temperature : 34°C (the mean of highest temperatures in September 1961 through 1974)

Maximum relative humidity : 74% (the mean of highest humidities in October 1961 through 1974)

(2) Precipitation

Monthly maximum precipitation: 119mm (October, 1961 through 1974)
Daily maximum precipitation : 43mm (October, 1961 through 1974)
Annual maximum precipitation : 742mm (October, 1969 through 1973)

(3) Wind direction and velocity

Dominant wind direction : Northeast
Maximum wind velocity : 30m/sec (Maximum mind velocity between 1951 and 1970)

6.10 Pollution Control Measures

6.10.1 General

The plant will comply with environmental standards in Venezuela or Japan, whichever applicable and stricter.

(1) Air pollution

Table 6-13 summarizes emission standards for major plant facilities in Venezuela and Japan.

Table 6-13 COMPARISON OF EMISSION STANDARDS

Facility Name	Country	SOx	NOx	Soot and Dust in Exhaust Gas
Coke oven	Venezuela	175 ppm	300 ppm	$0.15g/Nm^3$
	Japan	Concentration based on value k	170ppm (O_2 7%)	$0.15g/Nm^3$
Boiler	Venezuela	-	300 ppm	-
	Japan	Concentration based on value k	130ppm (O_2 5%)	$0.15g/Nm^3$
Light oil Heating Furnace	Venezuela	-	300 ppm	-
	Japan	Concentration based on value k	150ppm (O_2 7%)	$0.10g/Nm^3$

From the table, emission standards in Japan will be mostly applied. Note that SOx in Japan is regulated on the basis of concentration of gas after being diffused from a chimney, which is measured by value K. The lower the value becomes, the more strict regulation applies. The value is expressed by the following formula and varies greatly with regions and municipalities, ranging between 17.5 and 1.17. Since SOx concentration in exhaust gas from coke ovens in Japan is around 50ppm at the exhaust outlet of the chimney, the figure is used as a basis of SOx regulation at the plant. Assuming the chimney is 120m high, value K will be 1.0 or less.

$q = K \times 10^{-3} \cdot He^2$

Whereas,
q : Amount of sulfur oxide [Nm^3/hour]
K : Emission standard in a region or area
He: Height of exhaust outlet (correction value)

(2) Dust in the production process

Installation standards for dust producing facilities at the coke making plant in Japan can be used as a basis of designing the proposed plant. Excerpts of the standards relevant to the project are summarized in Table 6–14. The plant will be equipped with dust prevention measures indicated in the standards, as required.

Table 6–14 STANDARDS RELATED TO STRUCTURE AND USE OF DUST PRODUCING FACILITIES (1/2)

Dust Producing Facility	Plant Size/Capacity	Structure, Use and Control Standards
Coke Oven	Material processing capacity of 50 tons or more per day	1. Coal charging shall be conducted by using a smokeless charging device and charging cars equipped with hoods and dust collector, or the equivalent device 2. Coke pushing shall be conducted by using guide cars equipped with hoods and dust collector to catch dust from the hoods, or the equivalent device. If the guide car or the hearth on which the guide car runs or width of rails is too small to equip the hood, dust–proof cover or equivalent will suffice. 3. Coke quenching shall be performed by installing hurdle filters or the equivalent device to the quenching tower.

Table 6-14 STANDARDS RELATED TO STRUCTURE AND USE OF DUST PRODUCING FACILITIES (2/2)

Dust Producing Facility	Plant Size/Capacity	Structure, Use and Control Standards	
Stacking of mineral/sand and gravel	Covering land area of 1,000m^2 or larger	When mineral or sand and gravel are stacked in pile, a appropriate chemical shall be sprayed and the surface shall be compacted, in addition to the protective measures listed in the column on the right	1. The storage area shall be provided within a building of air-tight structure to prevent dust from coming out. 2. Water shall be sprayed by using a sprinkling device. 3. The dust-proof cover shall be used to cover the surface 4. Or any other equivalent or better measures
Belt and bucket conveyors	Belt width is 75cm or more, or bucket volume is 0.03 m^3 or larger	when mineral, sand and gravel or cement is transported, in addition to the protective measures on the right, the conveyor loading section shall be provided with the hood and dust collector, and other sections through which dust may disperse shall be provided with water spraying and dust proof devices	
Crusher and grinder (mineral, sand and gravel, cement)	Rated output of the prime mover over 75kw	The hood and dust collector shall be provided, in addition to the protective measures on the right	
Screening (mineral, sand and gravel, and cement)	Rated output of the prime mover over 15kw	Ditto	Ditto

(3) Effluent control

Effluent standards applied to Lake Maracaibo are stricter than those enforced in the general regions of Venezuela. As shown in Table 6-15, effluent standards for Lake Maracaibo are stricter than those applied to coke making plants in Japan. Thus, the plant will be designed to comply with the local effluent standards.

Table 6-15 EFFLUENT STANDARDS FOR LAKE MARACAIBO AND JAPAN

(Unit: mg/l)

	COD	BOD	SS	Phenol	T-N	T-P	Solubles	CN	pH
Maracaibo	150	40	50	0.05	10	1.0	3,000	0.1	6-9
Japan	160	160	200	5	120	16	-	1	5.8-8.6

(4) Working environment

As for work safety and health, coke ovens in Japan are provided with measures to protect workers from being contaminated by harmful matters produced from the coke oven, such as coal tar, as shown in Table 6-16.

Table 6-16 PROTECTION MEASURES FOR COKE OVEN WORKERS

Coal charging	(1) Pressurizing or sealing the operation room (2) Remote control (removal of lids or doors and mortar sealing) (3) Installation of dust collector (4) Smokeless charging (5) Water sealing of accession pipe
Coke pushing	(1) Pressurizing or sealing the operation room (2) Remote control (3) Installation of dust collector
Coke Quenching	(1) Pressurizing or sealing the operation room (2) Remote control (3) Dust catcher in quenching tower

6.10.2 Pollution Control Measures

(1) Air pollution

Combustion equipment at the plant will use COG produced in the coke making process. Emission standards in Table 6-17 can be cleared by reducing trace constituents in the COG to the levels specified in Table 6-4, and by selecting appropriate types of combusting equipment.

Table 6-17 EMISSION STANDARDS FOR MAJOR POLLUTANTS

	SOx	NOx	Soot and Dust in Exhaust Gas
Coke oven	50 ppm (O_2 7%)	170 ppm (O_2 7%)	0.15 g/Nm^3
Boiler	50 ppm (O_2 5%)	130 ppm (O_2 5%)	0.10 g/Nm^3
Light oil Heating furnace	50 ppm (O_2 7%)	150 ppm (O_2 7%)	0.10 g/Nm^3

(2) Dust in the production process

To prevent dust generation in the coke making plant, the coal and coke yards will be equipped with water sprinklers, and important parts of the coal and coke treatment processes will be provided with ventilators and dust collector. Also, guide car and charging car will be equipped with dust collector to prevent dust generation in the pushing and charging processes.

(3) Effluent treatment

Water produced from the gas purification process cannot be discharged without treatment. In particular, the proposed plant should comply with effluent standards applied to Lake Maracaibo in items listed in Table 6-18. Basically, the activated sludge and advanced treatment (absorption by activated carbon) processes are expected to clear these standards. Waste water from the coal and coke yards will be treated to adjust pH and SS before environmental release.

TABLE 6-18 EFFLUENT STANDARDS APPLIED TO LAKE MARACAIBO (RELATED TO COKE MAKING PLANT)

(Unit: mg/l)

	COD	BOD	SS	Phenol	T-N	T-P	Solubles	CN	pH
Content	150	40	50	0.05	10	1.0	3,000	0.1	6-9

(4) Working environment

Working environment in each machinery room related to operation of the coke oven will be maintained at a desirable level by means of pressurizing or sealing, in addition to air-conditioners. Control rooms and resting rooms will also be provided with air-conditioning.

Chapter 7 Construction Plan

Chapter 7 Construction Plan

7.1 Plant Facilities and Equipment

7.1.1 General

The coke making process consists of coal receiving and preparation, coke oven, coke handling and shipping, and gas purifying.

In the coke receiving process, the imported coal transported by ship is unloaded by using unloaders and the domestic coal transported by trucks is temporally stored in the receiving bin, and then, they are piled up in the coal yard by using stackers. Coals are stacked in the yard according to their type and brand. The storage capacity is 60 days in consideration to supply and demand trends and the size of shipment. The coal preparation process crushes and blends different brands of coal in proportions to produce high-grade quality of coke.

The coke making process consists of the coke oven and ancillary equipment for charging of coal, pushing and quenching of coke and is the most important process in the coke making plant.

The coke handling and shipping process involves adjusting the size of coke which has been quenched in the quenching tower after pushed by using the coke cutter and screening equipment, which is then stacked in the coke yard and is loaded to a ship as required.

The gas purifying process cools gas and tar produced in the coke oven, separates tar and ammonia liquor from the gas, removes ammonia, hydrogen sulfide, and BTX, and distributes the purified gas under pressure to other sections.

7.1.2 Process Flow

The entire process flow at the coke making plant is illustrated in Fig. 7-1, the coal receiving/ preparation and the coke handling/shipping process flow in Fig. 7-2, and the gas purifying process flow in Fig. 7-3.

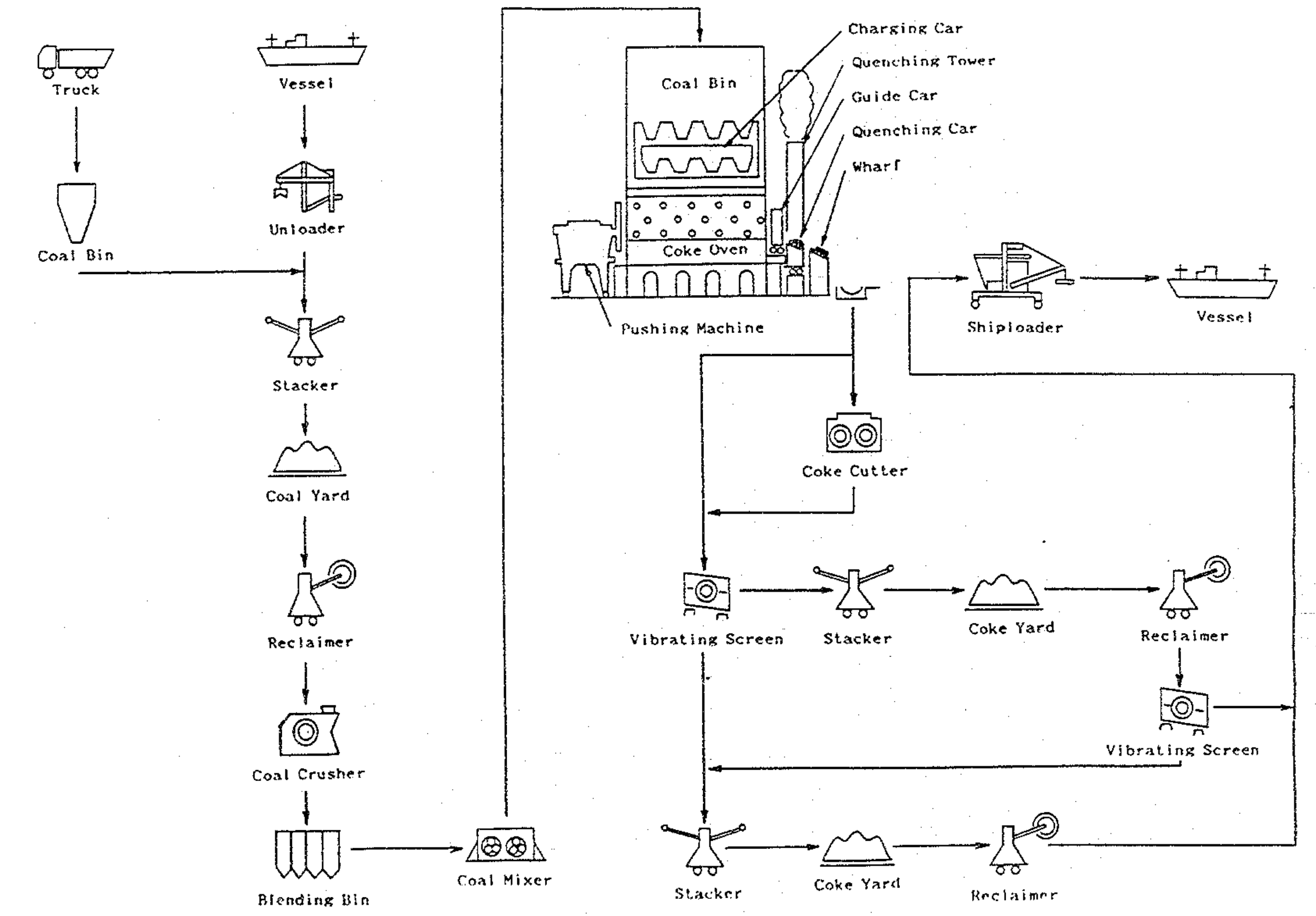


Fig.7-1 COKE MAKING PROCESS FLOW

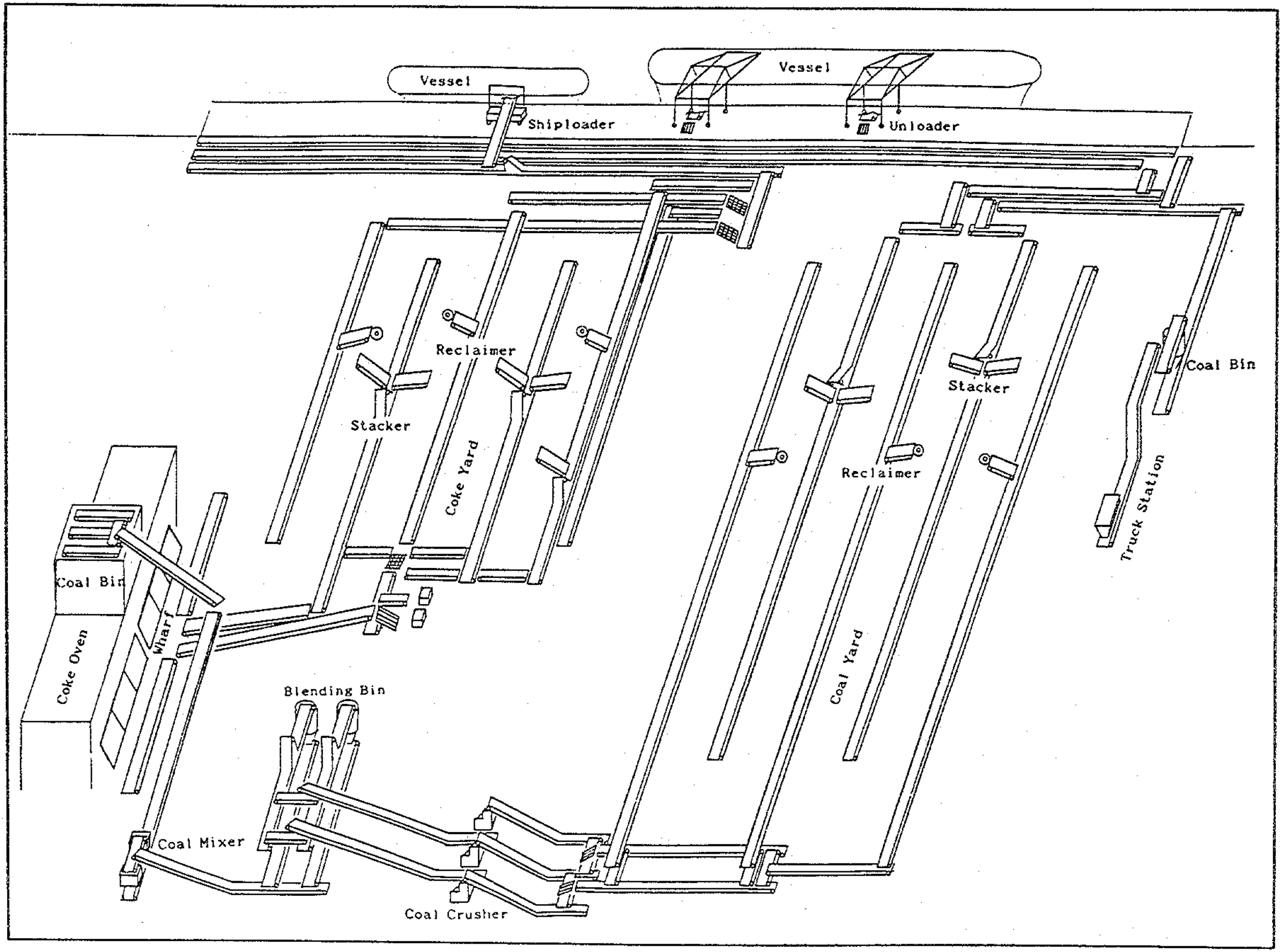


Fig.7-2 COAL RECEIVING/PREPARATION AND COKE HANDLING/SHIPPING PROCESS FLOW

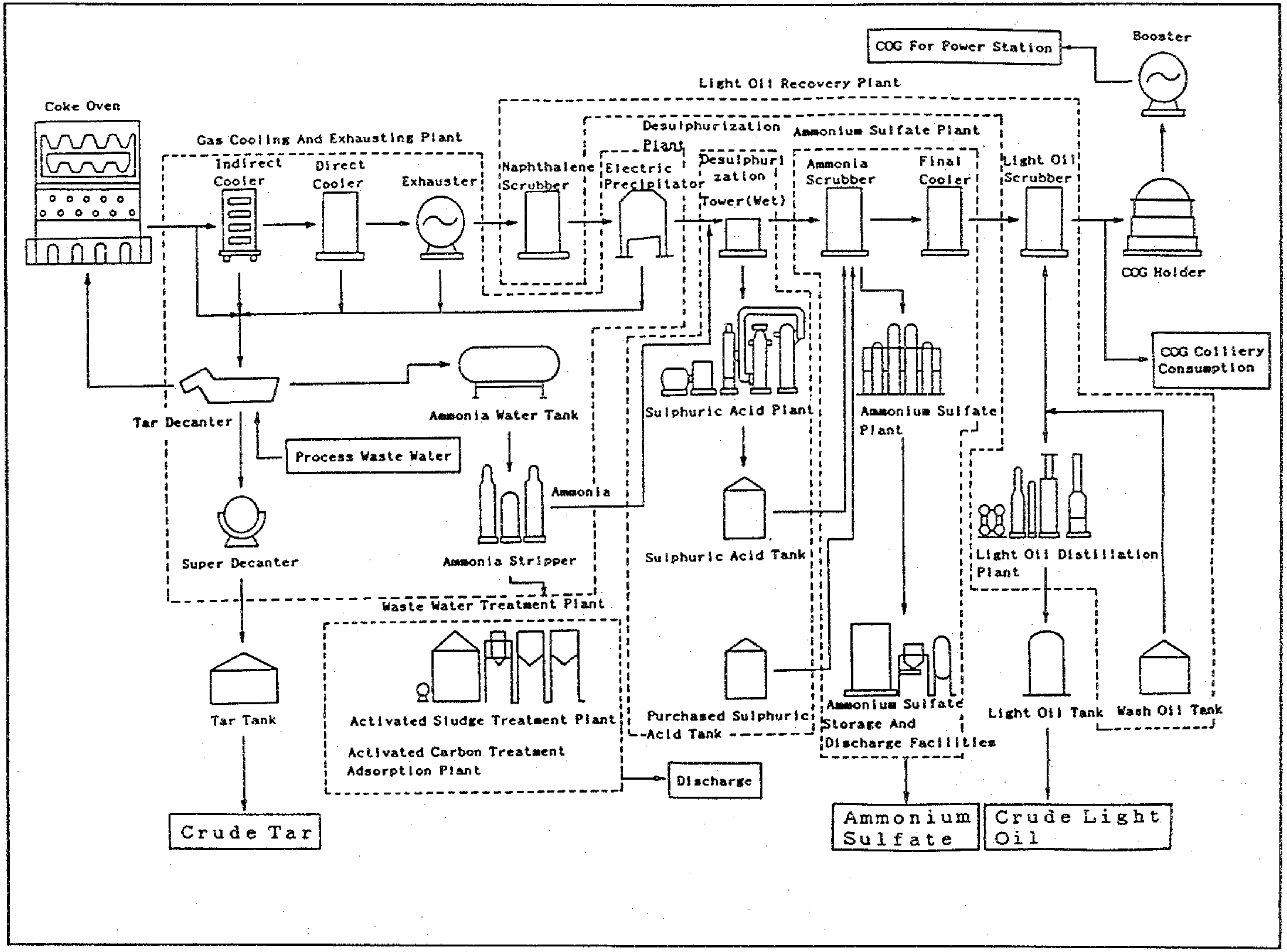


Fig.7-3 GAS PURIFYING PROCESS FLOW

7.2 Coal Receiving and Preparation Facilities

7.2.1 General

The increase in steel plant size and improvement of operating efficiency have led to significant improvement of the coke making plant and its related facilities and equipment to a more refined level. While active improvement has been made in mass production capacity, including construction of large coke ovens, new technologies and processes including pollution control equipment have been introduced to address issues related to availability of coking coal, energy and environmental protection. Most recently, coke making plants are increasingly automated for labor saving.

The coal receiving and storage process involves the unloading of coal transported by ship or truck by using the unloaders, and the piling up in the coal yard by using the stackers. These equipment have become larger in response to an increased use of large ships for coal transport, with unloading and stacking capacity of 1,500 tons – 3,000 tons/hour. In the coal yard, coals are stacked separately for each brand. The storage capacity varies with supply and demand conditions and the size of shipment, and most of coke making plants in Japan maintain 50 – 60 days of inventory.

In the coal preparation process, different brands of coals are crushed and blended in proportions required to produce high grade coke. The process sometimes combines crushing and blending processes in various forms.

The crushing process is necessary since the coal is a heterogeneous mixture of different constituents, which cannot produce hard coke with homogeneous quality if it is used without prior treatment. In particular, it is difficult to ensure desirable reaction among different coal particles of the coal charge, which blends many types of coal, in the carbonization process in the coke oven. To produce hard coke with even quality, therefore, coal crushing is an indispensable process. In general, the coal charge is crushed until 3mm or less in grain size accounts for 85% of total.

Coal blending is also essential in obtaining specific coke strength, for the coal mined as natural resources does not provide a balanced combination of coking property and the degree of coalification which is required to high quality coke. Thus blending different types of coal has become a normal practice to achieve the purpose.

The coal charge blended with constant feed weigher through the blending bin is overlapped in different layers on the beltconveyor, thoroughly mixed in the coal mixer, and sent to the coal bin.

Important assumptions made in plant design and operation planning are as follows:

1) Coal's moisture content is 9% on average.
2) The daily coal receiving and preparation capacity is 4,020 tons-wet on average.
3) Imported coal is delivered by ship and domestic and Colombian coals by truck.
4) Operating hours of major facilities are as follows:

	Coal Receiving (hours/day)	Yard – Blending Bin (hours/day)	Blending Bin – Coal Bin (hours/day)
Operating Hours	15	15	18
Line Switchover	3	3	–
Meal Hours	3	3	3
Inspection or Maintenance	3	3	3

5) 85% of the coal charge are 3mm or smaller in grain size.
6) The coal receiving and preparation lines are provided with samplers and conveyor weigher for quantitative monitoring and quality control.

7.2.2 Coal Receiving Facility

(1) Domestic coal

Domestic and Colombian coals are delivered to the site by truck and are transported through a hopper to a bin for temporary storage, from which they are transported by beltconveyor and are stored by stackers in the coal yard according to the brand.

Coal Brand	Blending Ratio	Consumption [t-wet/day]	No. of 50-ton Trucks Required	
Domestic Coals				
LAS	27%	1,085	1,085 x (7/6) ÷ 50 = 25.3 ->	26
FNO	5%	201	201 x (7/6) ÷ 50 = 4.7 ->	5
BOYACA	3%	121	121 x (7/6) ÷ 50 = 2.8 ->	3
Imported Coals				
L.V. U.S. coal	25%	2,613		
M.V. U.S. Coal	40%			
Total	100%	4,020		34

- No. of 50-ton trucks received per day = 34 x 1.2 = 41 trucks/day
- Average time required per truck = 24 x 60 ÷ 41 = 35 minutes
- Time required for handling by beltconveyor per truck (allowance factor = 50% or up) = 15 minutes
- Handling capacity of receiving beltconveyor = 50 tons x 60 ÷ 15 = 200 tons/hour
- Storage capacity of receiving bin = 300 tons x 5 tanks
- Handling capacity of feeding beltconveyor = 1,500 tons/hour

(2) Imported coal

Imported coal transported by ship is landed by unloaders, transported by belt conveyors, and stored by stackers in the coal yard according to the brand.
Capacities of the unloaders and the stackers are assumed in consideration to generally accepted demurrage conditions at various international ports, as follows.

- Unloader capacity = 1,500 tons/hour x 2 units
- Coal stacker capacity= 1,500 tons/hour x 2 units

(3) Coal yard

The coal yard is assumed to have storage capacity of 60-day supply by taking into account possible changes in delivery schedule (strike in coal mine, unfavorable weather, etc.), weathering of coal, and quality control requirements.

·Storage capacity of coal yard = 4,020 tons/day x 60 days = 240,000 tons

For convenience of quality control (for each brand) and yard work, the coal yard consists of 4 sections (25,000m^2 each) with storage capacity of 60,000 tons each.

7.2.3 Coal Preparation Facility

(1) Coal feeding facility

The coal stored in the coal yard is took out evenly and continuously from each section by using the coal feeding equipment (reclaimer) and transported to the crusher by belt conveyors. The crushed coal is sent to the blending bins. The constant feed weigher is provided below each blending bin to feed different brands of coal according to specific ratio. In general, the blending bins are provided in number more than types of coal to be blended, because one brand may use a few bins when blended in large quantities. The blended coal is mixed in the coal mixer and is sent to the coal bin by beltconveyor.

The coal yard arrangement requires 2 coal feeding lines. The reclaimer's handling capacity in each line is determined with load factor of 80% by taking into account possible fluctuation of feeding volume and moisture content.

· Capacity in each line = 4,020 tons/day ÷ (15 hours x 2 x 0.8) = 200 tons/hour

Thus, feeding capacity of the reclaimer and conveyor is assumed to be 200 tons/hour/line.

(2) Crusher

The crushers used at the plant are expected to have the following characteristics:

1) Capable of crushing in large quantities and stably
2) Crushing performance to ensure grain size distribution as evenly as possible
3) Producing the minimum amount of particles of fine coal
4) Solid construction with ease of maintenance
5) Producing minimum amounts of noise and adhesion

For the above reasons, the impact type or the hammer type which crushes coal by shock force is widely used.

Coking coal took out from the yard is crushed in each line to a specific grain size

distribution. One spare unit is provided for repair needs.
The hammer crusher has been selected on the account of ease of grain size adjustment. The conceptual diagram is shown in Fig. 7-4. The hammer crusher can also minimize dust production in the crushing process to reduce load for the dust collector.

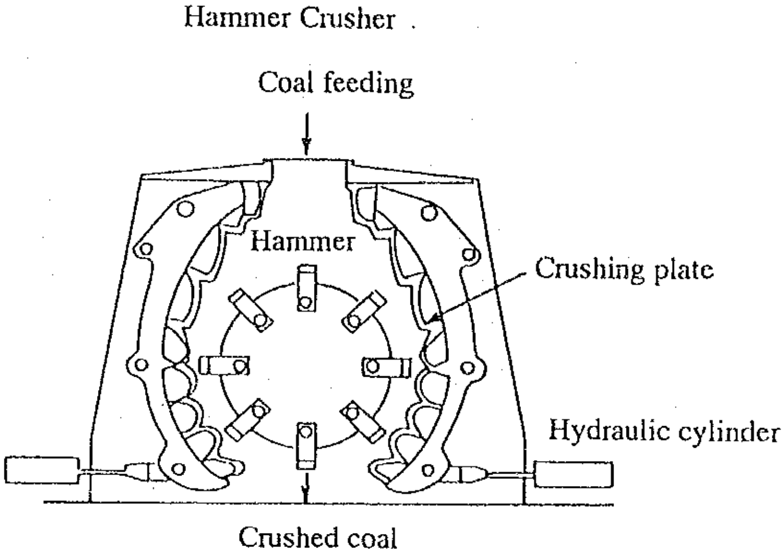


Fig.7-4 CONCEPTUAL DIAGRAM OF HAMMER TYPE COAL CRUSHER

(3) Blending bin

The blending bin stores coking coal according to the brand and serves as a buffer bin when failure occurs in the preceding process. The number of bins used is governed by the number of brands and their blending ratio. At the proposed plant, 5 brands at maximum are used with the maximum ratio of 20% and the average stock level of 70%. Also, the maximum duration of repairing or replacing belt conveyors is assumed to be 12 hours in order to minimize a risk of plant shutdown due to failure in the coal receiving line.

· Storage capacity of blending bin = 4,020 tons/day x (12 hours/24) ÷ 0.7 = 3,000 tons/day

Assuming that the maximum feeding capacity of each bin is assumed to 20%, as determined from the blending plan, 8 bins are required with 2 spare bins. As a result, the total storage capacity is 300 tons/bin x 5 x 2 rows.

(4) Constant feed weigher (CFW)

CFW combines a conveyor weigher and a discharge feeder. The amount of coal fed is measured by Merrick or electronic weigher, and is converted to electronic signals for comparison with the transported amount and a preset value. Based on the result, a variable speed (VS) motor installed in the belt feeder is controlled to obtain the feed equivalent to the present value.
CFW also controls coke quality by blending different types of coal in response to the changes in coking coal properties and blending ratio. The capacity of CFW per each bin is determined as follows:

· Maximum: 4,020 x 0.20 ÷ 18 hours = 50 tons/hour
· Minimum : 4,020 x 0.03 ÷ 18 hours = 6 tons/hour

The handling capacity of the collecting belt-conveyor is 300 tons per hour.

(5) Coal mixer

There are several types of devices to mix coals after blending, including motor-operated types such as the rotary type drum mixer and the pack mill, and the gravity method to use a mixing chute. For the project, a double roll mixer equipped with 2-axle rotors, most widely used, is selected. The capacity is 300 tons/hour (1 unit).

(6) Coal bin

The coal conveying line is reduced to one after the blending bin. To avoid plant shutdown due to failure in beltconveyor, 12 hours are allowed for replacement and repair of beltconveyor with the average inventory level of 70%.

· Storage capacity of coal bin = 4,020 tons/day x (12 hours/24) ÷ 0.7 = 3,000 tons/day

Thus, the total storage capacity of coal bins are assumed to be 1,000 tons/bin x 3 rows.

7.2.4 Pollution Control Facilities

(1) Water sprinkling system for coal and coke yards

A sprinkler system is provided in each of the coal and coke yards and sprays water to coal and coke piles if dust is expected to occur due to weather conditions. The system should be remotely controlled from the operation room.

(2) Regulating reservoir and treatment facility for surface run-off from coal and coke yards due to rain fall

Assuming that the monthly maximum precipitation is 119mm, the daily maximum precipitation 43mm, surface run-off factor for the coal yard 0.4, and that for coke yard 0.1, the storage capacity of the regulating reservoir and its treatment capacity are calculated from the yard areas, as follows:

Monthly:	Coal Yard	100,000 m^2 x 0.119 x 0.4 = 4,800 m^3/month	--->	160 m^3/day
	Coke Yard	64,000 m^2 x 0.119 x 0.1 = 800 m^3/month	--->	30 m^3/day
		Total		200 m^3/day

Daily:	Coal yard	100,000 m^2 x 0.043 x 0.4 =	1,720 m^3/day
	Coke Yard	64,000 m^2 x 0.043 x 0.1 =	280 m^3/day
		Total	2,000 m^3/day

Thus, the reservoir's storage capacity is assumed to be 2,000m^3 and the treatment capacity 10m^3/hour. Fig. 7-5 shows a conceptual view of the regulating reservoir and treatment facility for surface run-off from the yards. Note that run-off water stored in the reservoir is discharged after pH adjustment and sludge removal.

(3) Dust collector

To maintain good working environment in the crusher rooms, blending bin, and coal bin, dust is collected at sources and is removed through bag filters before release to the air.

(4) Other dust prevention measures

To prevent dust generation during the coal unloading and transportation, the unloaders are equipped with water sprinklers, and belt conveyors after crushers with windshields.

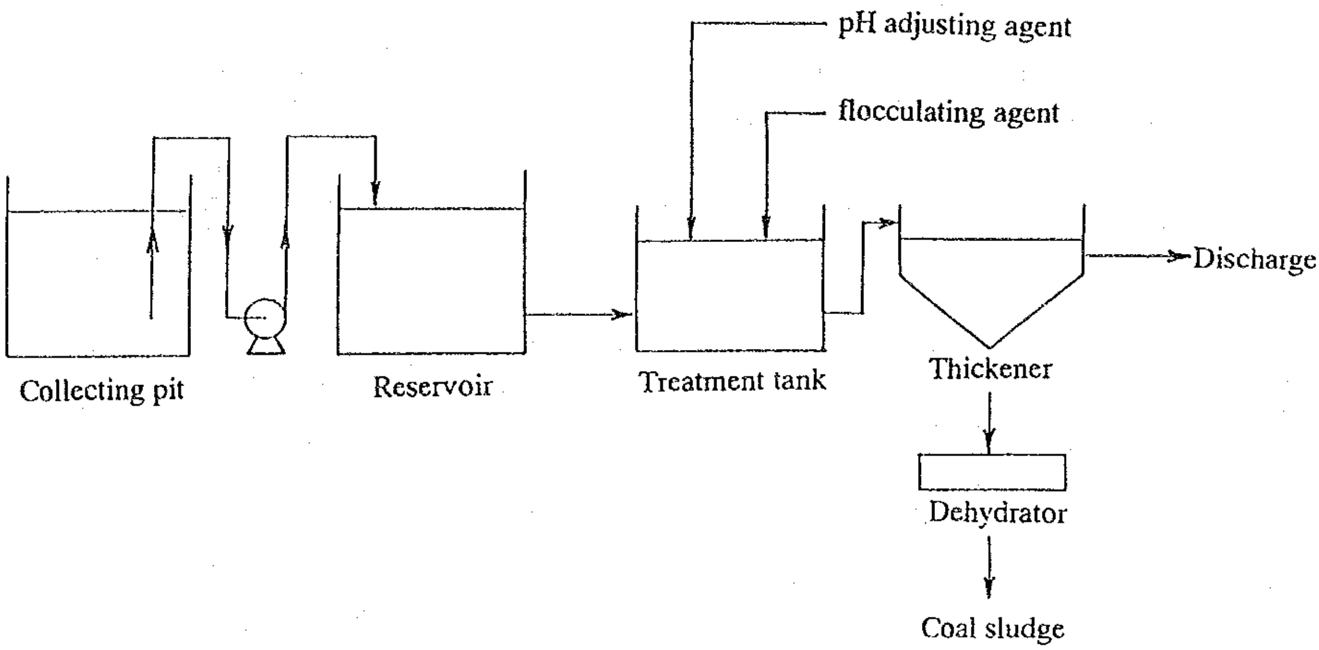


Fig.7-5 SURFACE RUN-OFF RESERVOIR AND TREATMENT FACILITY

7.3 Coke Oven Facility

7.3.1 General

As shown in Fig. 7-6, the coke oven facility consists of a coke oven to carbonize coal, a charging car to drop coal into the coking chamber, a pusher machine to discharge coke from the coking chamber, a coke guide car to lead red-hot coke from the coking chamber to a quenching car, and the quenching car to cool down red-hot coke, and a locomotive to draw the quenching car, which are collectively called moving machine around the coke oven.
Auxiliary equipment includes a heating arrangement and a gas reversing arrangement to supply gas for carbonization of coal charged to the coke oven. The gas reversing arrangement reverses a flow path of fuel gas and air at a specific interval in order to obtain waste heat recovery and preheating effect in the coke-oven regenerator. In addition, an ascension pipe is provided on the top of the coking chamber to aspirate COG and tar generated in the carbonization process and lead them to a dry main which is collecting main to recover by-products generated from each coking chamber. The dry main is equipped with a flare stack (flare pipe) to burn crude gas at the time of interruption of electric service and other emergency situations.

The chamber type by-product recovery coke oven is selected in consideration to the ease of temperature control, high thermal efficiency, and relatively small NOx generation.
Major assumptions for coke oven design and operation planning are as follows:

1) Moisture content of coal charge (average) is 9%.
2) Bulk density of coal charge is 0.70 tons-dry/m^3.
3) Coke yield is 75%.
4) The working rate of the coke oven is 125% at maximum.
5) The coke oven is operated for 18 hours per day.
   · Resting and meal time: 1 hour/shift x 3 shift/day
   · Daily inspection and meeting: 1 hour/shift x 3 shift/day

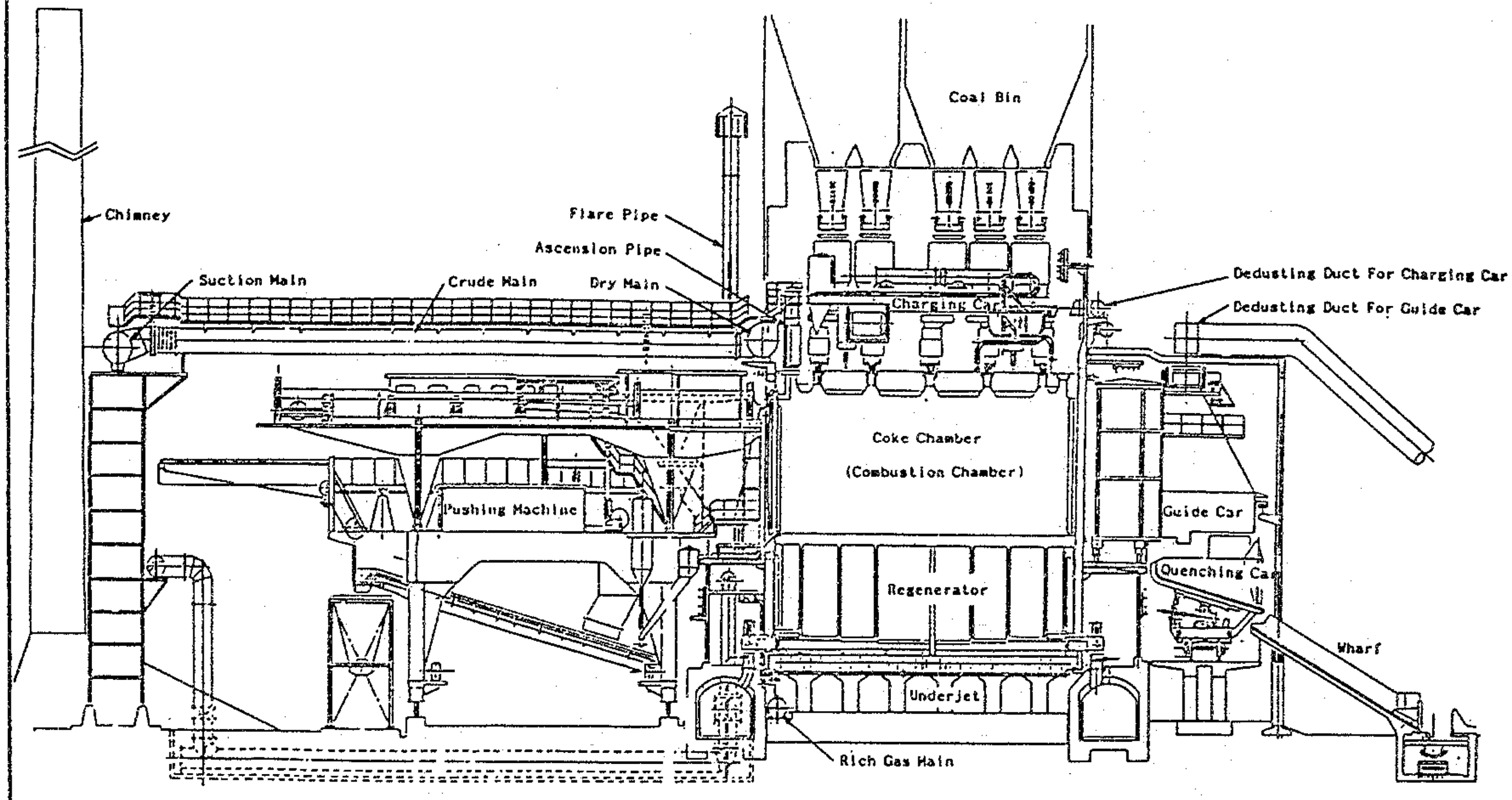


Fig. 7-6 CONCEPTUAL DIAGRAM OF COKE OVEN

7.3.2 Coal Carbonization Mechanism

(1) General description

Fig. 7–7 shows a coal carbonization mechanism. When the coal is charged to a coke oven, it starts to generate moisture and a small amount of adsorption gas below 100°C. The condition continues up to 300°C, without changing the basic quality of coal. When temperature rises above 300°C, the coal softens and melts to produce gas, tar, and ammonia liquor rapidly, while expanding itself. A further temperature rise causes coal grains to melt and react with each other to form porous coke. The softening and melting phenomenon completes near 500°C, and porous and lump semicoke is produced. As temperature rises further, high temperature tar and gas containing hydrogen rich produce and coke starts to contract and have cracks. Generation of hydrogen gas reaches its peak level at around 700°C and declines gradually to produce high temperature carbonized coke above 900°C.

(2) Carbonization process in the actual coke oven

As shown in Fig. 7–8, the coal charged to a chamber type coke oven receives heat from combustion chambers on both sides, and is gradually carbonized toward the center of the oven. Under these conditions, the coal near the oven wall is rapidly carbonized to coke after a certain period of time after charging, as shown in Fig. 7–9, while the inner side forms a softened and melted layer (plastic layer), and a further inner side is an unreacted coal charge. The rate of carbonization varies with position. Generally, the texture of coke is dense near the wall and becomes coarse toward the center, with decreased strength. The coke in this state is subjected to mechanical and thermal shock when being discharged from the coking chamber, or at the time of quenching, cutting, screening, and stacking on the yard, becoming produce coke with mean grain size of around 50mm.

Tar	—		Low temperature tar	High temperature tar (aromatic series) (small amount) (secondary thermal cracking products of low temperature tar)	
Gas liquor	Water of evapo-ration	Water of crystallization, constitution (small amount)	Water of constitution (large amount)	—	
Gas	Release of gas of occlusion ←→ (CH$_4$ and its homologues)		Low tempe-rature de-composed gas	High temperature decomposed gas ←— (Mainly H$_2$, CO) - - -> (Mainly H$_2$)	
Coal, coke	(No change in basic quality of coal)		Softening/melting Expansion Primary thermal decomposition	Solidified contraction Semi-coking Secondary termal decomposition	Coking

0 200 400 600 800 1000

Carbonization temperature [°C]

Fig. 7-7 COAL CARBONIZATION MECHANISM

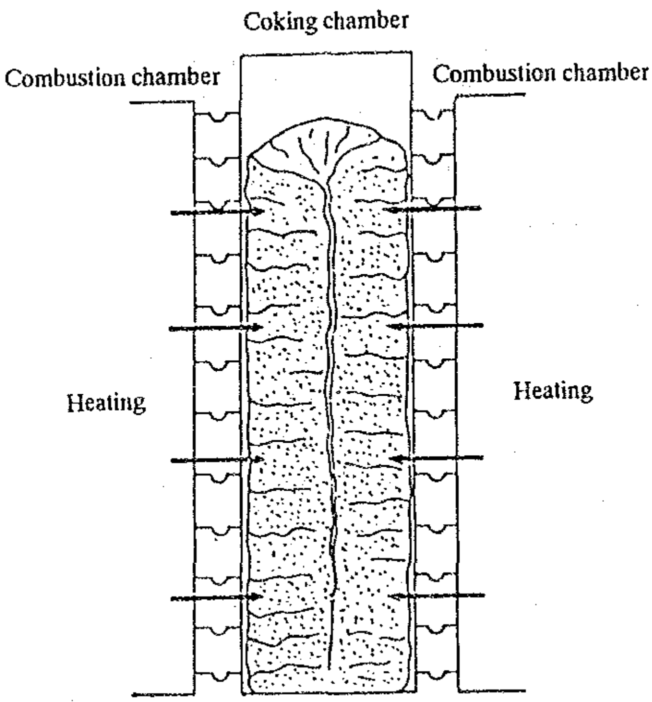


Fig. 7-8 STATE OF COKE AFTER CARBONIZATION IN THE COKING CHAMBER

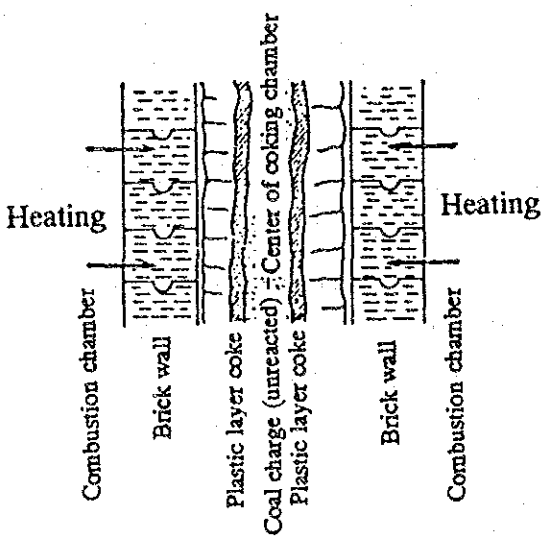


Fig. 7-9 STATE OF CARBONIZATION IN THE COKING CHAMBER

7.3.3 Structure of Coke Oven

(1) General description of structure of coke oven

At present, almost all of coke ovens used to produce for blast-furnace coke are chamber type by-product recovery coke ovens. The coke oven is mainly made of silica bricks and fire clay bricks (chamotte bricks), with small portions of insulating bricks and red bricks.
Cove ovens are divided into single type using COG of high calorific value only as fuel, and compound type using COG and blast furnace gas (BFG) of low calorific value. The project uses the COG single type because of dedicated coke making industry.
For convenience of understanding, the coke oven structure is described, mainly focusing on Koppers type oven, as follows.
Fig. 7-10 shows a traverse section of Koppers coke oven. On the upper half of the coke oven, the coking chambers and combustion chambers are arranged alternately. Regenerators are arranged in the lower half.
The coking chamber is a long and narrow space, 6.5m high, 16.5m long, and 450mm wide. It is tapered by 70mm in a direction of coke pushing in order to minimize pushing load resistance. The top of the coking chamber has 5 holes to charge coal, and the oven top in the pushing side is equipped with ascension pipes to remove gas and tar generated. Oven doors are installed in the pushing side (PS) and coke side (CS) of the coking chamber, removable during the coke pushing operation.
The combustion chamber burns fuel gas and transfers generated heat to the coking chamber. If COG is used as fuel, it is sent directly from the underjet via pipes. Air is inhaled from a waste gas reversing valve, preheated in the regenerator, and supplied to the combustion chamber through burners.
Bricks are laid inside of the regenerator which are designed to carry out heat exchange by passing gas between the bricks. In other words, the regenerator improves combustion efficiency by preheating air to be burned in the coke oven, thereby to rise flare temperature, while recovering waste heat.
The coke oven is made of silica and fire clay bricks, which expand or contract according to temperature. To prevent gap or looseness from occurring between bricks, the coke oven is equipped with backstays or tie-bolts which hold the coking chamber in a longitudinal direction by aid of springs. On the other hand, oven end walls and tie-belts are used to hold each battery (50 chambers) in a direction of battery.

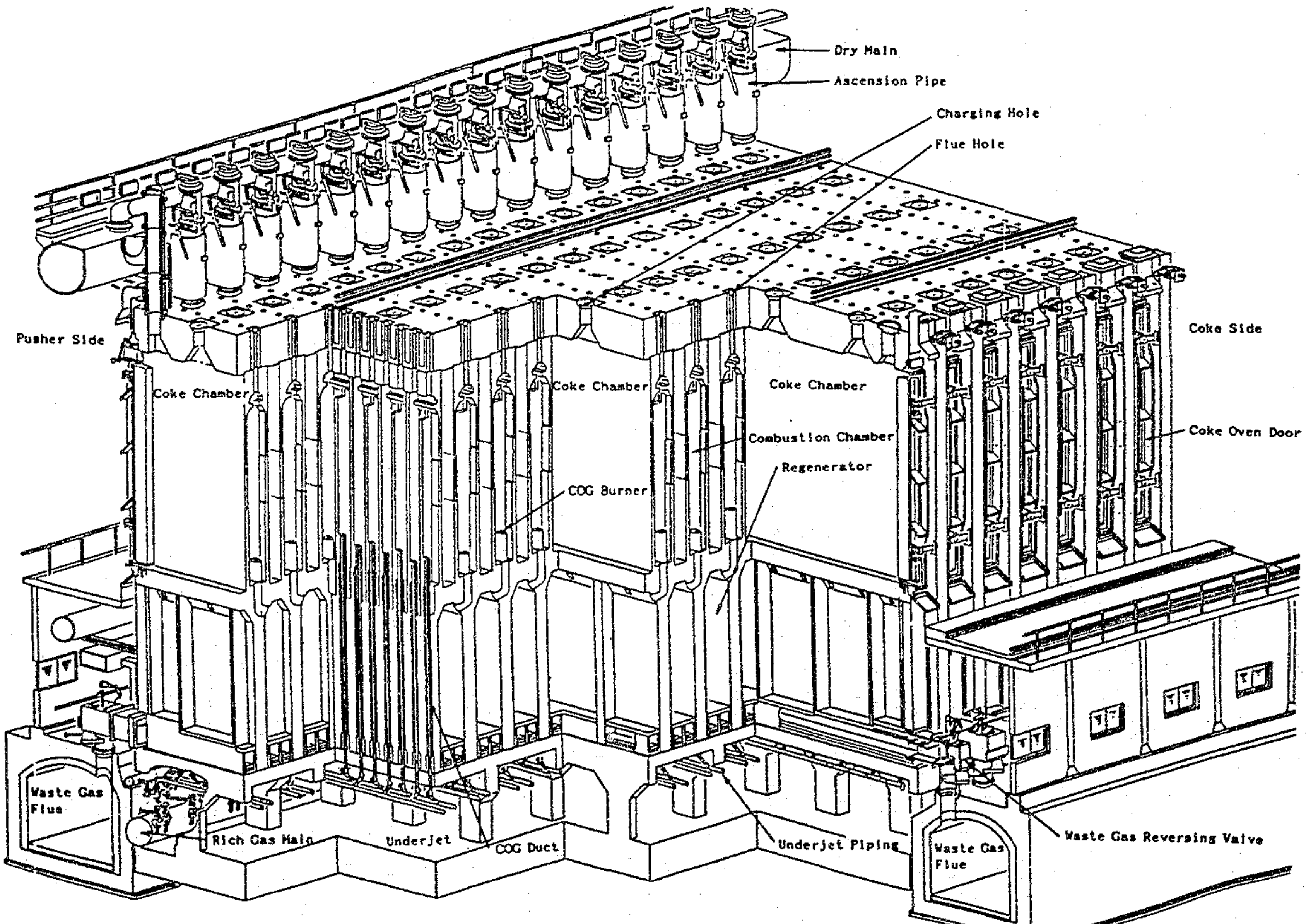


Fig.7-10 SECTIONAL VIEW OF COKE OVEN BLOCK

(2) Basis of determining the coke oven capacity

The number of ovens to be installed in a coke oven is expressed by the following equation:

$$n = A \div \{V \cdot D \cdot P \cdot (24/H)\}$$

Values of major parameters for the proposed plant are summarized in Table 7-1.

Table 7-1 PARAMETERS TO DETERMINE COKE OVEN CAPACITY

Parameter	Item	Value
V	Effective inner volume (cold)	42.5 [m^3/chamber]
D	Bulk density of coal charge	0.70 [ton/m^3]
P	Total coke yield	75 [%]
H	Gross coking time	19.2 [hours]
A	Coke production	2,740 [tons/day]
n	No. of ovens	

On the basis of the above defined parameters, the number of ovens to be installed at the coke oven is determined as follows:

$$n = 2{,}740 \div \{42.5 \times 0.70 \times 0.75 \times (24/19.2)\} = 100 \text{ chambers}$$

Gross coking time, which is a major factor in determining the coke oven capacity, is described as follows. Fig. 7-11 shows the relationship among the working rate of the coke oven, gross coking time, and average flue temperature. The standard operating rate of the project is assumed to be 125%(=working rate).
The working rate is defined as follows.

$$\text{Working Rate [\%]} = \frac{\text{Number of Pushing/Day (125)}}{\text{Number of Chambers (100)}} \times 100 = \frac{\text{24 [hours]}}{\text{Gross Coking Time (19.2 [hours])}} \times 100 = 125[\%]$$

The relationship between gross coking time, net coking time, and soaking time is expressed in the following equation:

GCT = NCT + ST

GCT: Gross coking time(time between charging of coal and pushing of coke)

NCT: Net coking time (time between charging of coal and completion of carbonization in the center of the oven)

ST : Soaking time (ripening period for coke after carbonization, until pushing)

Note that soaking time of 2 hours or longer contributes to improvement of coke quality, particularly strength.

The average flue temperature of the coke oven should be limited to 1,470°C at maximum and 1,000°C at minimum for each flue to protect bricks, which are thus considered to be operable temperature ranges.
In practice, however, temperature variation occurs within the flue row, due to temperature taper, reversing and carbonization process, between flue rows, as well as daily variation of average flue temperature, so that the range of the average oven temperature should be determined in consideration to these factors. For the project, the flue temperature as a basis of determining the design plant capacity is established at 1,130°C to ensure stable coke oven operation in the long term.

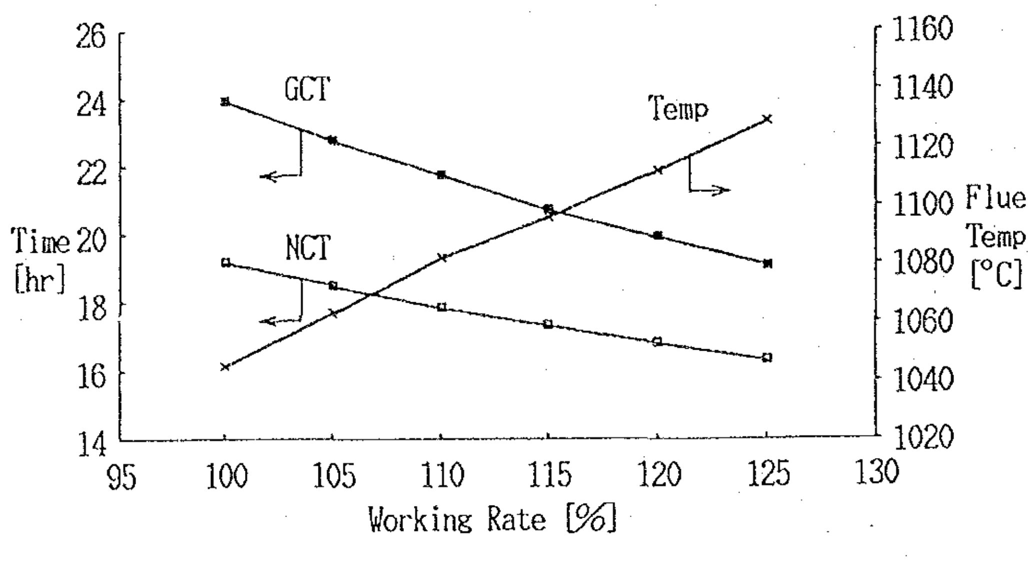


Fig. 7-11 WORKING RATE, GROSS COKING TIME, AND AVERAGE FLUE TEMPERATURE

(3) Specifications for bricks and mortars for oven construction

1) Bricks

Service life of the coke oven is governed by properties of coal, operating conditions, oven construction, and bricks used. Thus, properties of bricks used to build the coke oven should be thoroughly understood to operate the plant properly. Basically, coke oven bricks are expected to meet the following requirements:

· Excellent wear resistance
· Good heat conductivity
· High load strength at high temperatures
· Minimum thermal spalling
· Minimum thermal expansion
· Minimum chemical corrosion
· Dimensional accuracy

Silica bricks are widely used for coke ovens because they show excellent wear resistance, heat conductivity, and refractoriness. Table 7-2 shows types of bricks by part of coke oven block, and Table 7-3 qualities of major types of bricks.

Table 7-2 TYPES OF BRICKS BY PART OF COKE OVEN

Location	Silica Brick	Fire Clay Brick	Insulating Brick	Red Brick
Heating wall	o			
Both ends of heating wall		o	o	
Chamber roof	o			
Chamber sole	o			
Both ends of chamber sole		o		
Regenerator wall	o			
Regeneration brick		o		
Oven top		o	o	o
Buttress wall	o	o	o	o
Regenerator face wall			o	
Oven sole		o	o	o
Inner face of ascension pipe		o		
Oven door		o		
Waste gas flue		o	o	o

Table 7-3 QUALITIES OF MAJOR BRICKS

Quality	Location	Fire resistance S K	Nominal gravity	Nominal porosity [%]	Thermal linear expansion coefficient [%]	Point of load softeing 2kg/cm2 T1	Compressive strength [kg/cm2]	Chemical composition [%]			Applicable standard	Remarks
								SiO_2	Fe_2O_3	Al_2O_3		
Silica Brick	Coking chamber wall	more than 32 (more than 1,710)	less than 2.35	less than 22 23.5 (manual)	1,000 less than 1.25	more than 1,580	more than 350	more than 93	less than 2.0	less than 1.5	JIS-R2401 (1976) SC-1	Ordinarily dense
	Partition wall of combustion chamber	more than 32 (more than 1,710)	less than 2.35	less than 24	1,000 less than 1.25	more than 1,580	more than 300	more than 93	less than 2.0	less than 1.5	JIS-R2401 (1976) SC-2	Ordinarily semi-dense
	Regenerator and other	more than 32 (more than 1,710)	less than 2.35	less than 26	1,000 less than 1.25	more than 1,550	more than 200	more than 93	less than 3.0		JIS-R2401 (1976) SC-3	Ordinarily, commercial products

Quality	Location	Fire resistance S K	Bulk gravity	Nominal Porosity [%]	Compressive strength [kg/cm2]	Residual expansion coefficient[%]	Point of load softeing 2kg/cm2 T	Applicable standard	Remarks
Fire clay Brick	Coke oven general	more than 31 (more than 1,690)	[more than 1.90]	[less than 15kg : less than 24] [15`30kg : less than 26] [more than 30kg : less than 28]	more than 200	1,400 [0 ~ -0.6]	[more than 1,350]	JIS-R2304 (1976) N3 equivalent	Figures in [ ] not specified in JIS
	Regenerator	more than 31 (more than 1,690)	[more than 1.90]	less than 28	more than 150	1,400 [0 ~ -0.6]	[more than 1,350]	JIS-R2304 (1976) N6 equivalent	Figures in [ ] not specified in JIS
	Coke oven entrance	more than 33 (more than 1,730)	[more than 2.15]	less than 23	more than 200	[less than -0.5]	[more than 1,450]	JIS-R2304 (1976) N2 ~ 1 equivalent	
	Top of oven	less than 28 (less than 1,630)		less than 30	less than 120			JIS-R2304 (1976) N9 equivalent	

Quality	Location	Temperature not exceeding reheated contraction rate on 2% [ ]	Bulk gravity	Compressive strength [kg/cm2]	Thermal conductivity [kcal /mh] (average temperature 350±10)	Applicable standard	Remarks
Insulating Brick	Center of coking chamber ceiling, oven end, external wall of regenerator, other	900	less than 0.70	more then 25	less than 0.17	JIS-R2611 (1976) B1 equivalent	
	Center of coking chamber ceiling, oven end, external wall of regenerator, other	1,200	less than 0.80	more then 25	less than 0.22	JIS-R2611 (1976) B4 equivalent	

2) Mortar for coke oven construction

As the coke oven is operated for a fairly long period of time once built, mortar is an important element to be carefully selected and designed.

Mortar for coke oven construction should meet the following requirements:

(a) High temperature section (coking chamber)
- · Thermal expandability/contractility similar to those of bricks
- · Adequate thermal adhesive strength
- · Not softening at high temperatures
- · Wear resistance
- · Not producing cracks after drying
- · Good workability

(b) Low temperature section
- · Relatively high thermal adhesive strength at low temperatures
- · Thermal expandability/contractility similar to those of bricks
- · Not producing cracks after drying
- · Good workability

Qualities of mortar for coke oven construction are summarized in Table 7-4.

Table 7-4 QUALITIES OF MORTAR FOR COKE OVEN CONSTRUCTION

Category/type	Silica	Silica	Chamotte	Chamotte	Chamotte	Chamotte	Insulating
State	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Fire Resistance (SK)	32	27	30	31	26	26	Maximum 1,200°C
Water Added (%)	30	32	33	32	29	34	38
Grain size							
Maximum (mm)	1	0.6	0.6	0.3	1	0.3	0.3
0.074mm>(%)	46	65	62	63	46	60	63
Chemical Composition (%)							
Al_2O_3	2.1	3.7	36.2	38.8	19.8	34.2	31.6
SiO_2	93.3	90.5	56.7	54.5	75.9	58.5	62.4
Fe_2O_3	0.8	1.3	1.7	1.8	1.4	2.1	1.9
Adhesive/Bending Strength (kg/cm^2)							
105°C	10.8	16.2	18.5	20.7	10.2	22.6	14.6
400°C	7.7	8.5	–	–	–	–	11.5
800°C	9.6	14.7	28.1	27.5	12.5	29.4	12.0
1,000°C	14.2	26.0	42.0	34.6	15.7	44.0	18.7
1,200°C	30.0	28.5	64.3	66.8	30.4	70.8	20.3
1,400°C	47.4	–	–	95.6	–	–	–
Sintering Temperature (°C)	950	700	–	–	850	–	–
Point of load softening (T1) (°C)	1,500	1,450	–	–	–	–	–

(4) Moving machine around the coke oven

Moving machine used for operation of the coke oven includes a charging car, a pusher machine, a coke guide car, a quenching car, and a locomotive. These machines are designed in consideration to automation, pollution control and operation safety.

1) Basic design conditions

(a) The coke oven consists of 100 (batteries A and B) and is operated by one team.
(b) One team consists of the following moving machine:

· Pusher machine	1
· Charging car	1
· Coke guide car	1
· Quenching car and locomotive	1

(c) The cycle time of moving machine is 8 minutes and 30 seconds/oven or less.
(d) Working hours are 18 hours/day.
(e) The pushing sequence is every 5 ovens.
(Example) 100 ovens

-> 1 -> 6 -> 11 -> ···· -> 91 -> 96
-> 3 -> 8 -> 13 -> ···· -> 93 -> 98
-> 5 -> 10 -> 15 -> ···· -> 95 -> 100
-> 2 -> 7 -> 12 -> ···· -> 92 -> 97
-> 4 -> 9 -> 14 -> ···· -> 94 -> 99

(f) Each moving machine is automatically operated for each work unit (1 oven).
(g) One spare machine is reserved for each machine for maintenance and equipment failure.
(h) Moving machine is operated from the operation room, except for auxiliary equipment with less frequency of operation which is operated manually.
(i) An interlocking mechanism is provided to prevent accidents due to incorrect operation.

2) Arrangement of moving machines

General arrangement of moving machines in relation to the coke oven is shown in Fig. 7-12.

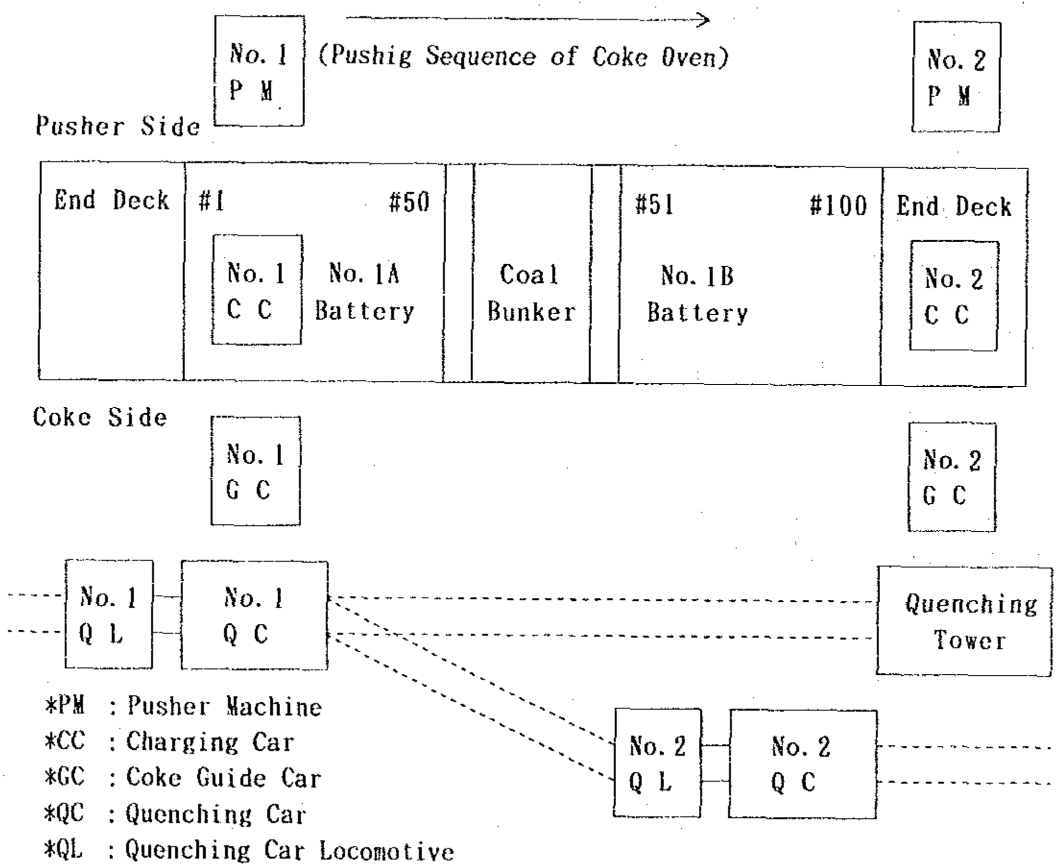


Fig.7-12 ARRANGEMENT OF MOVING MACHINES

3) Charging car

The charging car is made of gate frame of welded steel structure, with 5 hoppers, and has 8 wheels to run on rails laid over the oven. It loads and meters the coal charge from the coal bin and drops it to a specified oven. The charging sequence is controlled from the operation room on the frame.

The charging car consists of traveling equipment, hoppers, coal feeder, charging lid extractor, dust collector, hydraulic unit, cooling unit, over roof cleaner, air cleaner, and gate frame to mount these equipment.

The above equipment can be either automatically operated on the basis of a present program or manually in each work unit.

Fig. 7-13 shows a general view of the charging car.

4) Pusher machine

The pusher runs on the rails laid on the pusher side of the oven to a specific oven, extracts the oven door, pushes red–hot coke from the oven, cleans the oven door frame and levelling door, levels the coal charge, and disposes return coal and coke.

The pusher machine consists of traveling equipment, oven door extractor, oven door cleaner, frame cleaner, levelling door cleaner, pushing ram, return coke disposer, air scarfing device, levelling door opener, coal charge leveller, return coal disposer, hydraulic unit, air compressor, air–conditioning unit, and gate frame to mount them.

The above equipment can be either automatically operated on the basis of a present program or manually in each work unit.

Fig. 7–14 shows a general view of the pusher machine.

5) Coke guide car

The coke guide car runs on the rails laid on the platform to a specific oven, extracts the oven door, cleans the oven door and frame, and leads red–hot coke pushed from the oven to the quenching car.

The coke guide cars consists of traveling equipment, oven door extractor, coke guide device, oven door cleaner, frame cleaner, dust collection hood, connector, cooling unit, hydraulic unit, platform cleaner, and gate frame to mount them.

The above equipment can be either automatically operated on the basis of a present program or manually in each work unit.

Fig. 7–15 shows a general view of the coke guide car.

6) Quenching car and locomotive

The coke quenching car and the locomotive run on the rails laid on the coke side, loads red–hot coke pushed out from the oven, and after quenching at the quenching tower, feeds coke to the coke wharf. The quenching car and the locomotive are operated as a pair.

The quenching car consists of traveling equipment, coke bucket, gate opener, and truck frame to mount them, while the locomotive consists of driving gear and traveling control equipment, having a machine room and an operator cab.

Fig. 7–16 shows a general view of the locomotive and the quenching car.

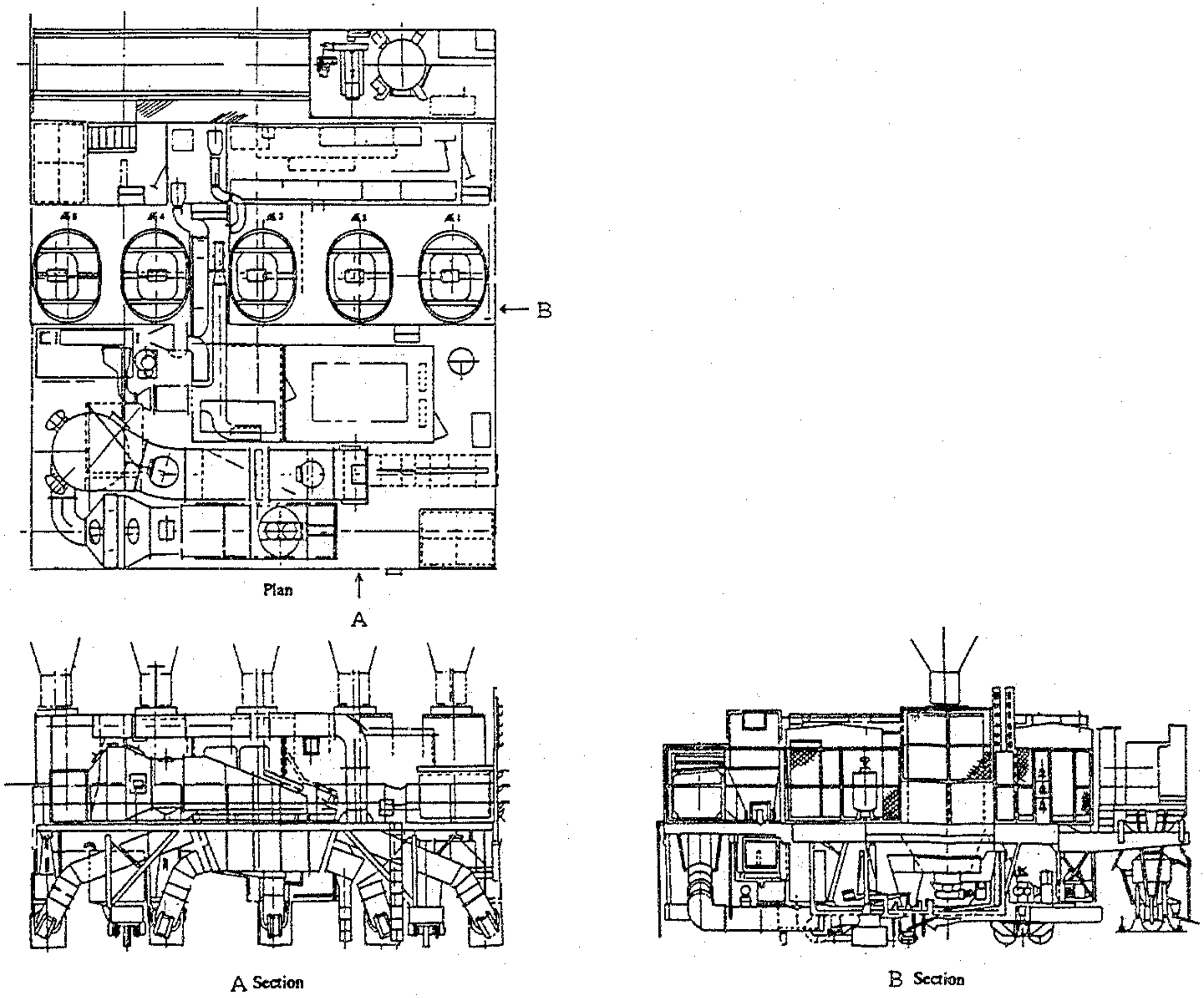


Fig.7-13 GENERAL VIEW OF CHARGING CAR

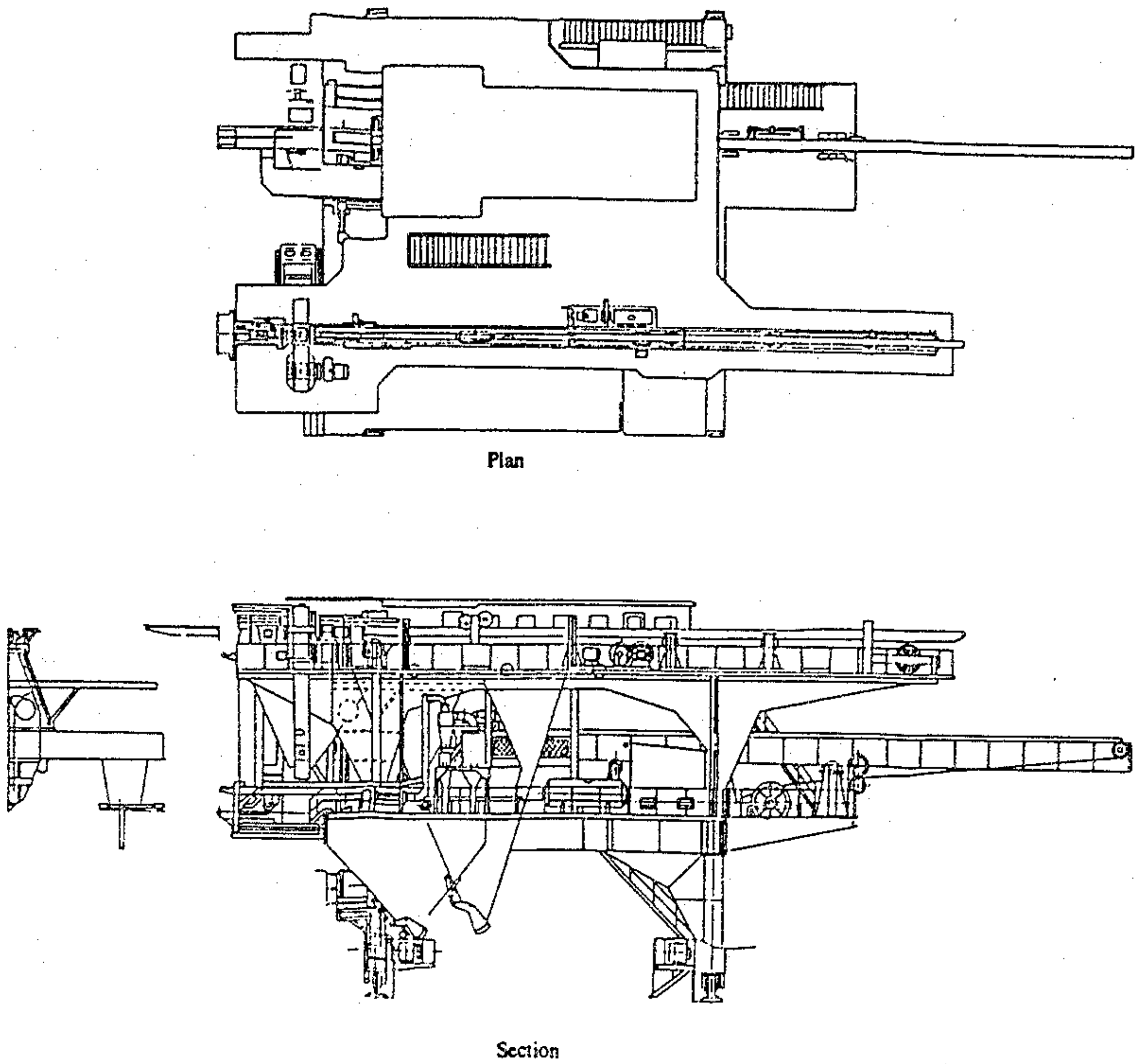


Fig.7-14 GENERAL VIEW OF PUSHER MACHINE

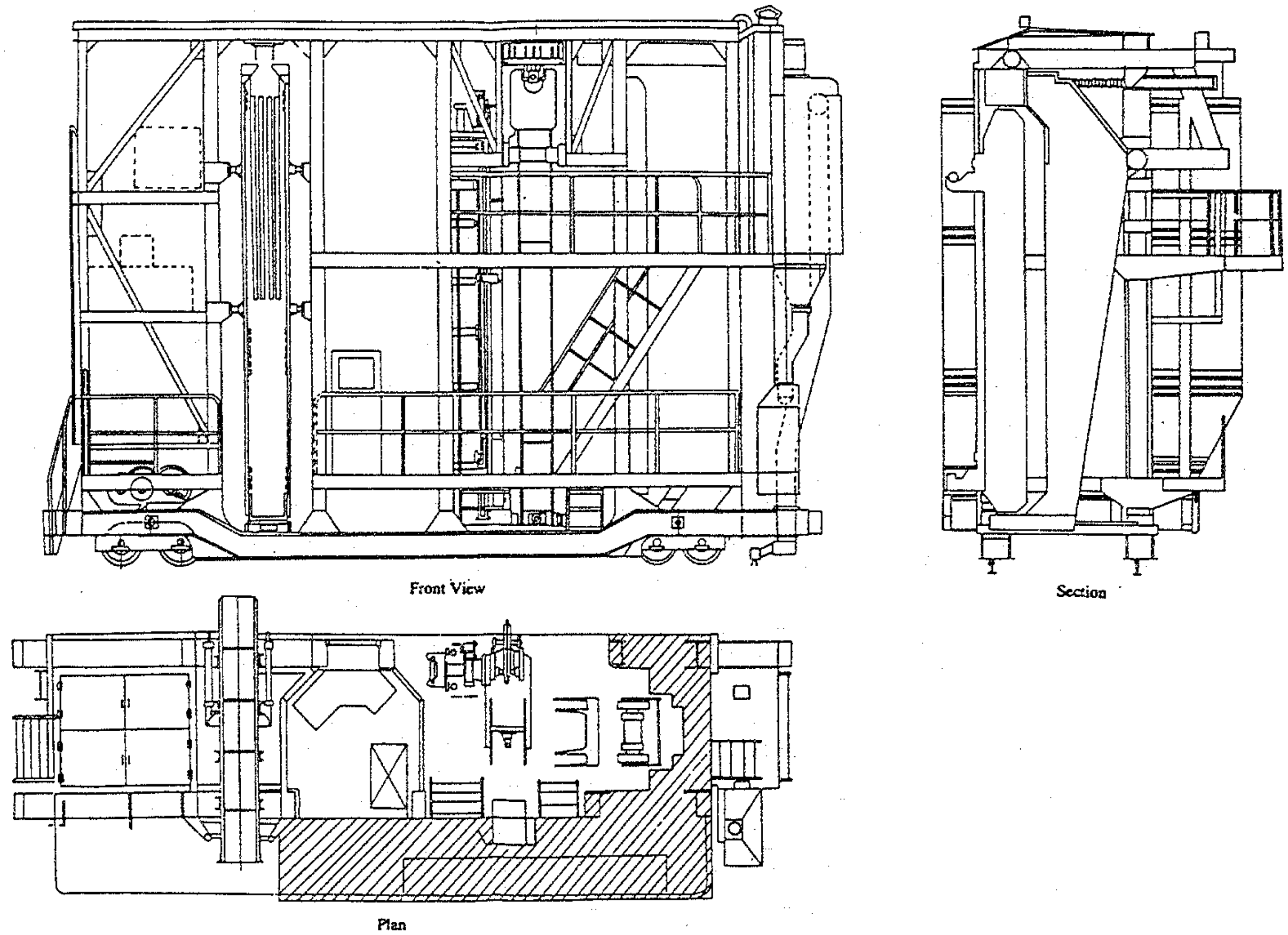


Fig.7-15 GENERAL VIEW OF COKE GUIDE CAR

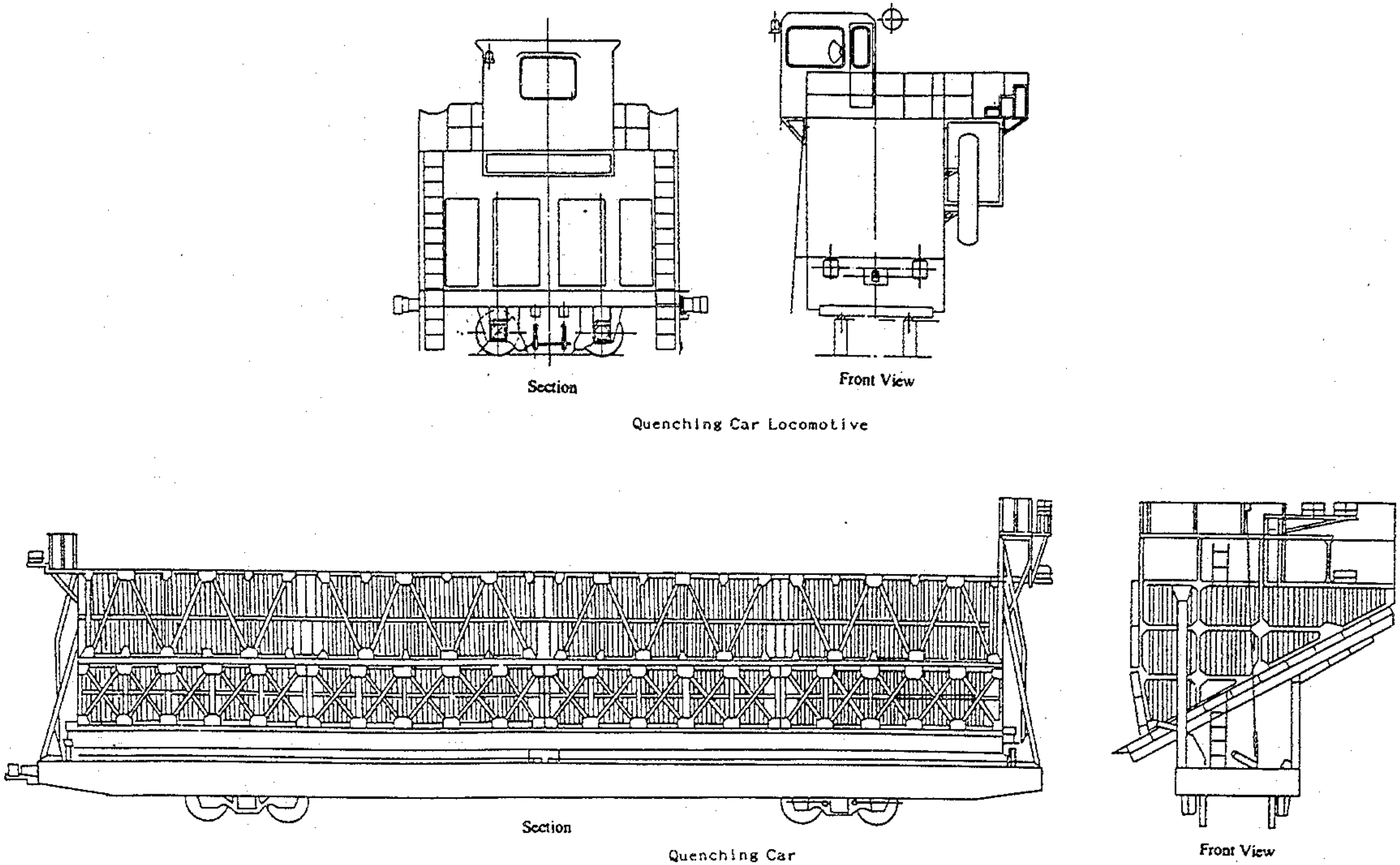


Fig.7-16 GENERAL VIEW OF QUENCHING CAR AND LOCOMOTIVE

(5) Other auxiliary equipment

1) Coke oven heating unit

(a) Heating gas supply system
The conceptual diagram of the heating gas supply system for the coke oven is shown in Fig. 7-17.

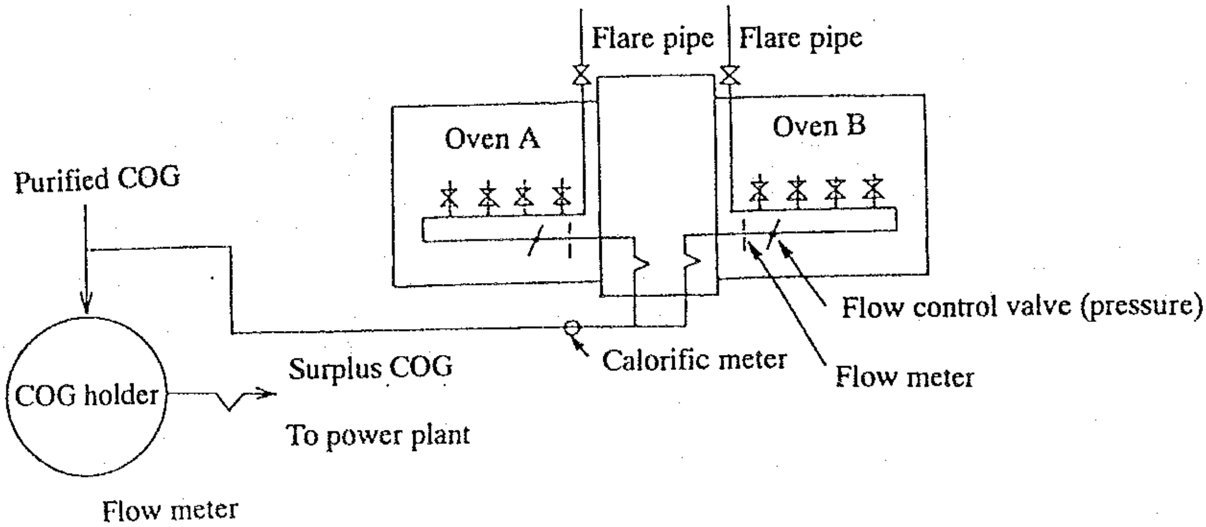


Fig.7-17 HEATING GAS SUPPLY SYSTEM FOR COKE OVEN

Flow rate of heating gas is measured for half battery (A and B) and is controlled in consideration to calorific value of COG by setting oven temperatures according to the working rate, moisture content of coal charge, and the amount of coal charge.

(b) Heating mechanism
The major issue accompanying the increase in coke oven size is to ensure uniform heating. This can be accomplished by supplying gas from the underjet for heating in a longitudinal direction and adjusting orifice diameter. Air for combustion obtains from natural ventilation (gun type).

2) Gas reversing arrangement
The gas reversing arrangement serves as the core of the coke oven and supply gas, air, waste gas alternately in an automatic sequence at a 20 – 30 minute interval.

The gas reversing arrangement consists of electromagnetic valves, valve stands, power unit, surge tank, and reversing cylinders, which operate gas reversing cocks and waste gas reversing valves.
In addition, an accumulator is provided to reserve at least one reversing operation when hydraulic operation from the power unit becomes inactivated due to power outage and other reasons.
Fig. 7-18 shows a gas reversing sequence.

3) Ascension pipe and dry main
The ascension pipe leads gas and tar produced in each coking chamber to the dry main. The dry main is a pipe to collect and recover gas and tar from the coking chambers. Generated gas at 600 - 800°C is cooled down at each bend of the ascension pipe by spraying ammonia liquor. A seal damper is installed to cut off the dry main and the coking chamber during coke pushing and charging. The dry main is maintained at 5 - 8mmAq by using a pressure regulating valve mounted on the crude main in order to maintain the oven pressure at a positive level during operation. Also, an automatic flare pipe is provided to deal with poor gas aspiration in case of emergency, e.g., the gas exhauster stops to operate.

4) Oven doors
Oven doors are provided on the pushing and coke sides, and extracted when coke is pushed out from the oven. They are sealed by metal contact bonding using springs and knife edges in order to prevent air entry to or gas leakage from the oven in the carbonization process. Inner faces of oven doors are heat insulated by covering with fire clay bricks.

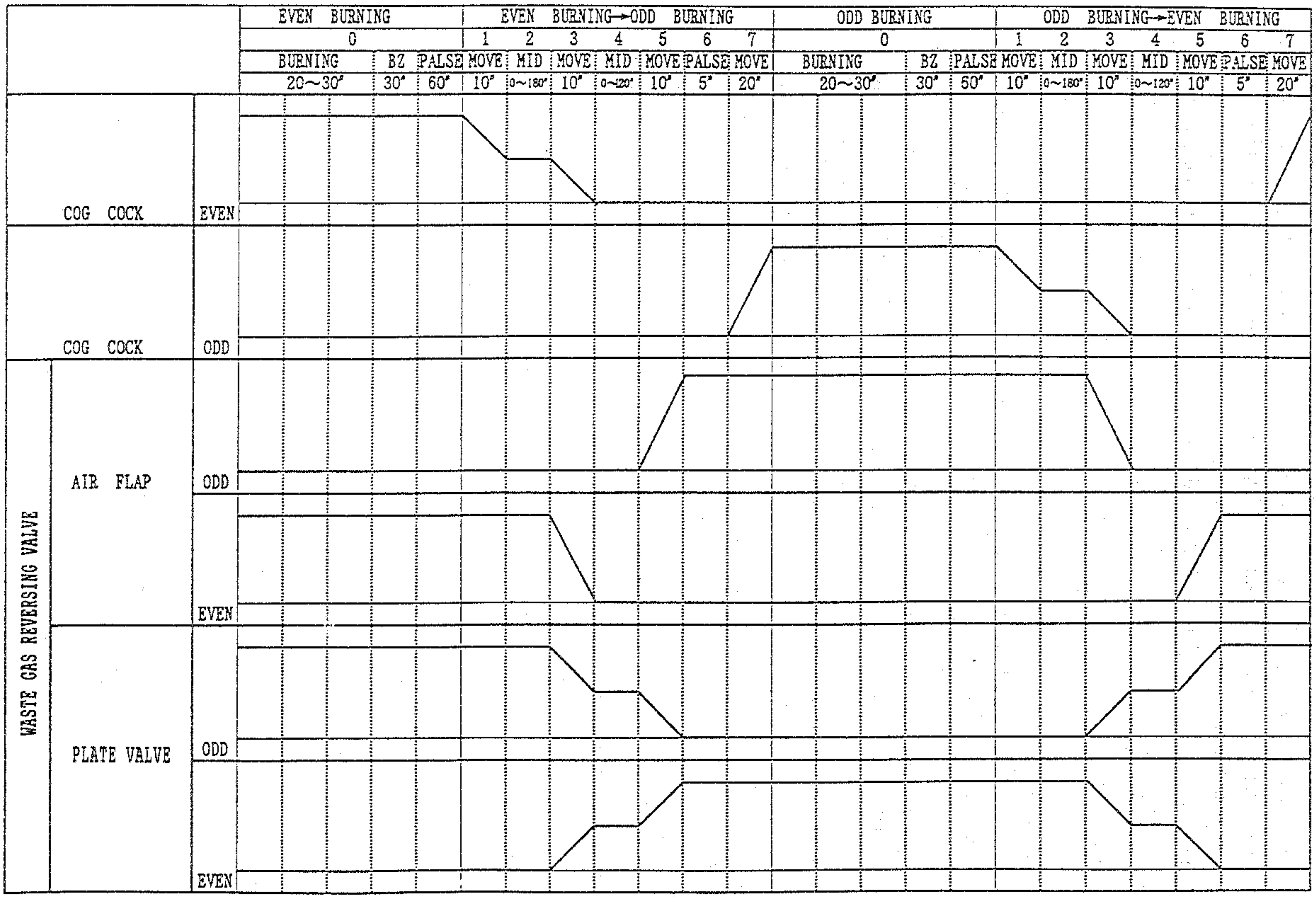


Fig.7-18 ONE EXAMPLE OF REVERSING DIAGRAM DURING COG COMBUSTION

7.3.4 Environmental Measures

(1) Dust collector for the coke guide car

Air containing dust produced during the opening of the oven door and the pushing of coke is collected by the hood mounted on the coke guide car, and is sent to a fixed duct through a connector, then to bag filters on ground. Fig. 7–19 shows the conceptual diagram.

(2) Dust collector for the charging car

Air containing dust produced when coal is charged to the coke oven is collected through a fixed duct and connector, and sent to bag filters on ground before atmospheric release. The device is also used for dust collection with the smokeless charge device for the ascension pipe. Fig. 7–20 shows the conceptual diagram.

(3) Smokeless charge device for the ascension pipe

The device collects spouted gas from the ascension pipe, as occurred during the charging of coal to the coke oven, by using suction force of high pressure ammonia liquor and sending it to the dry main. Fig. 7–20 shows the conceptual diagram.

(4) Deduster for the quenching tower

The device is designed to remove fine particulate and water produced when red–hot coke is cooled down by sprinkling water from the quenching tower. Fig. 7–21 shows the conceptual diagram.

(5) Flare pipe

The flare pipe automatically ignites and burns gas produced from the coke oven at the time of power outage and other emergency situation in order to prevent the gas from accidental release. Fig. 7–22 shows the conceptual diagram.

(6) Air–cooled oven doors

Coke oven doors are provided at both ends of the coking chamber and are attached tightly to the oven frame all the time except when coke is pushed out of the oven, thereby to seal the coking chamber and to prevent air entry to the chamber or gas leakage from the chamber.

The oven doors are made of heat resistant cast iron, equipped with suspension rollers to hold their in place, latch and spring mechanisms to provide adhesion, and knife edges sealing gas. Inner face is lined with bricks for heat insulation. The oven door on the pusher side is provided with a levelling door to insert an levelling bar into the oven.

Another design feature is to provide a space between the oven door body and bricks and to fix knife edges to the door through a flexible seal plate. This is designed to make up for the conventional type door which knife edge is often deformed when the oven door is subject to thermal deformation, causing gas leakage. Also, the air-cooled door can prevent the leakage of gas produced in the carbonization process. Fig. 7-23 shows the conceptual diagram of the air-cooled oven door.

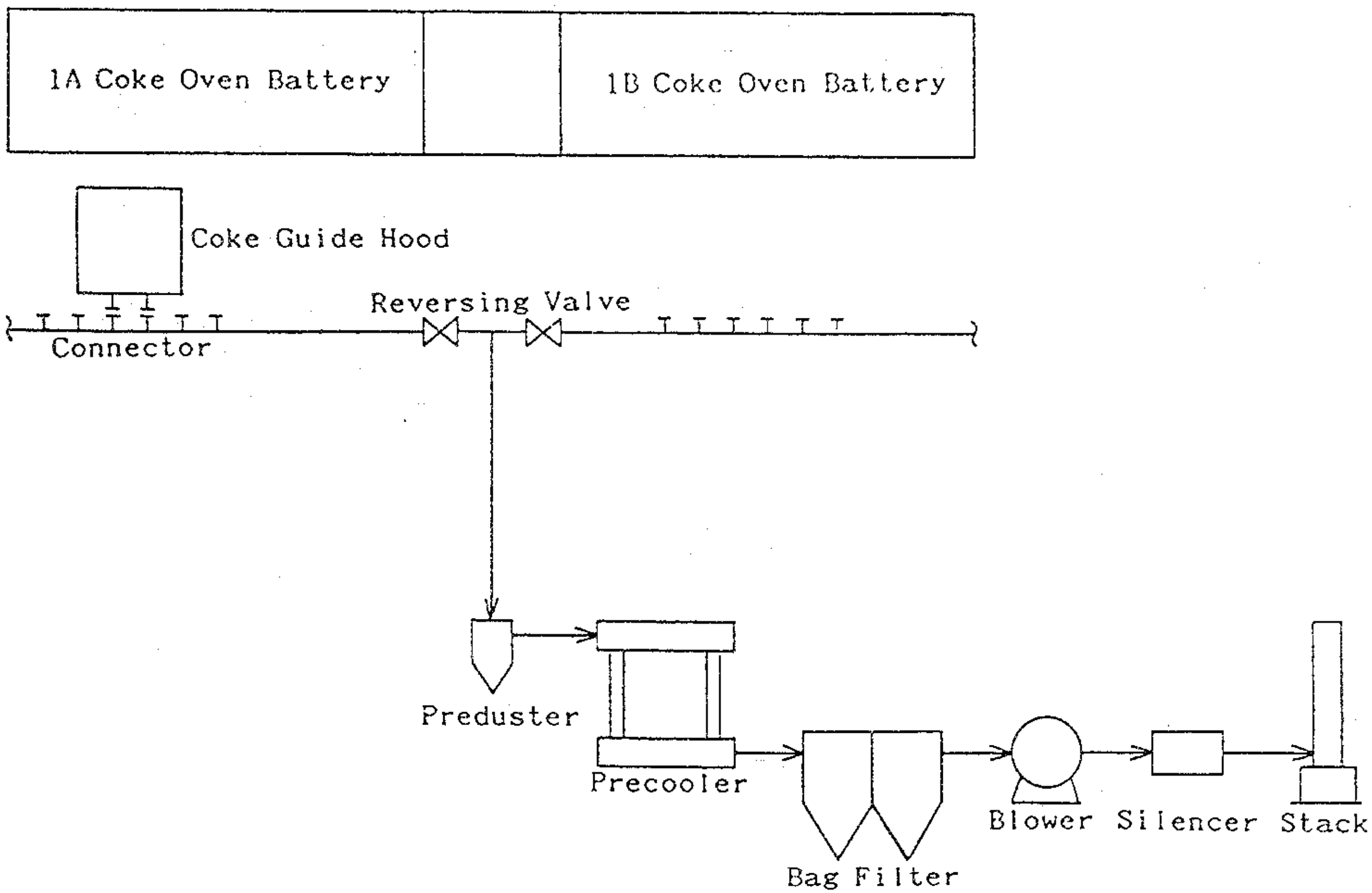


Fig.7-19 DUST COLLECTOR FOR COKE GUIDE CAR

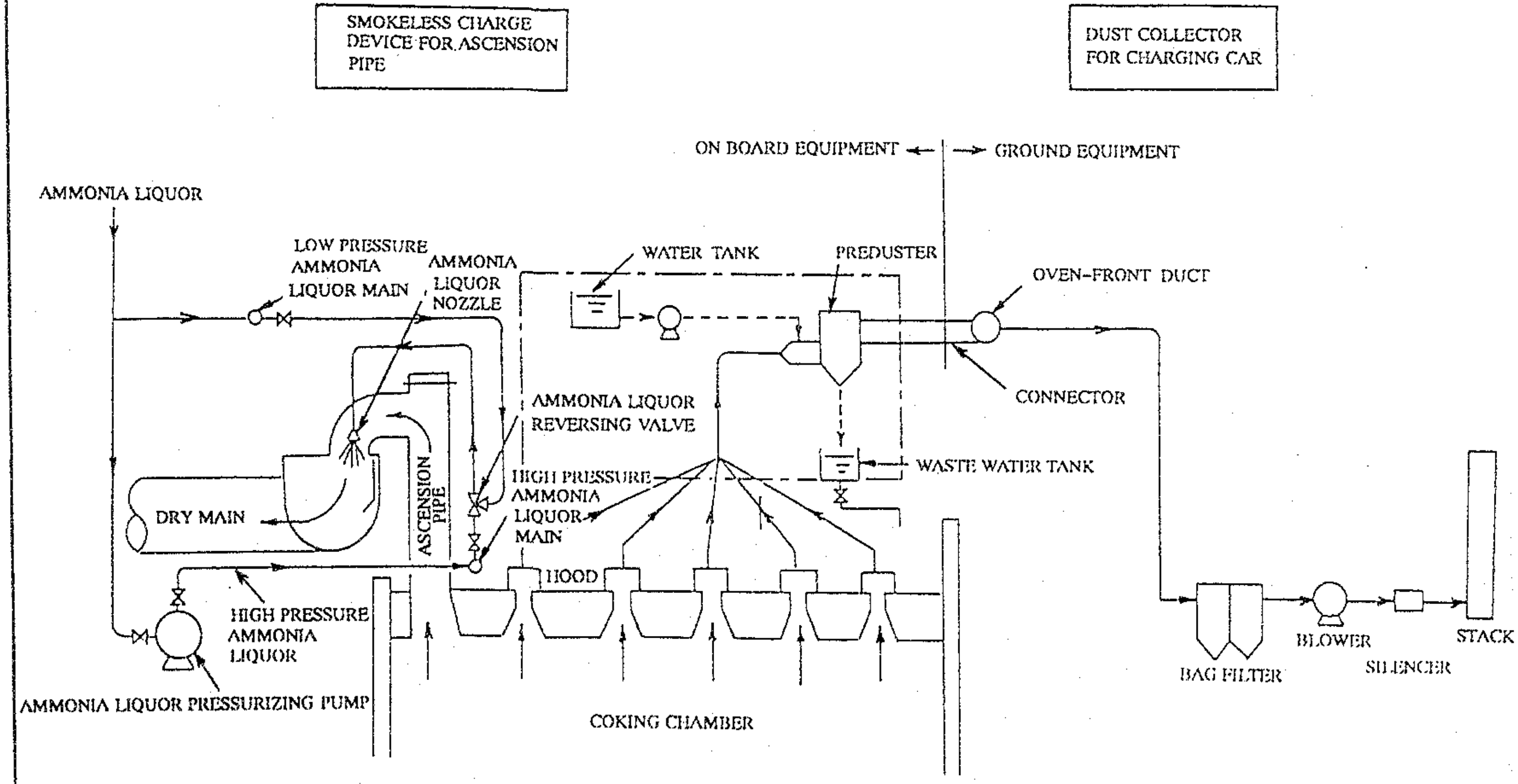


Fig.7-20 SMOKELESS CHARGE DEVICE FOR ASCENSION PIPE AND DUST COLLECTOR FOR CHARGING CAR

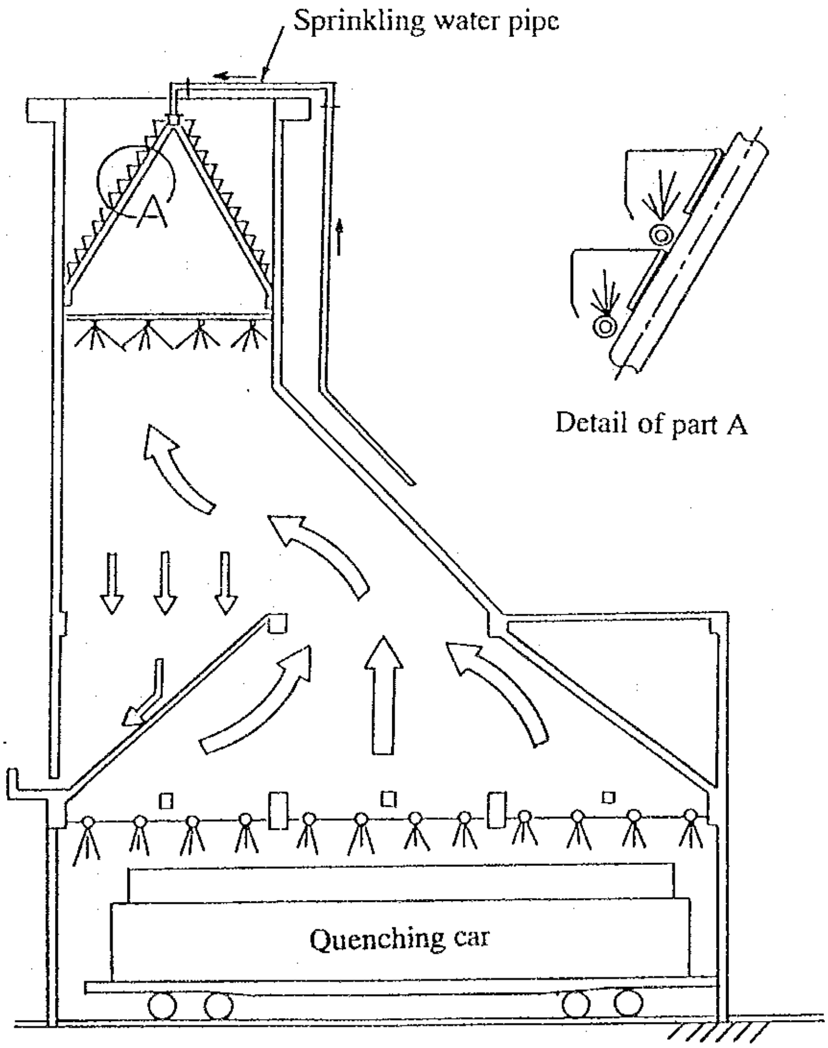


Fig.7-21 DEDUSTER FOR QUENCHING TOWER

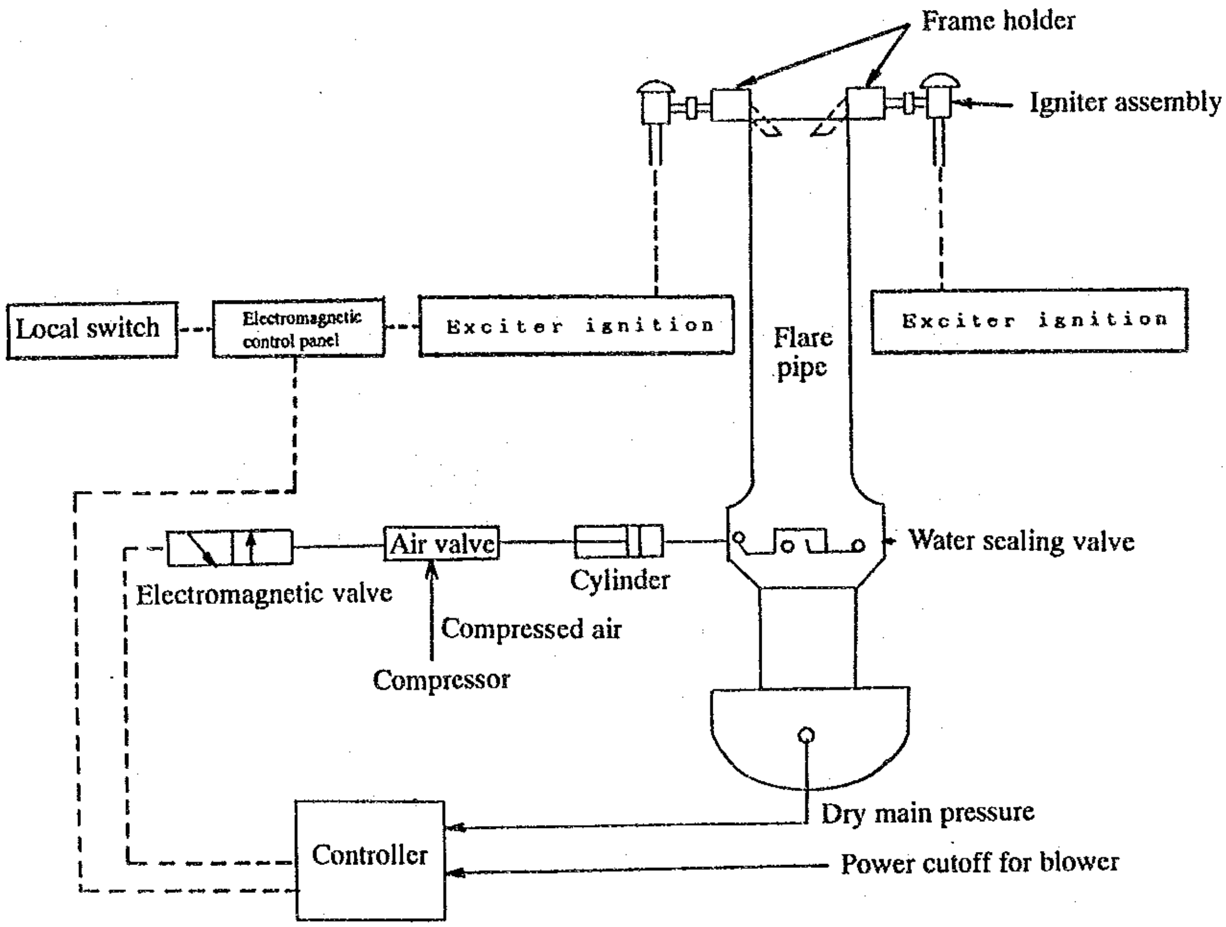


Fig.7-22 FLARE PIPE DIFFUSING AND BURNING THE RAW GAS FOR EMERGENCY MEASURES

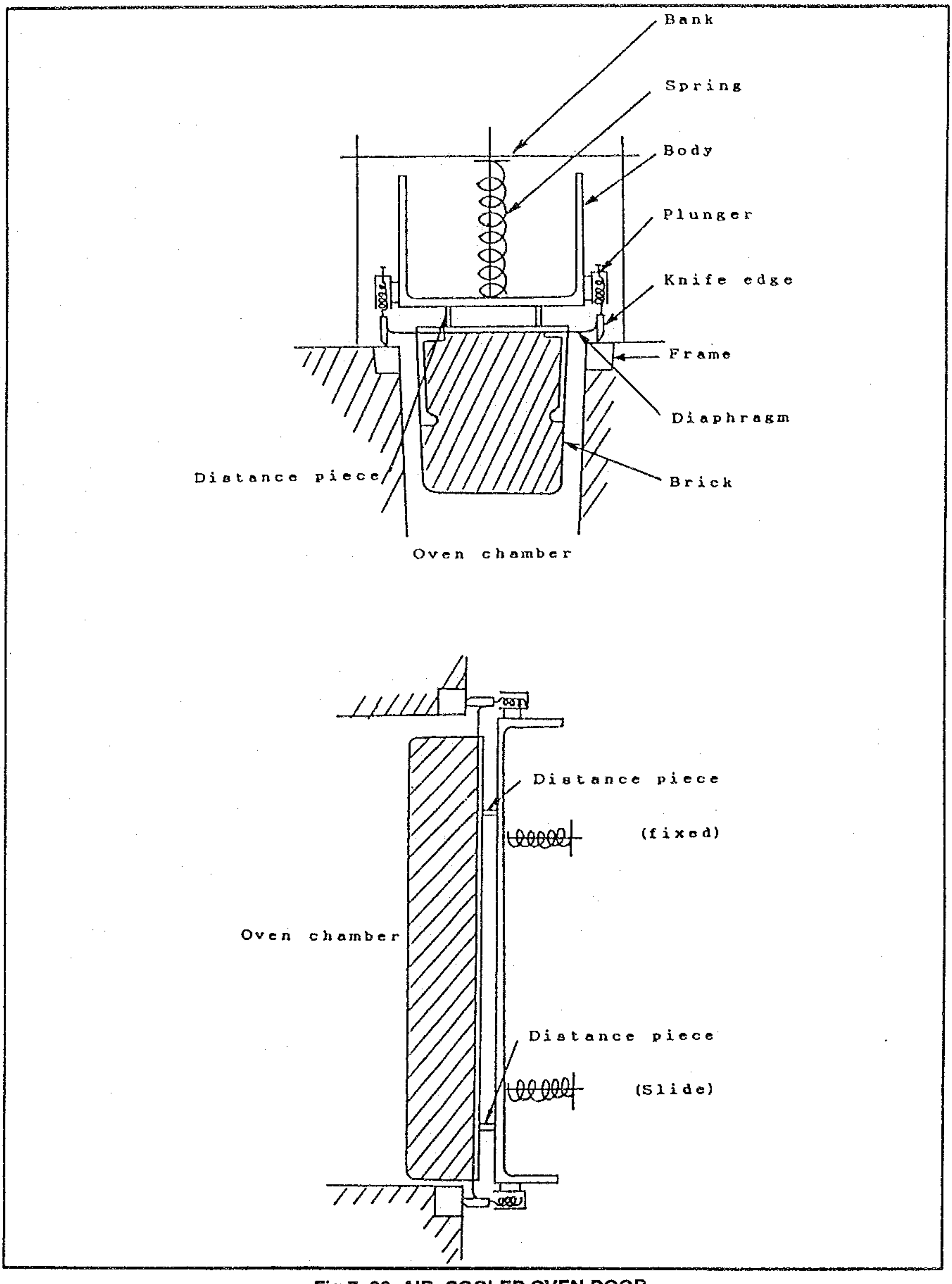


Fig.7-23 AIR-COOLED OVEN DOOR

7.3.5 Heating-up of Coke Oven

The coke oven is a complicated masonry structure mainly using silica bricks, as well as Chamotte, insulating, and red bricks in part, which are shaped into a few hundred varieties. Silica bricks change their expansion coefficient significantly below 900°C, so that the coke oven should be dried thoroughly before the start of operation and should be operated within temperature ranges which cause relatively small amounts of expansion or contraction. Fig. 7-24 shows expansion curves of silica and Chamotte bricks.

(1) Heating-up process and gas consumption

Generally, the coke oven is heated up by raising flue temperature gradually to a range between 1,110°C - 1,150°C for 80 - 90 days, in order to ensure uniform expansion of the oven block and to keep it in stable condition. The final expansion rate is 1.1% to 1.2%. Figures 7-25 and 7-26 show the typical heating-up plan and gas consumption, respectively.

(2) Heating-up equipment

The coke oven is generally heated up by using COG. A separate gas pipe is installed in front of the coke oven, other than an original fuel supply line, and temporary burners are installed in the lower part of the coke oven door to burn gas in the coking chamber. Exhaust gas is led through a drying hole opened in the upper part of the coking chamber to the combustion chamber, then it passes the regenerator and the sole flue to the waste gas flue.

The heating-up operation is terminated when flue temperature reaches 800°C - 850°C, and the oven is fired by the normal fuel supply system, called "flue firing." Then, the oven is kept at the temperature range without load for 15 - 20 days, while preparation work, including the removal of heating-up equipment and piping, cleaning of dried bricks, repairing of brick joints, adjustment of metal fittings, trial operation of moving machine and pollution control devices, is conducted for the start of commercial operation. The entire process is called "heating up of coke oven" and generally takes 80 - 90 days.

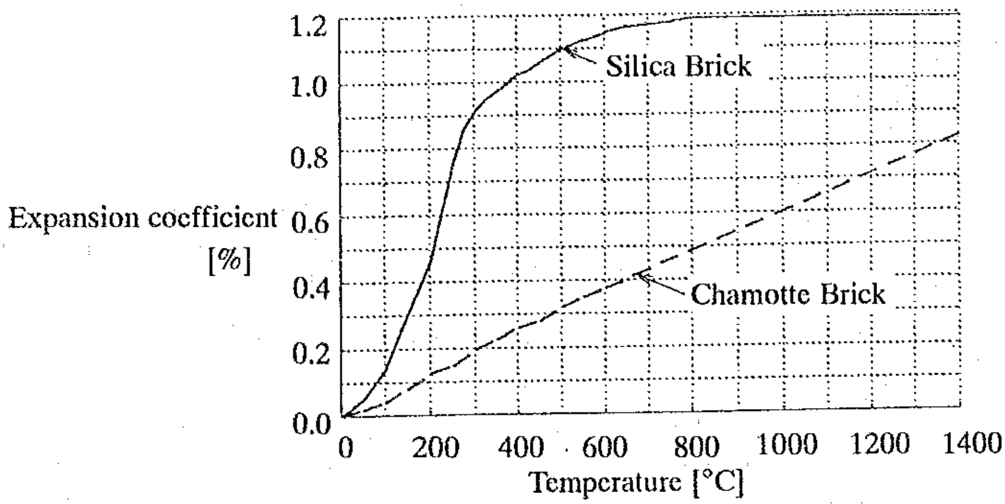


Fig.7-24 EXPANSION CURVES OF SILICA AND CHAMOTTE FIREBRICKS

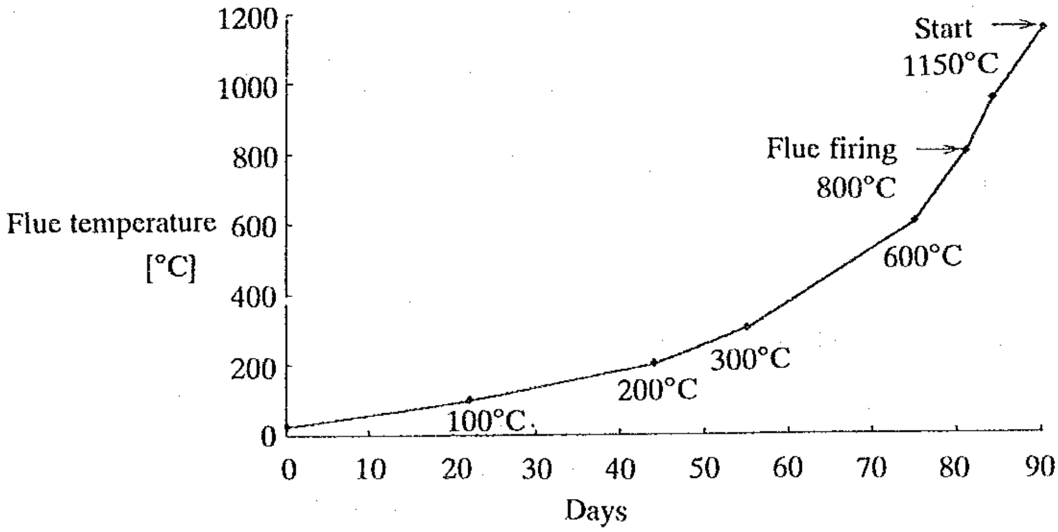


Fig.7-25 TYPICAL COKE OVEN HEATING-UP CURVE

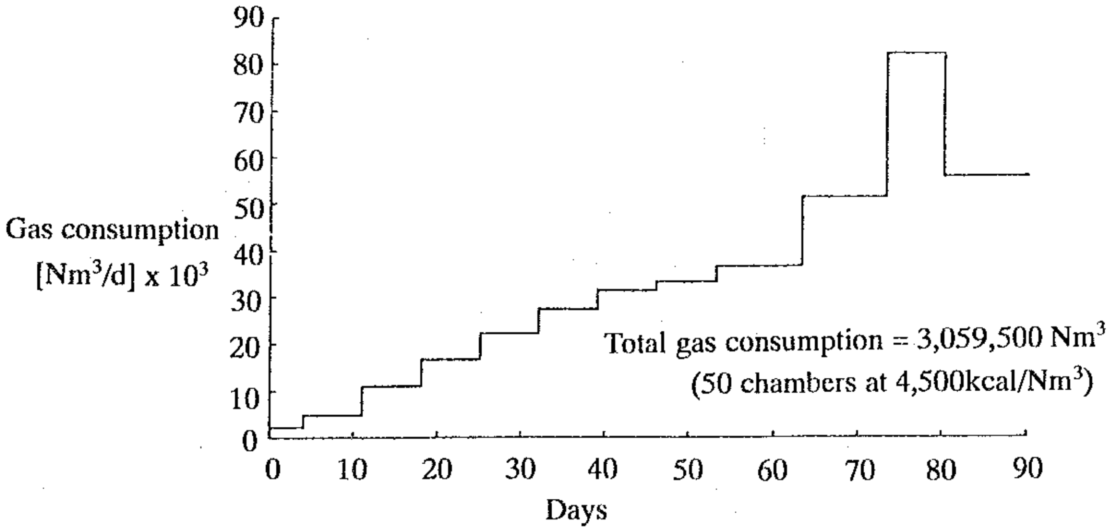


Fig.7-26 TYPICAL GAS CONSUMPTION FOR HEATING-UP OPERATION

7.4 Coke Handling and Shipping Facilities

7.4.1 General

Coke handling and shipping facilities are the entire process of adjusting size and screening coke produced and quenched, storing it in the coke yard, and loading to the ship for export.
Coke size is adjusted by the screen and the coke cutter. The process starts from a 80mm spacing bar screen. Then, lump cokes are crushed by the coke cutter and pass through a 25mm-square vibrating screen to be classified to 25mm or larger coke grains for blast furnace, and less 25mm grains as coke breeze. They are carried by belt conveyors to the coke yard, where they are separately piled up by the stacker. The storage capacity of the coke yard should cover a full capacity of 2 or more Panamax class ships, since the whole amount of coke produced at the plant will be exported.

Major assumptions made for facility design and operation planning are as follows:

(1) Total coke yield : 75%
(2) Total coke handling volume : Average 2,740 tons/day
(3) Lump coke handling volume : Average 2,330 tons/day
(4) Coke breeze handling volume : Average 410 tons/day
(5) Operating hours of major facilities are as follows:

	Wharf - Yard
Operating hours	18 hours/day
Meal and resting time	3 hours/day
Inspection time	3 hours/day

(6) Bulk density of lump coke : 0.45 tons/m^3
(7) Bulk density of coke breeze : 0.60 tons/m^3
(8) The coke handling and shipping lines will be equipped with samplers and conveyor weigher for quality control and quantitative monitoring.

7.4.2 Coke Handling Facility

(1) Coke wharf

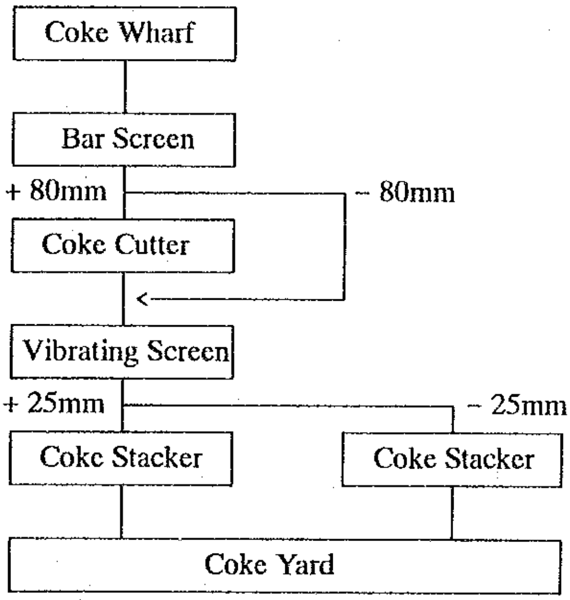
The coke immediately after quenching contains a large amount of water which is unevenly distributed. For equalizing water content and smooth coke oven operation, 6 coke wharves are installed. The feeding from the wharves is automatically done by roll feeders.

· Feeding capacity = 2,740 tons/day ÷ 18 hours x 1.2 = 200 tons/hour

(2) Adjusting coke size and screening

To shape coke fed from the coke wharf into target grain sizes, large lumps are process through the coke cutter. Then, all the cokes are classified through the vibrating screen to lump coke for blast furnace and coke breeze. Then they are stored in the coke yard by using the stacker.

Coke Size Adjustment Flow



(3) Coke yard

The storage capacity of the coke yard is assumed to be a full load of 2 Panamax class ships (40,000 tons each) in consideration to expected coke production, unit shipment volume, and variation of shipments.
The coke yard is divided into 4 sections, with capacity of 24,000 tons (16,000m^2) each.

7.4.3 Coke Shipping Facility

(1) Coke shipping

In consideration to general demurrage conditions at major international ports, the loading capacity of the ship loader is assumed to be 600 tons/hour x 1 unit.

(2) Coke feeding

Based on the ship loader's capacity and yard layout, 2 coke reclaimers are installed, with capacity of 300 tons/hour each.
Shipping and screening facilities are assumed to be 300 tons/hour x 2 units.

7.4.4 Pollution Control Facilities

(1) Dust collector

Dust produced in the adjusting size/screening and shipping/screening processes is collected at sources and is sent to bag filters before atmospheric release.

(2) Other dust prevention measures

Water sprinklers and windshields are installed to prevent dust generated from coke conveyors and openings between them.

7.5 Gas Purifying Facility

7.5.1 General

In the process of making coke by coking coal, water and volatile matters contained in coal evaporate to gaseous form. This is called raw gas or crude gas, which contains many useful matters and impurities. Major useful products are tar, ammonia, and benzene. Impurities include naphthalene, hydrogen sulfide, and cyanides. Thus, the raw gas cannot be used as a fuel because it causes incomplete combustion, and clogging or corrosion of piping and nozzle, and produces large amounts of SOx and NOx in exhaust gas. Furthermore, ammonia liquor produced with raw gas contains detrimental matters such as phenol and ammonia, and needs to be treated property before discharge, although some can be recirculated in the system. The gas purifying section, thus, recovers useful matters, removes impurities, and converts raw gas to purified gas suitable as a fuel.

The gas purifying facility is divided into gas exhausting, desulphurization and sulfuric acid production, ammonium sulfate production, crude light oil recovery, and waste water treatment processes.

Gaseous products produced form the coke oven are cooled by ammonia liquor to 90°C – 95°C in the ascension pipe, and are further cooled by a gas cooler to 35°C – 40°C, removing tar and ammonia liquor. Tar and ammonia liquor are separated by difference in specific gravity. Tar is recovered for use, and ammonia liquor is treated by ammonia distillation and activated sludge processes, and is discharged as non-harmful effluent. The gas after the cooler is exhausted and pressurized by an exhaust blower before being sent to the subsequent process.

Naphthalene contained in the gas is exhausted by the blower and removed by spraying wash oil from the top of the scrubber, so as to prevent the clogging of pipe in the subsequent process and to minimize the increase in pressure loss in the scrubber.

Although tar in the gas is mostly removed at the gas cooler, some continue to float in mist form, which contaminates mother liquor in the ammonia recovery equipment and colors ammonium sulfate crystals, leading to deterioration. An electric precipitator will be used to remove tar mist.

In the desulphurization tower, the gas contacts an alkaline solution which absorbs hydrogen sulfide and cyan. Sulfur content in the absorbent liquid is recovered as sulfuric acid.

Ammonia in the gas reacts with a dilute sulfuric acid solution to produce ammonium sulfate which is recovered for use as the fertilizer. Alternatively, ammonia may be converted to liquid ammonia or decomposed by burning.

Light oil content in the gas is cooled by sprinkled water in the final cooler to improve absorbency, then is removed by sprinkling coal-based or petroleum-based wash oil from the top of the scrubber. After benzene rich oil containing light oil is distillated in the light oil recovery plant, it is circulated and used as the wash oil.

In the proposed process, impurities in the gas will be removed to a level not detrimental to the environment nor impeding to transportation, and remaining gas will be consumed internally or sold outside as purified clean gas.

Tar, crude light oil, ammonia, sulfur compounds extracted from the gas in the purifying process are recovered as useful products. On the other hand, ammonia liquor produced in the process is treated to a level conforming to effluent standards applicable to Maracaibo. Major design considerations are summarized as follows:

- COG treatment capacity is assumed to be 60,000Nm^3/hour at maximum to absorb possible fluctuation of supply.
- Facilities are arranged according to the process, in consideration to ease of operation and maintenance.
- Products are stored in amount suitable for delivery.
- Important equipment is provided with one spare unit.
- Each process can be separated at the time of accident or failure to prevent its effect from spreading to other processes. In particular, the COG purifying line is provided with a bypass line.
- Disaster prevention facilities, including oil retaining walls and fire hydrants are provided in consideration to adequate layout.
- The gas purifying process can be monitored from an instrument room (center).

7.5.2 Gas Exhaust Blower

COG produced in the coke oven, after treatment in the down comer to separate tar and ammonia liquor, is cooled down to 35°C – 40°C through indirect and direct gas coolers. COG after the direct gas cooler passes through a pressure adjusting valve to obtain constant pressure at the outlet of the indirect gas cooler, and is suctioned by the gas exhaust blower. Then, it passes through the naphthalene scrubber and the electric precipitator to remove tar mist, then sent to the COG desulphurizer.

Meanwhile, tar and ammonia liquor separated in the down comer are sent with condensed water discharged from the gas coolers and slop ammonia liquor from other equipment to an ammonia liquor decanter where the mixture stands and separates into ammonia liquor and water. Tar and ammonia liquor are sent by an ammonia liquor circulation pump to the coke oven facility and are used as COG cooling water. Surplus ammonia liquor is sent to a ammonia liquor distillation plant via a storage tank, where ammonia is removed by using steam, and is sent to a waste water treatment plant. Ammonia removed in the distillation plant is returned to COG.

Tar separated in the ammonia liquor decanter is sent to a tar decanter to remove water and sludge. It is then sent to a super decanter (centrifuge) to remove remaining sludge. The tar is sent to a tar tank for storage as crude tar. The tar sludge removed is added to the coal charge in the coal preparation process for recycling.

7.5.3 Desulphurization and Sulfuric Acid Plants

COG has long been used as a fuel, and the size of desulphurization plants has increased with more strict environmental regulation. COG contains 4 – 7g/Nm^3 of H_2S and trace amount of organic sulfur.
The desulphurization process is roughly divided into the dry type and the wet type. The dry type removes hydrogen sulfide in the gas by using iron oxide. The wet method uses alkaline solution. Under the both methods, cyan is also removed.
These desulphurization processes produce sulfur, hydrogen sulfide, hydrogen cyanide, and other waste water. To prevent secondary contamination by these detrimental matters, various treatment methods are used and produce various by-products, including sulfur, sulfuric acid, and gypsum. Thus, the desulphurization process and the by-product treatment process are essential elements of the entire desulphurization system.

The desulphurization and sulfuric acid production system at the proposed plant is designed with the following considerations:

· Appropriate measures to prevent secondary contamination, including water contamination
· Treatment of sulfur content
· Desulphurization rate
· Low cost
· Simultaneous removal of cyan

To meet the above requirements, the wet type desulphurization system is selected because of excellent desulphurization performance and ease of operation. The system is designed to reduce H_2S in COG to 0.2g/Nm^3 and HCN to 0.15g/Nm^3. Fig. 7-27 shows the wet type desulphurization process flow.
Removed H_2S is sent to a sulfuric acid production plant as a raw material. Sulfuric acid produced at the plant is used as a sulfuric acid source (called by-produce sulfuric acid) for the subsequent ammonia removal process.

7.5.4 Ammonium Sulfate Production Plant

COG generally contains 7 - 10g/Nm^3 of ammonia. Ammonia has been conventionally removed in the ammonium sulfate recovery process, but other processes are increasingly used. These processes use water, dilute sulfuric acid or ammonium phosphate to absorb ammonia in COG.
The ammonium sulfate recovery method uses dilute sulfuric acid to absorb and chemically covert ammonia to ammonium sulfate. The method shows a high rate of ammonia removal and is suitable if sufficient demand for ammonium sulfate exists.
The method to absorb ammonia by water is further divided into two methods. One is to directly burn ammonia after distillation and another is to burn it after decomposing ammonia into hydrogen and nitrogen by catalyst. The former tends to produce NOx in the process of burning ammonia, while the latter requires a catalyst for decomposition and a fuel.
The method to absorb ammonia by phosphoric acid is also divided into two methods. One method involves distillation and purifying to obtain high purity ammonia, and another the burning of ammonia after distillation. The former is suitable when there is demand for high purity ammonia, and the latter tends to produce NOx in the burning process.

Clearly, a major difference between the processes lies in method of disposing recovered ammonia. The most suitable process is selected in consideration to the following factors:

· Cost
· Demand for by-products
· Environmental consideration
· Ease of operation

For the project, the ammonium sulfate recovery process using by-product sulfuric acid as well as the purchased one is selected to reduce ammonia in COG to 0.1g/Nm^3. Fig. 7-28 shows the ammonia removal and ammonium sulfate production process flow. Ammonium sulfate produced is purified for commercial sales.
The final cooler is provided to cool COG which temperature rises in the ammonium sulfate production process.

7.5.5 Light Oil Recovery Plant

Since naphthalene in COG deposits at low temperatures, it should be removed as much as possible if COG is used in an area with relatively low atmospheric temperature. Naphthalene is mainly removed by the cleaning and absorption method. Previously, water has been used, but because of low removal rate and presence of hydrogen sulfide and hydrogen cyanide in addition

to naphthalene, the cleaning method using wash oil is increasingly used.
The removal of light oil content (BTX) in COG is generally done by using wash oil.
The wash oil containing light oil and naphthalene is processed through the distillation plant, and light oil and naphthalene are separated by blowing steam.

In the project, naphthalene will be recovered through the naphthalene scrubber, and light oil through the light oil scrubber. It is planned to reduce naphthalene content to $0.3g/Nm^3$ and light oil (BTX) to $5g/Nm^3$. Fig. 7-29 shows the light oil recovery process flow.
Coal-based creosote oil will be used as the wash oil.

Benzene rich oil which has absorbed light oil is distilled by steam in the light oil recovery process to recover crude light oil. Benzene lean oil after distillation is sent to the light oil scrubber for recirculation.

7.5.6 By-product Shipping Facility

Crude light oil and tar are generally transported by tanker, ship, or tank lorry, pipeline, freight car, container, or truck. The mode of transport suitable for the project is selected in consideration to the following factors:

- Distance to major users
- Handling volume
- Production volume
- Restrictions on transport (environmental regulation, and potential hazard)
- Route conditions, including the road and navigation route
- Shipping package

By taking into account the above factors, crude tar and light oil produced in the project will all be sent from storage tanks to ships via a special loading facility for exports.
Ammonium sulfate will be loaded to trucks by a shovel loader for shipment to domestic markets.

7.5.7 Waste Water Treatment Plant

Waste water produced in the proposed plant mainly consists of water attached to the coal charge (9%), water of crystallization produced in the carbonization process, and combined water made by reaction between oxygen and hydrogen contained in the coal, which are led with producer gas to the gas purifying plant and are condensed in the gas coolers. On the other hand, it contains process waste water remained in the gas purifying process. Since the water highly contains water soluble substances in COG, particularly ammonium salt, it is called ammonia liquor or gas liquor. The water is considered to be highly contaminated and requires careful treatment before discharge to the environment.

Although ammonia liquor has been an important source of ammonia or phenol, it no longer offer a significant economic value for recovery, and instead it has become a water contaminant to be removed before discharge to the environment. Various technologies are applied to treatment of ammonia liquor, and key processes are described below.

(1) Distillation

Volatile matters in ammonia liquor, such as free ammonium salt, hydrogen cyanide, and hydrogen sulfide are removed through heating and distillation. An distillation tower is used. However, some of ammonium salts which are not easily decomposed, called fixed ammonium salt, have to be decomposed by adding strong alkali such as milk of lime and caustic soda.

$NaOH + NH_4Cl \dashrightarrow NH_3\uparrow + NaCl + H_2O$

Under the method, more than 90% of ammonia and cyan can be removed easily, but no decrease in phenol and COD(Chemical Oxgen Demand).

(2) Biological treatment/activated sludge method

Self-purification of waste water in natural environment is primarily a result of oxidation or digestion by microorganisms or bacteria. The biological treatment method, particularly the activated sludge method has significantly improved the natural process in terms of productivity. Recently, introduction of strict water quality requirements demand high removal rates for many substances, including phenol, cyan, oil, COD, and BOD (Biochemical Oxgen Demand), shedding light on versatility of the biological treatment method.

In principle, the activated sludge method uses flocks of bacteria and protozoans (activated sludge) which are mixed with waste water. When air is injected into the mixture, organic substances in the waste water are absorbed and digested by bacteria and protozoans. In the process, certain portions are assimilated and fixed as the substance to form cell membranes, and remaining portions are decomposed to inorganic matters while supplying energy needed for the assimilation and fixation process. Then, the sludge is separated from water, leaving few organic matters to complete the purification process.

Ammonia liquor is homogenized through various pretreatment processes to remove ammonia and oil, and after dilution to a specific concentration, it is introduced to an aeration tank. In the tank, air is injected from the bottom or is mixed by agitation of water surface in order to ensure close contact among the sludge, air, and water. The aeration tank at the proposed plant will be operated in the temperature range between 25°C and 35°C, with dissolved oxygen concentration of 1 – 5ppm, and sludge concentration of 4,000 – 6,000ppm. Standard phenol loading is assumed to be 1 $\pm$ 0.2kg phenol/m^3/day or 0.2 $\pm$ 0.04kg phenol/kg·MLSS/day.

The water after the aeration tank enters a sedimentation tank to separate sludge. The sludge so separated is mostly returned to the aeration tank, with a surplus being removed. Nutrients are sometimes added to promote growth of sludge, and flocculating agents to encourage sedimentation and dehydration.

(3) Advanced treatment method

The activated sludge treatment method does not improve residual COD in the treated water, which remains in the range between 50 – 200ppm, and produces brown color to result in poor visibility. To improve water quality in these areas require other methods, which are generally called advanced treatment. Major advanced treatment methods are summarized as follows:

1) Flocculating sedimentation method: To separate suspended solid in waste water by adding a flocculating agent, such as polymer flocculating agents and ferric chloride salt. The method is effective in reducing COD caused by suspended organic solid in waste water, removing cyan in the form of iron salt, and reducing color.

2) Sand filtration method : To remove fine suspended solid through a tank filled with sand or anthracite.

3) Activated carbon method : To absorb residual organic solid and coloring ingredients through activated carbon as the final treatment process. Not suitable for removing inorganic salt.

In addition, ion exchange resin and reverse osmosis methods are available.

Having compared the above processes, the waste water treatment process shown in Fig.7-30 has been selected for the project. In this treatment process, ammonia liquor after ammonia is removed in the steam distillation process is treated in a channeling type aeration tank to remove detrimental matters including COD components.
Then, the advanced treatment plant using activated carbon is provided to comply with effluent standards applied to Lake Maracaibo.

7.5.8 Utilities Facilities

Production facilities for steam, nitrogen and compressed air will be newly constructed within the plant. Also, a cooling water supply system will be installed separately.

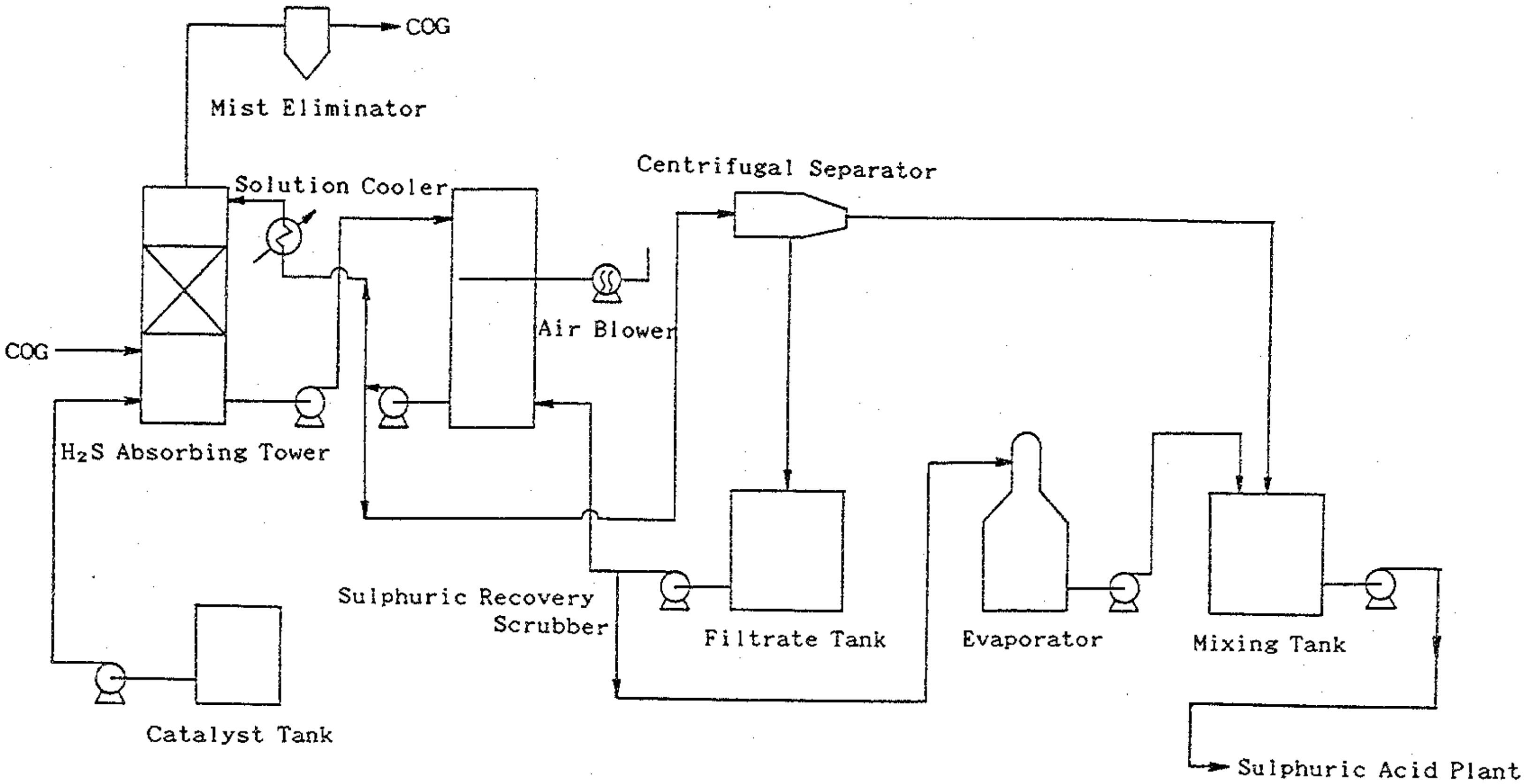


Fig.7-27 WET DESULPHURIZATION PROCESS FLOW

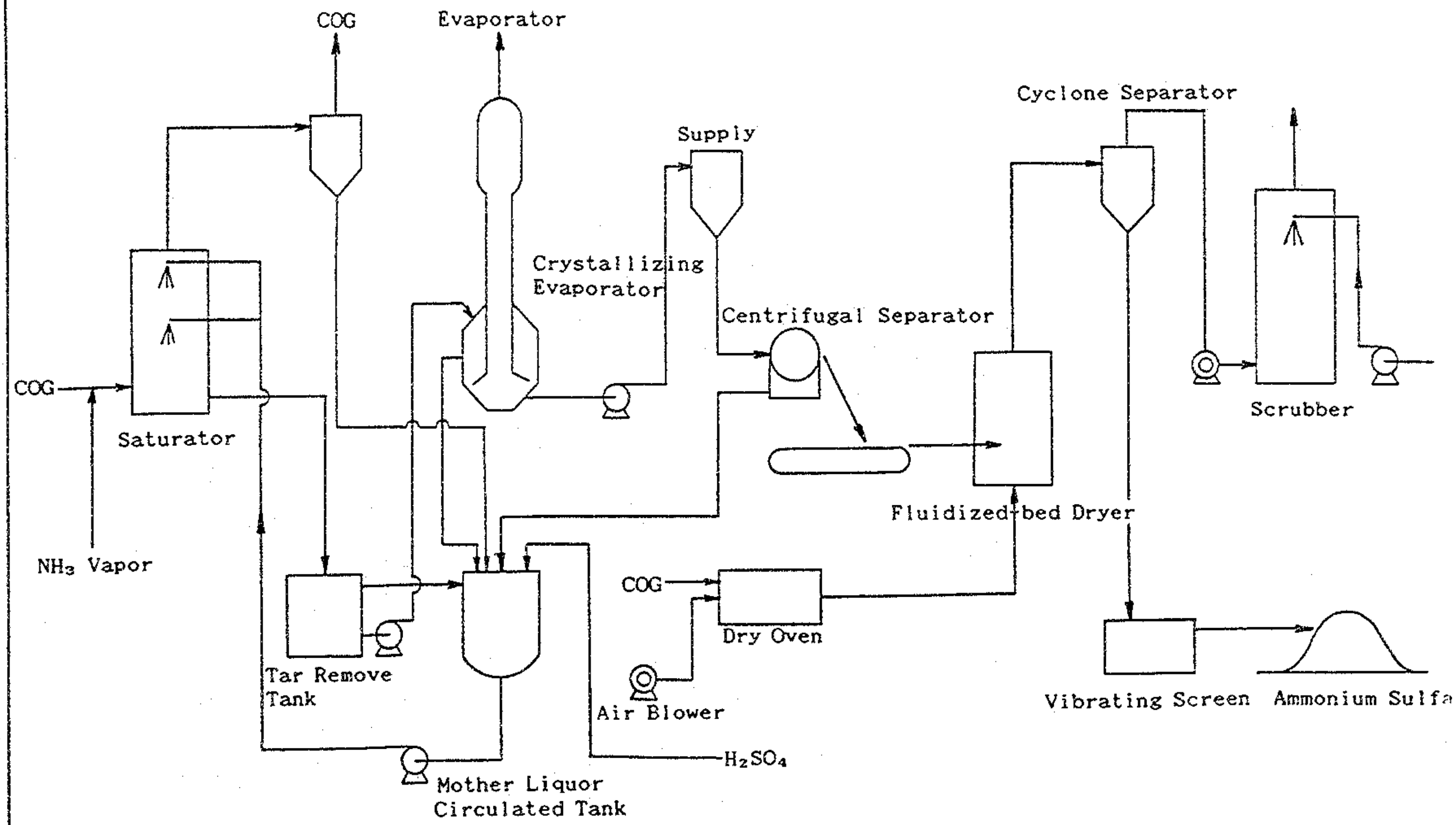


Fig.7-28 AMMONIA REMOVAL AND AMMONIUM SULFATE PRODUCTION PROCESS FLOW

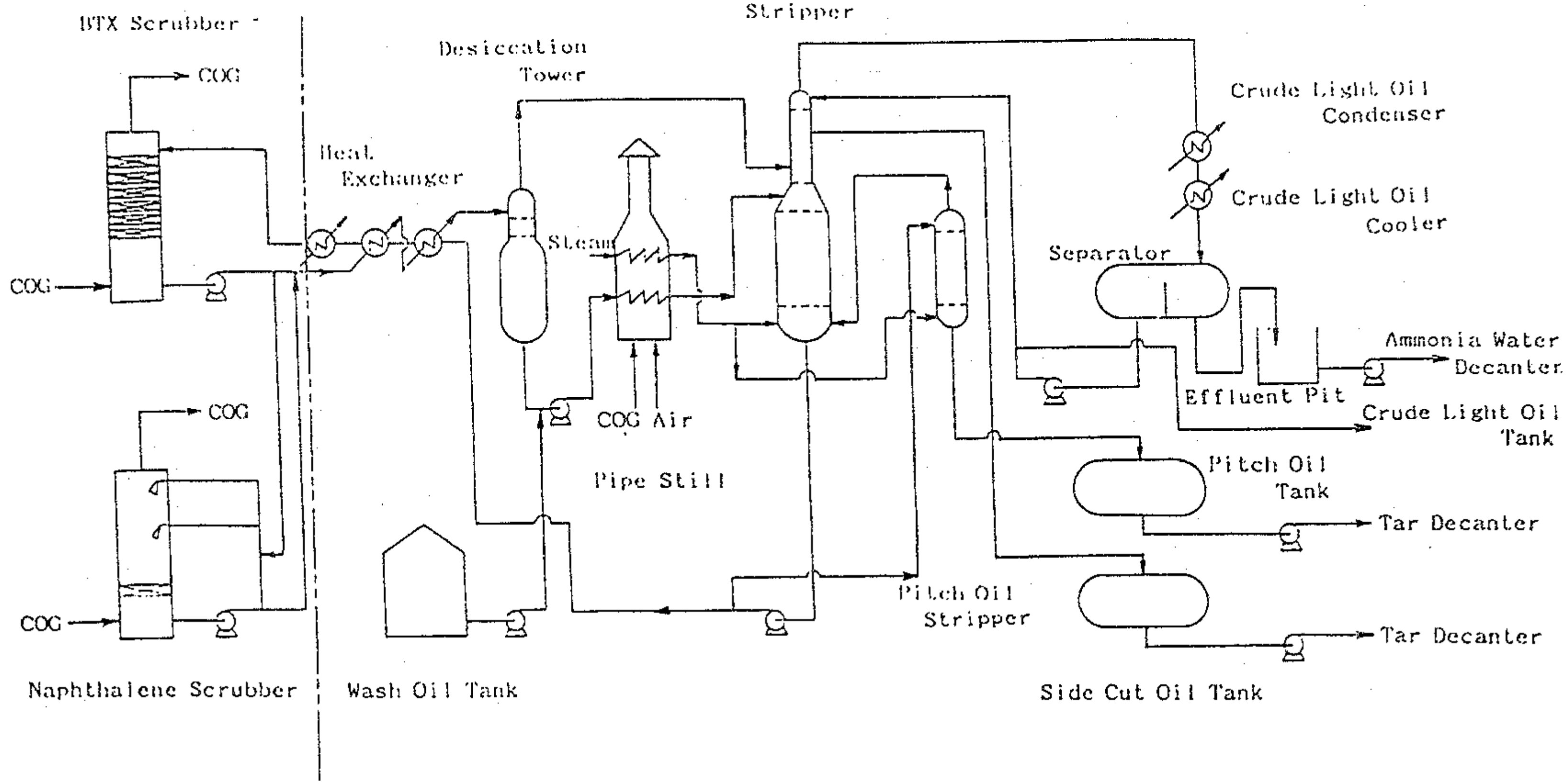


Fig.7-29 LIGHT OIL RECOVERY PROCESS FLOW

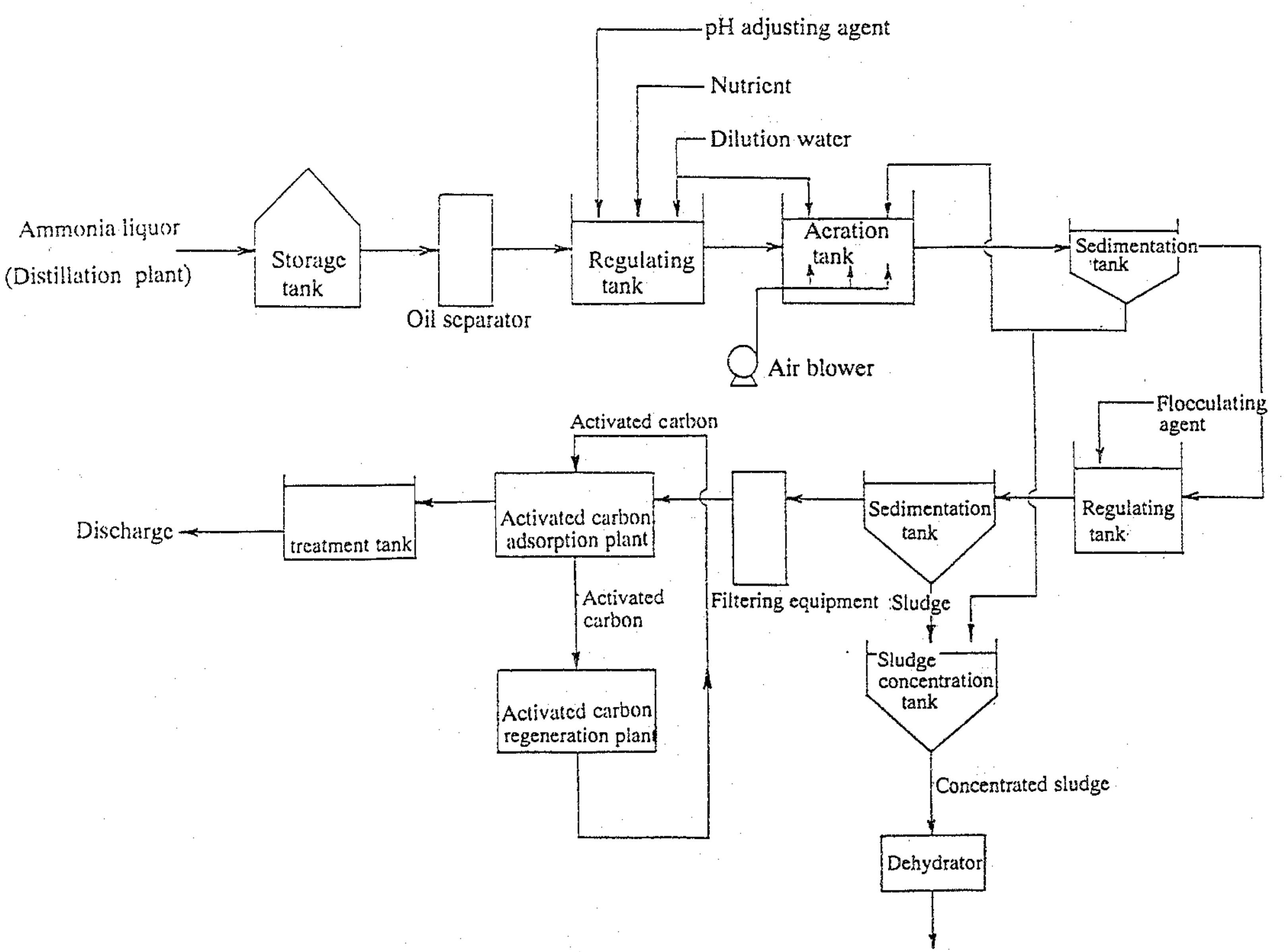


Fig.7–30 WASTE WATER TREATMENT PROCESS FLOW

7.6 Utilities and Other Ancillary Facilities

7.6.1 Water Supply Facility

(1) General

It is assumed that the plant will receive water supply from public water corporation.

1) Industrial water
Daily consumption is assumed to be 9,000m^3. To ensure uninterrupted plant operation, a pit to store water in amount equivalent to one-day consumption will be provided. From the pit, water will be pumped to each production process.

2) Portable water
Daily consumption is assumed to be 400m^3. Water, received from the main, is treated through filters and is stored in a tank with capacity equivalent to half-day consumption. From the tank, water is pumped throughout the plant.

(2) Water balance

Fig.7-31 shows water balance and distribution system at the plant.

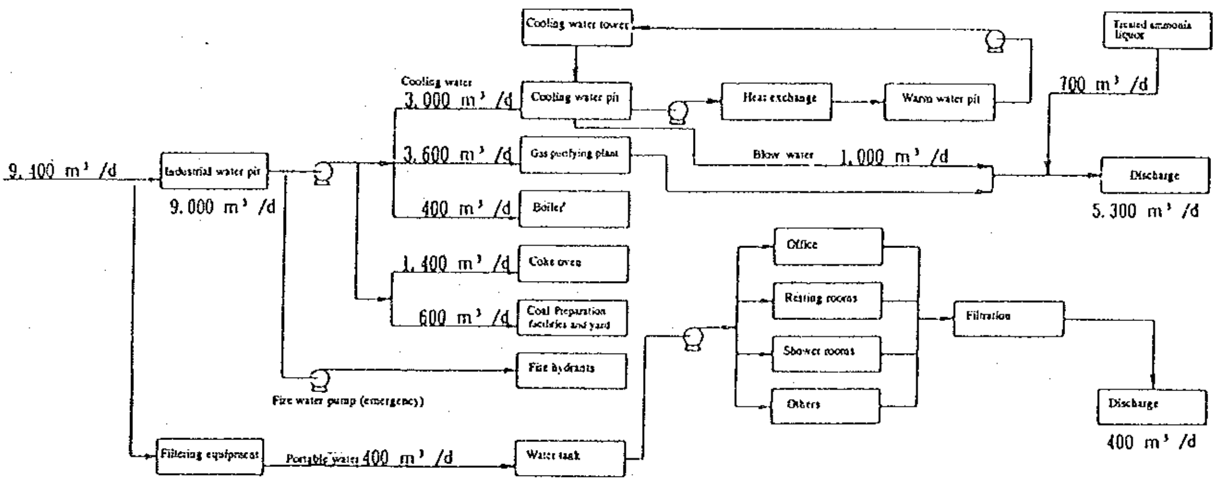


Fig.7-31 PLANT WATER BALANCE AND DISTRIBUTION SYSTEM

7.6.2 Electrical Installations and Equipment

(1) General

Electrical installations and equipment provide motive power for coke making plant facilities and equipment, and include power receiving and distribution facilities and equipment, motors, control device, and communications equipment.
Electricity will be supplied from a substation adjacent to the thermal power plant by using 24KV, 60Hz, 3-phase 2 circuit and will be received at a substation to be installed within the plant. It will then be distributed to switchboard rooms for the coal preparation process, berth, coke oven (coke oven end deck), gas blower, gas purifying plant, and utilities.
Electrical equipment installed in the gas purifying process and the underjet of coke oven will conform to explosion-proof standards.
Communications equipment includes a plant-wide telephone network and a paging system for each process. Portable phones will be provided for moving machines at the coke oven.

(2) Power supply system

Fig.7-32 shows the power supply system at the proposed plant.

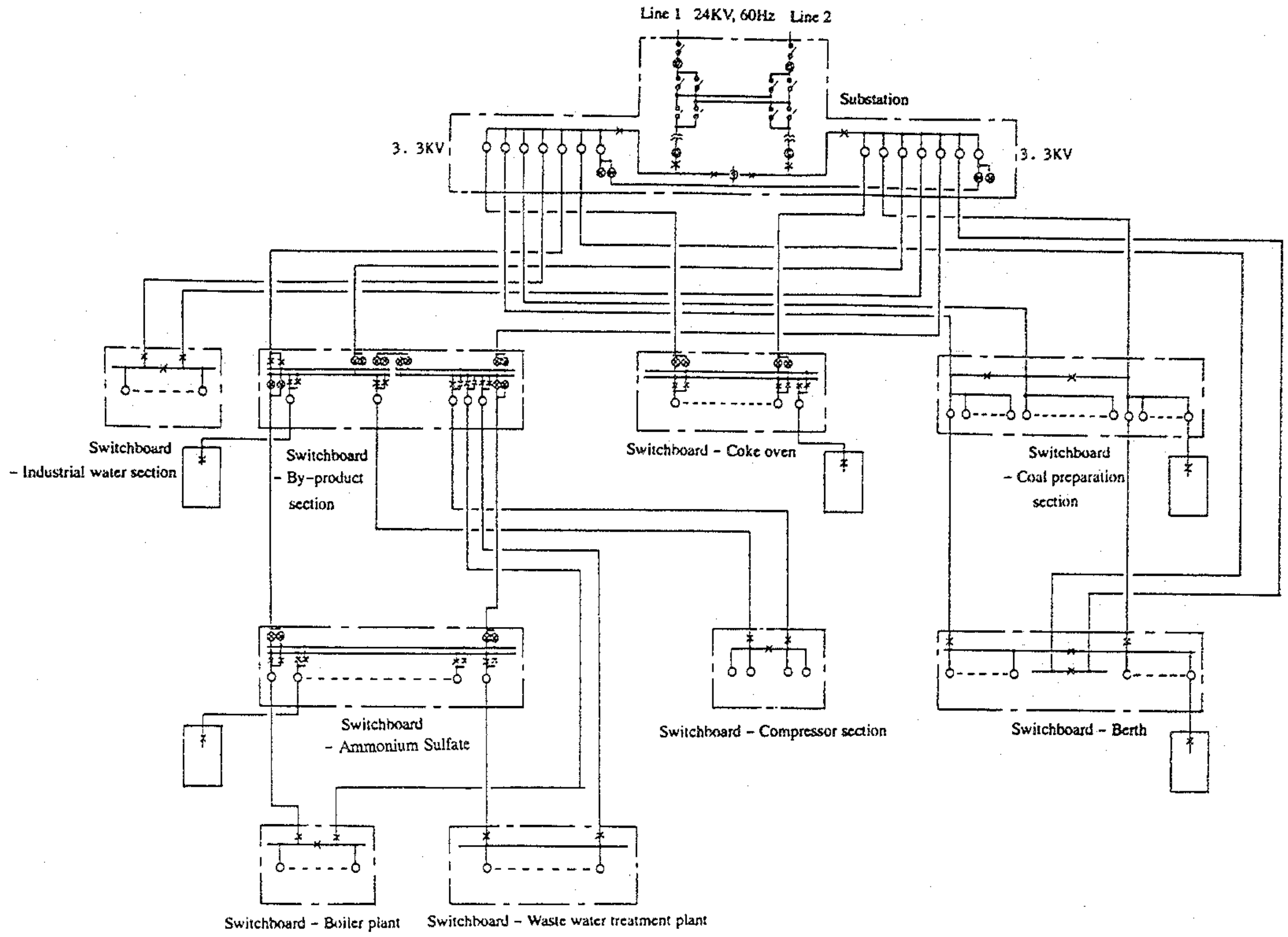


Fig.7-32 POWER SUPPLY SYSTEM

7.6.3 Instruments and Instrumentation

(1) General

Instrumentation at the plant is designed to provide automatic and remote control operations for efficient operation, working safety and labor saving.
Switches and measuring instruments required to operate and monitor individual process and equipment will be installed on or near respective equipment. Instruments are primarily of electronic analog type, operated hydraulically or pneumatically. Process monitoring, operation control, and data collection are performed digitally by process computers to be installed in control rooms.
Instruments installed in the gas purifying plant and the underjet of coke oven will conform to explosion-proof standards.

(2) Control rooms

1) Control room for the coke oven
2) Control room for the coal preparation facilities
3) Control room for the gas purifying plant

(3) Major instrumentation work

Instrumentation work required for the proposed coke making plant is listed in Table 7-5.

Table 7-5 SUMMARY OF INSTRUMENTATION WORK (1/2)

Major Category	Sub-category	Remarks
1 Coke oven	(1) COG heat flow control (2) COG pressure control (3) Pressure control for main waste gas flue (4) O2 control for exhaust gas (5) Flue temperature control (6) Automated evaluation system for net coking time (7) Pressure control for crude gas produced from dry main (8) Crude gas combustion and dispersion control	
2 Gas exhausting plant	(1) Temperature control for direct and indirect coolers (2) Pressure control before enhauster (3) Liquid level control for ammonia liquor decanter (4) Flow control for steam distilling ammonia liquor (5) Outlet temperature control for ammonia liquor stripper	
3 COG desulfurization plant	(1) Liquid level control for absorption tower (2) Flow rate control for absorption liquid (3) Temperature control for incinerator	
4 Ammonium sulfate production plant	(1) Liquid level control for absorption tower (2) Flow rate control for absorption liquid (3) Temperature control for hot blast stove	
5 Light oil recovery plant	(1) Liquid level control for light oil scrubber	