(11) Battery System

i) Type — Lead acid cell

ii) Rating — DC 125 V System 2,000 AH (incl. UPS)
DC 48 V System 500 AH

(12) Control and Instrumentation

i) Data Aquisition System

ii) Automatic Plant Control System

iii) Mill Burner Control System

iv) Boiler Sequential Control System

v) Turbine Sequential Control System

6.3.11 Ash Handling System (per unit)

(1) Chain Conveyor

| | |
|---|---|
| Capacity | 11.7 t/h |
| Number | 1 set |

(2) Clinker Crusher

| | |
|---|---|
| Capacity | 11.7 t/h |
| Number | 1 set |

(3) Bottom Ash Carrying Conveyor

| | |
|---|---|
| Capacity | 11.7 t/h |
| Number | 1 set |

(4) Fly Ash Silo

| | |
|---|---|
| Type | Steel plate type (with cyclone separator, bag filter and fluidizer) |
| Capacity | 1,000 $m^3$ |
| Number | 1 set |

(5) Vacuum Blower

| | |
|---|---|
| Type | Rotary blower type |
| Number | 3 sets/2 units |

(6) Dustless Unloader

| | |
|---|---|
| Capacity | 110 t/h |
| Number | 2 sets |

### 6.3.12 Powerhouse

(1) Structure

| | |
|---|---|
| Foundation | Reinforced concrete footing |
| Frame | Steel structure |
| Exterior wall | Aluminum panel cladding |
| Roof | - ditto - |

(2) Size

| | |
|---|---|
| Ground floor area | 5,800 $m^2$ |
| Building volume | 148,000 $m^3$ |
| Height | 32 m |

### 6.3.13 Stack

(1) Foundation Reinforced concrete footing

| | |
|---|---|
| (2) Outer Tube | Reinforced concrete construction<br>Diameter Top 13 m<br>Bottom 20 m |
| (3) Inner Tube | Steel construction<br>Diameter Top 4.0 m<br>Mean 5.0 m<br>Height 120 m |

### 6.3.14 Ancillary Buildings

(1) Administration Office

| | |
|---|---|
| i) Structure | |
| Foundation | Reinforced concrete footing |
| Frame | Reinforced concrete construction |
| ii) Total area | 1,600 $m^2$ |
| iii) Rooms accommodated | |
| 1st floor | Chemical laboratory<br>Dinning room<br>Rest room<br>Air conditioner room<br>Warehouse |
| 2nd floor | Office<br>Conference room<br>Plant manager's room<br>Locker room<br>Library |

(2) Others

| | |
|---|---|
| i) Work shop | Reinforced concrete construction<br>1 floor 500 m2 |
| ii) Warehouse | Reinforced concrete construction<br>1 floor 1,000 $m^2$ |

| | | |
|---|---|---|
| iii) | Coal yard control room | Reinforced concrete construction<br>3 floor 1,000 $m^2$ |
| iv) | Demineralization house | Reinforced concrete construction<br>1 floor 350 $m^2$ |
| v) | ESP Electricity house | Reinforced concrete construction<br>1 floor 100 $m^2$ |
| vi) | Chlorination plant house | Reinforced concrete construction<br>1 floor 120 $m^2$ |
| vii) | Ash silo structure | Reinforced concrete construction<br>2 floor 250 $m^2$ |
| viii) | Guest house | Reinforced concrete construction<br>1 floor 250 $m^2$ |
| ix) | Domitory | Reinformce concrete construction<br>1 floor 1,400 $m^2$ |

### 6.3.15 Environmental Protection Facilities

(1) Electrostatic Precipitator

| | |
|---|---|
| Type | Dry type |
| Number | 1 set |
| Flue gas capacity | 1,034 x $10^3$ $Nm^3/h$ |
| Inlet temperature | 140°C |
| Dust removal efficiency | 99% or more |

(2) Waste Water Treatment

| | |
|---|---|
| Type | Sedimentation, filteration, neutralization method |
| Number | 1 set/2 units |
| Treatment capacity | 1,000 $m^3$/day |

| | |
|---|---|
| Outlet water quality | PH 5.5 to 9 |
| | SS 200 mg/l or less |
| | Oil 15 mg/l or less |

(3) Coal Storage Yard Water Treatment

| | |
|---|---|
| Type | Gravity sedimentation method |
| Number | 1 set/2 units |

(4) Waste Water Treatment for Ash Disposal Area

| | |
|---|---|
| Type | Gravity sedimentation method |
| Number | 1 set/2 units |

## 6.4 Plant Layout

### 6.4.1 Basic Concept for Layout

The Masinloc site is surrounded by a hill on the northern side. The coral reefs form a natural shoal lessens the effects of waves in the area. These site characteristics help in making the decision as to the location of the power plant in Bani Point. The matters that were taken into consideration in deciding the location are the following.

i) To minimize the effects of waves coming in from the south and southwest direction.

ii) To minimize the effects of prevailing wind blowing from north-west.

iii) To place the main structures on sound foundation.

iv) To shorten to the utmost the total length of cooling water pipe and offshore belt conveyor.

v) To secure the plant site with relative ease.

vi) To secure the approach channel and turning basin for coal vessels without large scale dredging work.

vii) To secure the inland ash disposal area near the power plant.

### 6.4.2 Space of the Power Plant

The space of the power plant, calculated on the basis of preliminary design conditions and basic items, is as follows:

| | |
|---|---|
| (1) Power Plant Site and Coal Storage Yard | 329,000 $m^2$ |
| i) Power plant | 44,600 $m^2$ |
| ii) Switch yard | 14,600 $m^2$ |
| iii) Tank yard and water treatment facilities | 15,000 $m^2$ |
| iv) Administration office | 22,700 $m^2$ |

v) Coal storage yard — 96,600 $m^2$

vi) Intra site road, green belt, etc. — 135,500 $m^2$

(2) Ash Disposal Area

| | | |
|---|---|---|
| 10 years' portion | | 306,000 $m^2$ |
| 30 years' portion | | 727,000 $m^2$ |
| Total area | 10 years' portion | 635,000 $m^2$ |
| | 30 years' portion | 1,056,000 $m^2$ |

### 6.4.3 Layout of Structures and Facilities

(1) Power Plant and Coal Storage Yard

The power plant and the coal storage yard are to be located on the eastern side of Bani Point to lessen the effects of waves and winds. The power plant is to situated on the southern side, while the coal storage yard is placed on the northern side for the following reasons.

i) According to the results of boring carried out by NAPOCOR, bedrock is exposed at the tip of Bani Point located on the southern side. As the ground is excellent, the heavy main units of the power plant are located on the southern side.

ii) The total length of cooling water pipe is short.

(2) Coal Unloading Jetty

The coal unloading jetty is to be positioned at the entrance of Oyon Bay for the following reasons:

i) As most of the waves are broken at the shoal of the coral reef situated on the western side of the jetty the required calmness of the port can be secured.

ii) A turning basin can be secured in front of the jetty by relatively small dredging.

iii) The total length of offshore conveyor is relatively short.

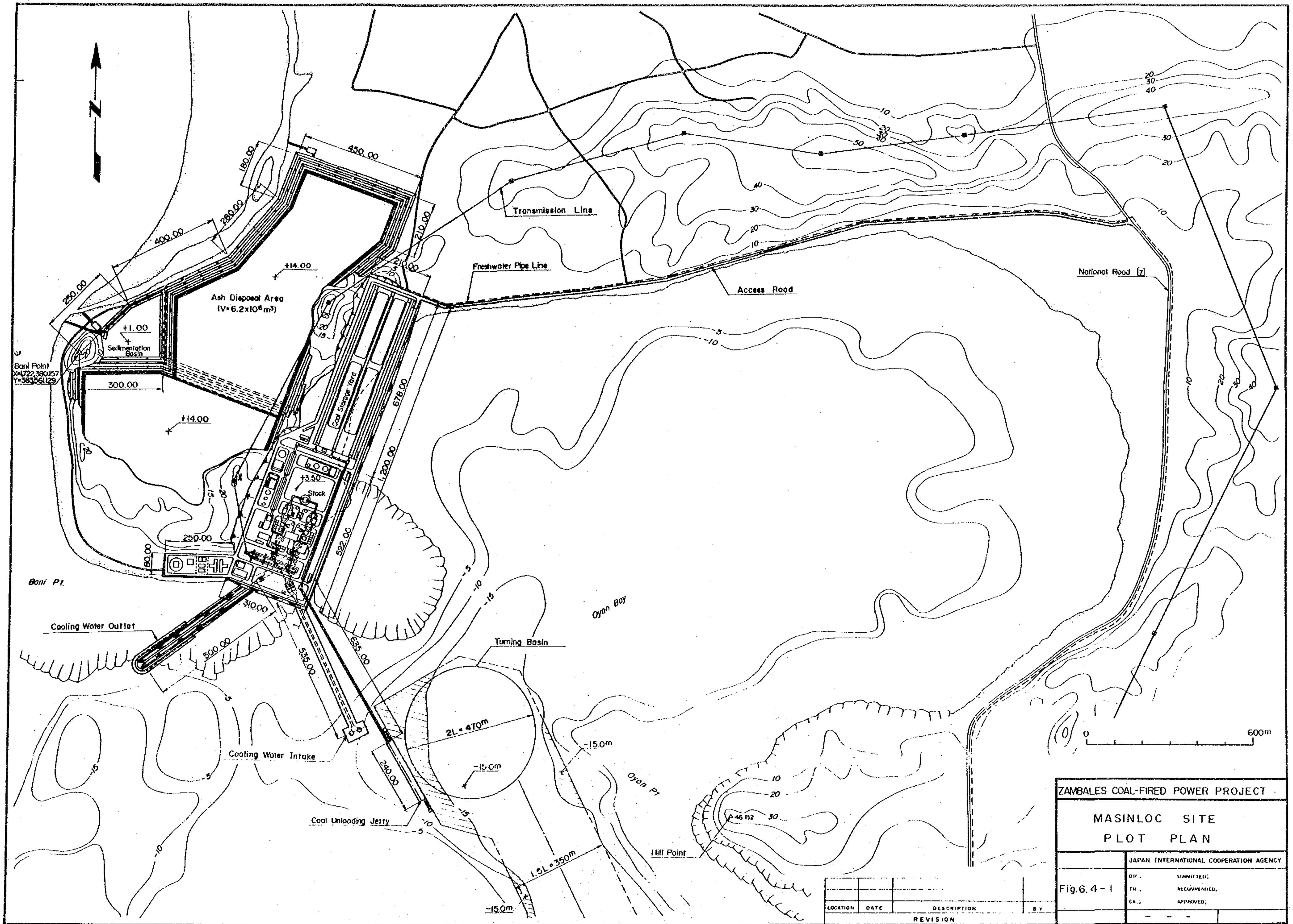
(3) Condenser Cooling Water Facilities

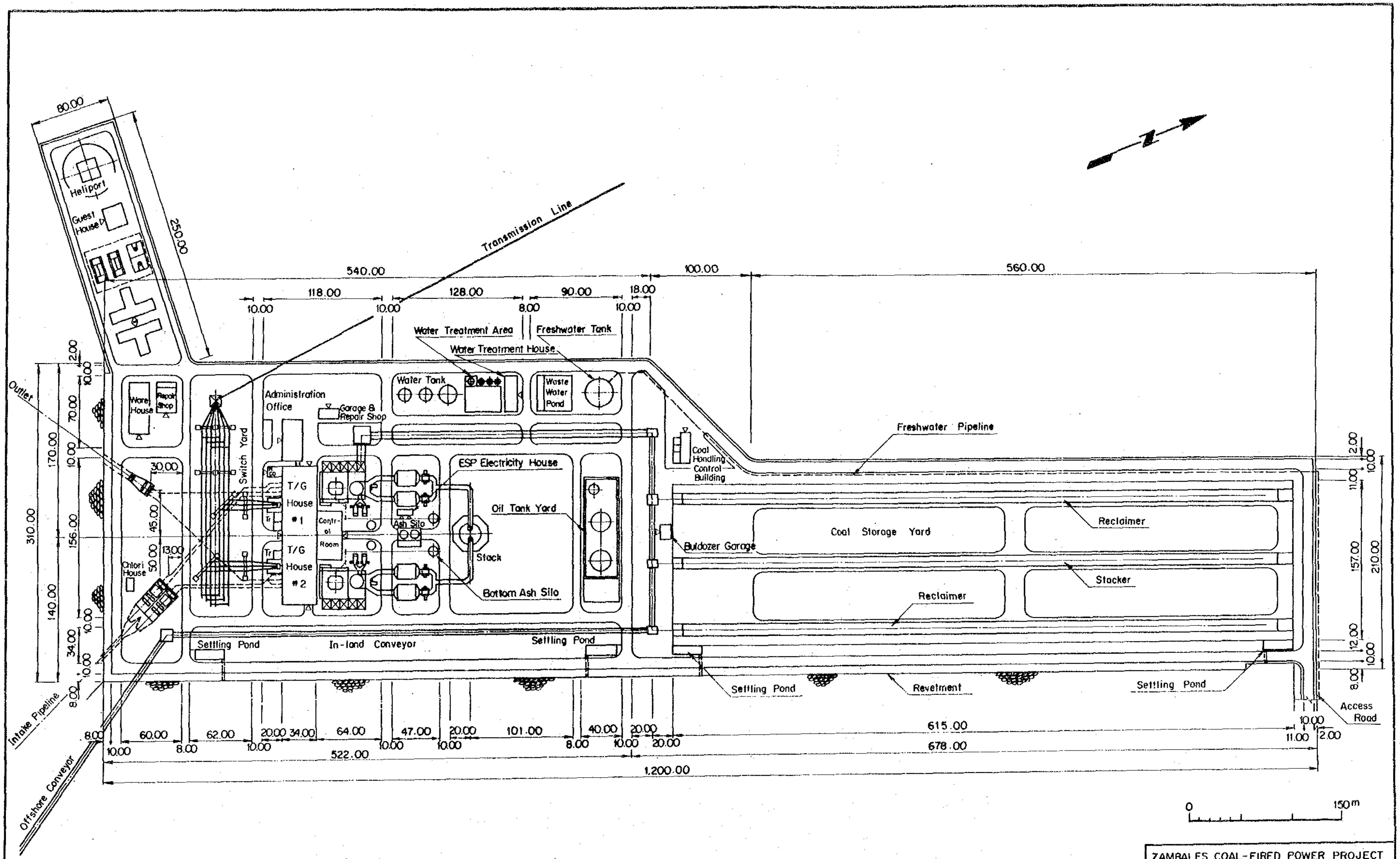
The intake is located at the entrance of Oyon Bay on the back side of the jetty, where influences of waves are small.

The outlet is located at the western side of the coral reef shoal a relatively deep basin which is situated far from the intake to of prevent recirculation of thermal effluent to the intake and greater diffusion effect of thermal effluent can be expected.

(4) Ash Disposal Area

This is placed on the western side of the plant so that the transport distance of ash will be shortened and the hill on the western side of the power plant can be utilized as a retaining wall for the ash disposal area.


N
Transmission Line
Freshwater Pipe Line
Access Road
National Road [7]
Ash Disposal Area
(V=6.2x10⁶m³)
Sedimentation Basin
Bani Point
X=1,722,380.157
Y=383,561.129
Coal Storage Yard
Stock
Bani Pt.
Cooling Water Outlet
Cooling Water Intake
Turning Basin
2L=470m
Oyon Bay
Oyon Pt.
Coal Unloading Jetty
1.5L=350m
Hill Point
600m
ZAMBALES COAL-FIRED POWER PROJECT
MASINLOC SITE
PLOT PLAN
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig.6.4-1
SUBMITTED;
RECOMMENDED;
APPROVED;
LOCATION
DATE
DESCRIPTION
BY
REVISION




ZAMBALES COAL-FIRED POWER PROJECT

GENERAL ARRANGEMENT OF EQUIPMENT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.4-2

## 6.5 Land Reclamation of Plant Site

### 6.5.1 Outline

In designing land reclamation, consideration was given to the following points:

i) Since the time interval of taking over between unit No. 1 and unit No. 2 will be very short, half a year, land reclamation will be carried out including the tract of land for unit No.2.

ii) Since most of the hilly area to the east of the Bani Point consists of alternations of sandstone and shale, they are suitable for banking material. The power plant ground can be prepared by partially excavating the hilly area and banking part of the low-land and Oyon Bay with this material.

iii) Since the hilly area to the west of the site can be used as a shield to prevailing winds and also as a retaining wall for ash disposal area, it was decided to leave it intact insofar as possible.

### 6.5.2 Height of Reclaimed Land

Reclaimed land height was set at DL (Datum Level) + 3.50 m for the following reasons:

i) It was set at a level including wave height and tolerance to prevent overtopping during the highest water level (H.H.W.L.) DL + 1.6 m on record.

ii) It was set at a level mean spring high water level (H.W.L.) DL + 1.3 m to provide drainage gradient for drain duct to be constructed in the plant area.

### 6.5.3 Land Reclamation and Revetment

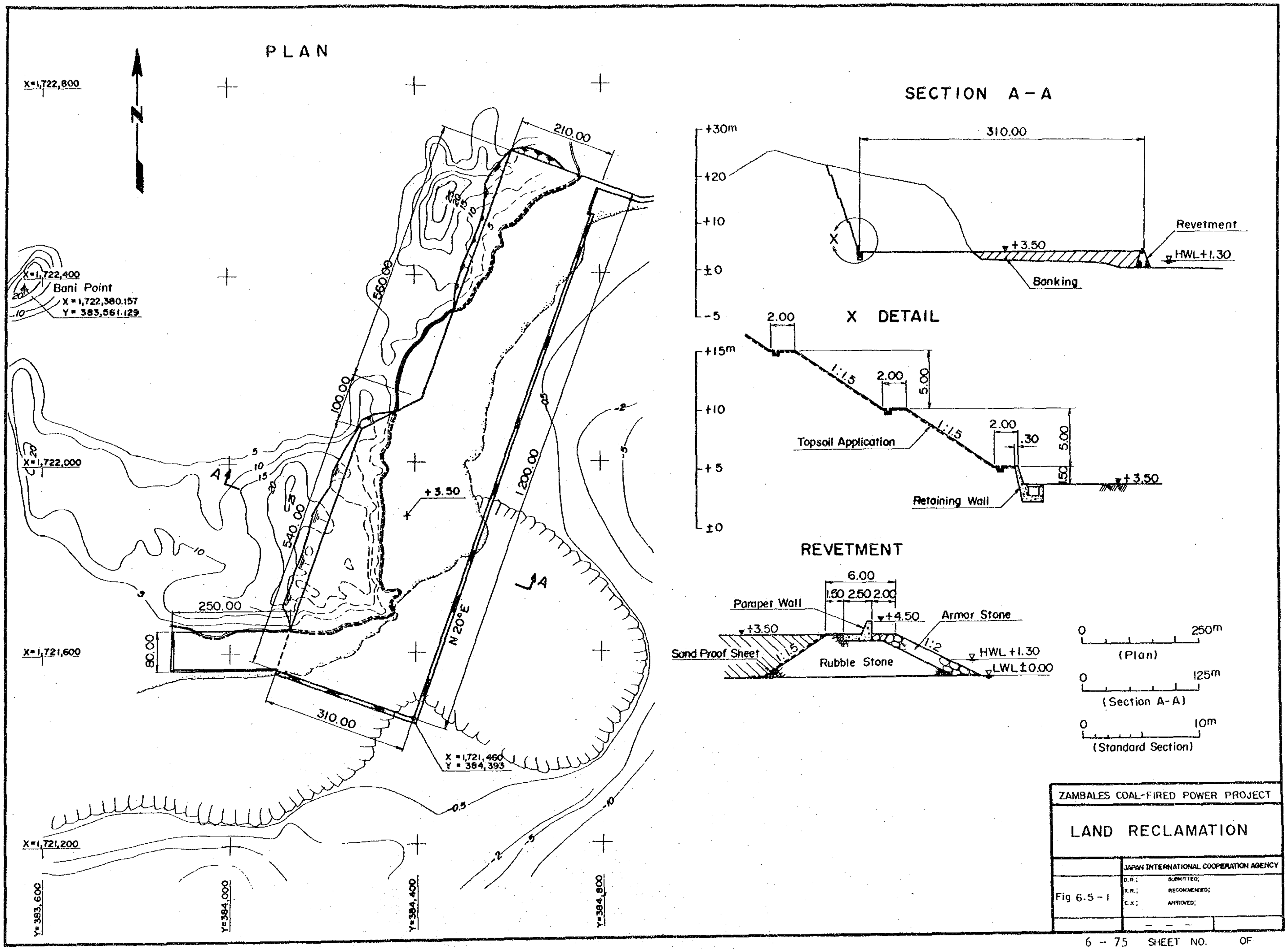
(1) Land Reclamation

The location of the plant area was decided after taking into consideration excavation and banking volume balance based on land height of DL + 3.50. Also, to shorten the length of the site as far as possible in order to locate the power plant and coal storage yard from south to north, heliport and guest house are separately placed to the west of the power station. Excavation volume is about 710,000 $m^3$. On the mountain slope, a retaining wall will be constructed at foot of the slope, and the excavated face of the slope will be greened by placing top-soil.

(2) Revetment

As for the reclaimed land in the sea, revetment will be constructed around the plant site. The total length of the revetment will be about 1,400 m.

The revetment will be of rubble stone construction, with riprap and parapet wall for preventing overtopping of waves into the power plant area.


PLAN
N
X=1,722,800
X=1,722,400
Bani Point
X = 1,722,380.157
Y = 383,561.129
X=1,722,000
X=1,721,600
X=1,721,200
Y=383,600
Y=384,000
Y=384,400
Y=384,800
210.00
560.00
100.00
540.00
1200.00
250.00
80.00
310.00
+3.50
N 20°E
A
X = 1,721,460
Y = 384,393
SECTION A-A
310.00
+30m
+20
+10
±0
-5
Revetment
+3.50
HWL+1.30
Banking
X
X DETAIL
+15m
+10
+5
±0
2.00
1:1.5
5.00
Topsoil Application
.30
.50
Retaining Wall
REVETMENT
6.00
1.50 2.50 2.00
Parapet Wall
+4.50
Armor Stone
Sand Proof Sheet
Rubble Stone
1:2
HWL +1.30
LWL ±0.00
0 250m (Plan)
0 125m (Section A-A)
0 10m (Standard Section)
ZAMBALES COAL-FIRED POWER PROJECT
LAND RECLAMATION
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 6.5 - 1
D.R.; SUBMITTED;
T.R.; RECOMMENDED;
C.K.; APPROVED;

## 6.6 Port Plan

### 6.6.1 Basic Concept

(1) Current Situation of the Bay Area

The characteristics of the bay area at the Masinloc site and the problems in ocean transport and unloading of coal at the power plant by utilizing this bay area can be summarized as follows:

i) The approach channel from the open sea to the power plant site is considerably long and both sides of the approach channel are shoals. Since there are three remarkable winding points in the approach channel to reach the power station, large coal vessels navigating this approach channel will be required to make continuous changes in their course which will call for skillful operation by the pilots.

ii) Currently ships including vessels of maximum sizes of 40,000 DWT class pass through the existing approach channel and enter and leave from the two ports in the bay. Fishing boats are also sailing in the bay. Under the current plan, coal vessels will utilize more than one half of this approach channel to navigate into the harbor, therefore, the number of vessels passing through the existing approach channel is expected to increase after the power plant starts operation. There will also be cases of coal vessels encountering other vessels navigating through the approach channel.

iii) The site of the power plant is only 2 km from the South China Sea and being located very close to the South China Sea, it is essential to gain knowledge of the maximum wave height and annual tranquil conditions at the port area.

There is no navigational problem relating to other natural conditions such as tide, tidal current (Refer to Section 6.2.1).

(2) Basic Concept

Port plan was studied under the following circumstance taking into consideration the matters stated in sub-paragraph (1) above:

i) The approach channel, the turning basin and the navigation aids will be designed so that large coal vessels can readily and safely navigate under normal navigation practice in the bay.

ii) New navigation control including navigational restrictions during inclement weather for vessels in the bay will be examined.

iii) Wave analysis will be made at the port area based on weather data.

This is the port plan in a complex sea area, therefore, study on safe navigation was performed with the cooperation of a maritime specialist who represents Japan in this field. The plan was prepared taking into consideration the following additional matters:

a) The port facilities will be in accordance with the "Technical standard for port and harbour facilities in Japan".

b) The sea chart which was published in the U.S.A. will be used for the topography of sea bottom at the site.

c) Dimensions of coal vessel:

| Vessel type | For oversea's Coal 60,000 DWT | For indigenous Coal 5,000 DWT |
|---|---|---|
| L.O.A. : | 233 m | 103 m |
| Moulded breadth (B): | 35 m | 15.4 m |
| Moulded depth (D) : | 18 m | 8.4 m |
| Full load draft (d): | 12.6 m | 6.8 m |
| Number of annual arrival of vessels: | 14 | 168 |

### 6.6.2 Port Facilities

(1) Layout

i) Jetty

The location of the coal unloading jetty was decided by taking into consideration the following matters (refer to Fig. 6.6-1):

a) To be able to maintain calmness in the sea area in front of the jetty for coal vessels to berth, or unberth and unload coal.

b) To be the shortest distance from the jetty to the power plant and to facilitate construction and operation of the jetty and the coal conveyor.

ii) Turning basin

The turning basin will be located between the jetty and Oyon Point so that vessels can turn the bow in the bay in front of the jetty.

iii) Approach channel in the bay

Taking into consideration the location of the jetty, sea bottom topography inside the bay, past navigation records of large vessels as well as reduction of approach channel construction cost, the approach channel for coal vessels was decided to:

- utilize the existing approach channel from the open sea to the area in front of Port Masinloc; and
- take a course where the sea bottom is deepest from Port Masinloc up to the jetty.

iv) Anchorage basin in the bay

The anchorage basin has been selected as follows:

- The offshore area of Port Masinloc where the water depth is 22 to 23 meters with sandy bottom.
- The central part of Oyon Bay where the water depth is 13 to 14 meters.

(2) Design

i) Approach channel

a) As there would be possibility of encountering other vessels, the approach channel will be two way traffic.

b) Although the length of the approach channel is long, marine traffic is relatively limited. Therefore, the width of the approach channel shall be 1.5 times the overall length of the vessel, i.e. 350 meters.

c) At the remarkably winding points, the center line at a curve of the approach channel shall be a circular arc with a radius of curvature of 4 times of the overall length of the vessel, i.e. 932 meters and the width of the approach channel shall be enlarged.

d) The water depth of the approach channel shall not be less than 16.5 meters below the datum level. The 16.5 m level was obtained by adding an allowance to the full load draft of a 60,000 DWT vessel (12.6 meters).

The allowance took into consideration rolling and pitching of vessels by waves and wind, settlement of vessels by moving, sea bed materials and relatively high frequency of sea surface being lower than the datum level in the approach channel.

ii) Jetty and turning basin

a) Considering easy operation of the vessel during berthing and un-berthing, the normal line of the jetty was made approximately parallel to the center line of the approach channel (Refer to Section 6.7 for the structural design of the jetty).

b) Under the premise that large vessels will be turned with tug boats (Refer to Fig. 6.6-2), the water area for the turning basin shall be a circle with a diameter of two times the overall length of the vessel (470 meters).

c) The water depth at the turning basin and the jetty shall be not less than 15 meters below the datum level. The 15 m level was obtained by adding an allowance to the full load draft (12.6 m).

The allowance took into consideration the small rolling and pitching of the vessels in the basin as well as the condition of the sea surface.

iii) Navigation aids

It will be necessary to install navigation aids such as light buoys to indicate approach channel and shoals and also wave meter, anemometer and others to provide information for navigation control of vessels.

iv) Dredging

From the sea charts, dredging will be required in several places in the approach channel, the jetty and the turning basin. Materials to be dredged are assumed to be sand and silt based on boring investigation.

### 6.6.3 Navigation Control in the Bay

There are two existing ports in the bay and navigation of vessels are regulated by compulsory pilotage for large vessels. Once the power plant is constructed, it will be necessary to add the following navigation control for vessels:

(1) When the wind velocity is 15 m/s or more, the wave height is 1.5 meters or more, or when the visibility is less than one mile, navigation of vessels in the bay shall be restricted. Vessels shall be anchored at the specified anchorage basin.

However, it will be necessary to restudy the above considerations taking into account natural conditions and vessel traffic.

(2) Prohibiting navigation of vessels during the night, and having vessels anchor at the specified anchorage basin.

(3) Piloting large coal vessels with the assistance of tug boats.

(4) Establishing a liason system and selecting a person who is well-versed in vessels to carry out the navigation control.

### 6.6.4 Examination of Calmness and Design Wave

(1) Design Wave

As the power plant site is located only 2 km from the South China Sea, the design wave was calculated at jetty, cooling water outlet and revetment and the information obtained will be used for safe design of these structures. The probable maximum wave of return period of 50 years was calculated by analyzing program of waves using typhoon records collected during the field survey. The design wave height was established as follows:

| | |
|---|---|
| • Wave height offshore of the site (South China Sea) | Approx. 10 meters |
| • Wave height at cooling water outlet (inside the bay) | 3 meters |
| • Wave height at jetty and revetment (inside the bay) | 2 meters |

The noticeable difference in wave height of offshore waves and waves inside the bay are due to the transformation of waves caused by coast topography and particularly formed by wave breaking on the shoals (Refer to Table 6.6-1, Fig. 6.6-3).

(2) Calmness in the Berthing Basin

In order to constantly supply the annual coal requirement to the power plant, the following calmness must be obtained at the sea area in front of the coal unloading jetty (berthing basin).

i) The conditions for berthing and un-berthing of coal vessels as well as for unloading are assumed to be less than 0.7 meter in wave height and be less than 13 meters per second in wind velocity in the berthing basin.

ii) The calmness is expressed by the frequency of the above-mentioned based on wind and wave data.

iii) The required calmness should not be less than 85%.

The calmness at the berthing basin is calculated by the calmness analysis program using the daily wind data that have been collected during the field survey. As a result, annual mean calmness is 96% and monthly mean calmness are more than 85% (Refer to Table 6.6-2).

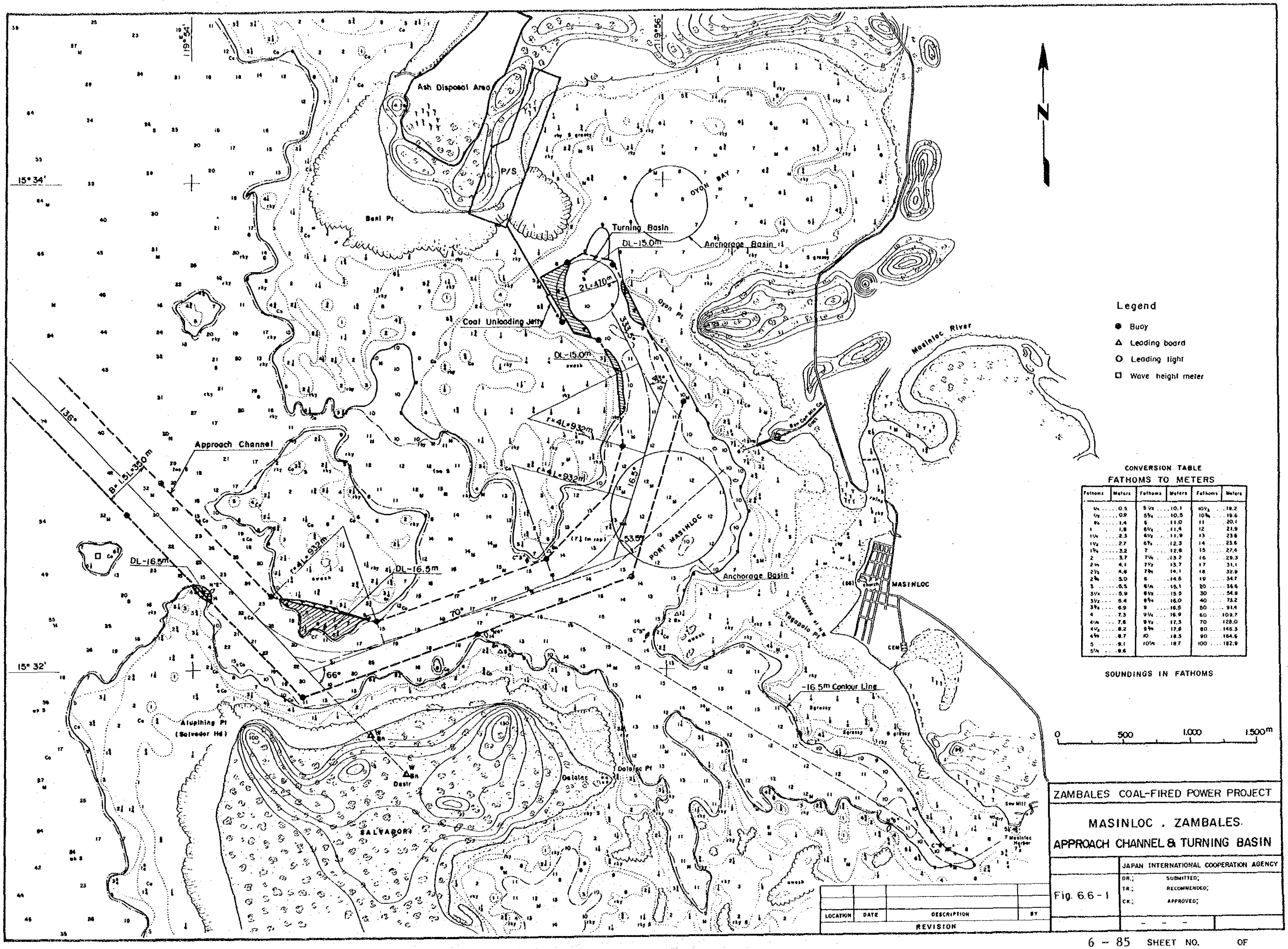
It is considered that the calmness estimated above is reasonable and that the berthing basin satisfies the conditions for constantly supplying coal, because of the following:

i) The deepwater waves entering the berthing basin from the south-south west to west directions only influence the calmness in the berthing basin due to the configuration of the bay mouth. The deepwater waves from other directions do not influence the calmness of the berthing basin.

ii) In the narrow bay surrounded by the hills, waves do not fully develop ordinary winds.

iii) The frequency of strong winds of more than 13 meter per second is limited.

The details of design wave and calmness in the berthing basin are shown in the Appendix on "Wave Analysis at Masinloc Site".




CONVERSION TABLE
FATHOMS TO METERS

| Fathoms | Meters | Fathoms | Meters | Fathoms | Meters |
|---|---|---|---|---|---|
| 1/4 | 0.5 | 5 1/2 | 10.1 | 10 1/2 | 19.2 |
| 1/2 | 0.9 | 5 3/4 | 10.5 | 10 3/4 | 19.6 |
| 3/4 | 1.4 | 6 | 11.0 | 11 | 20.1 |
| 1 | 1.8 | 6 1/4 | 11.4 | 12 | 21.9 |
| 1 1/4 | 2.3 | 6 1/2 | 11.9 | 13 | 23.8 |
| 1 1/2 | 2.7 | 6 3/4 | 12.3 | 14 | 25.6 |
| 1 3/4 | 3.2 | 7 | 12.8 | 15 | 27.4 |
| 2 | 3.7 | 7 1/4 | 13.2 | 16 | 29.3 |
| 2 1/4 | 4.1 | 7 1/2 | 13.7 | 17 | 31.1 |
| 2 1/2 | 4.6 | 7 3/4 | 14.1 | 18 | 32.9 |
| 2 3/4 | 5.0 | 8 | 14.6 | 19 | 34.7 |
| 3 | 5.5 | 8 1/4 | 15.1 | 20 | 36.6 |
| 3 1/4 | 5.9 | 8 1/2 | 15.5 | 30 | 54.9 |
| 3 1/2 | 6.4 | 8 3/4 | 16.0 | 40 | 73.2 |
| 3 3/4 | 6.9 | 9 | 16.5 | 50 | 91.4 |
| 4 | 7.3 | 9 1/4 | 16.9 | 60 | 109.7 |
| 4 1/4 | 7.8 | 9 1/2 | 17.3 | 70 | 128.0 |
| 4 1/2 | 8.2 | 9 3/4 | 17.8 | 80 | 146.3 |
| 4 3/4 | 8.7 | 10 | 18.3 | 90 | 164.6 |
| 5 | 9.1 | 10 1/4 | 18.7 | 100 | 182.9 |
| 5 1/4 | 9.6 | | | | |

SOUNDINGS IN FATHOMS

ZAMBALES COAL-FIRED POWER PROJECT

MASINLOC , ZAMBALES

APPROACH CHANNEL & TURNING BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.6-1

DR.; SUBMITTED;
TR.; RECOMMENDED;
CK.; APPROVED;

| LOCATION | DATE | DESCRIPTION | BY |
|---|---|---|---|

REVISION

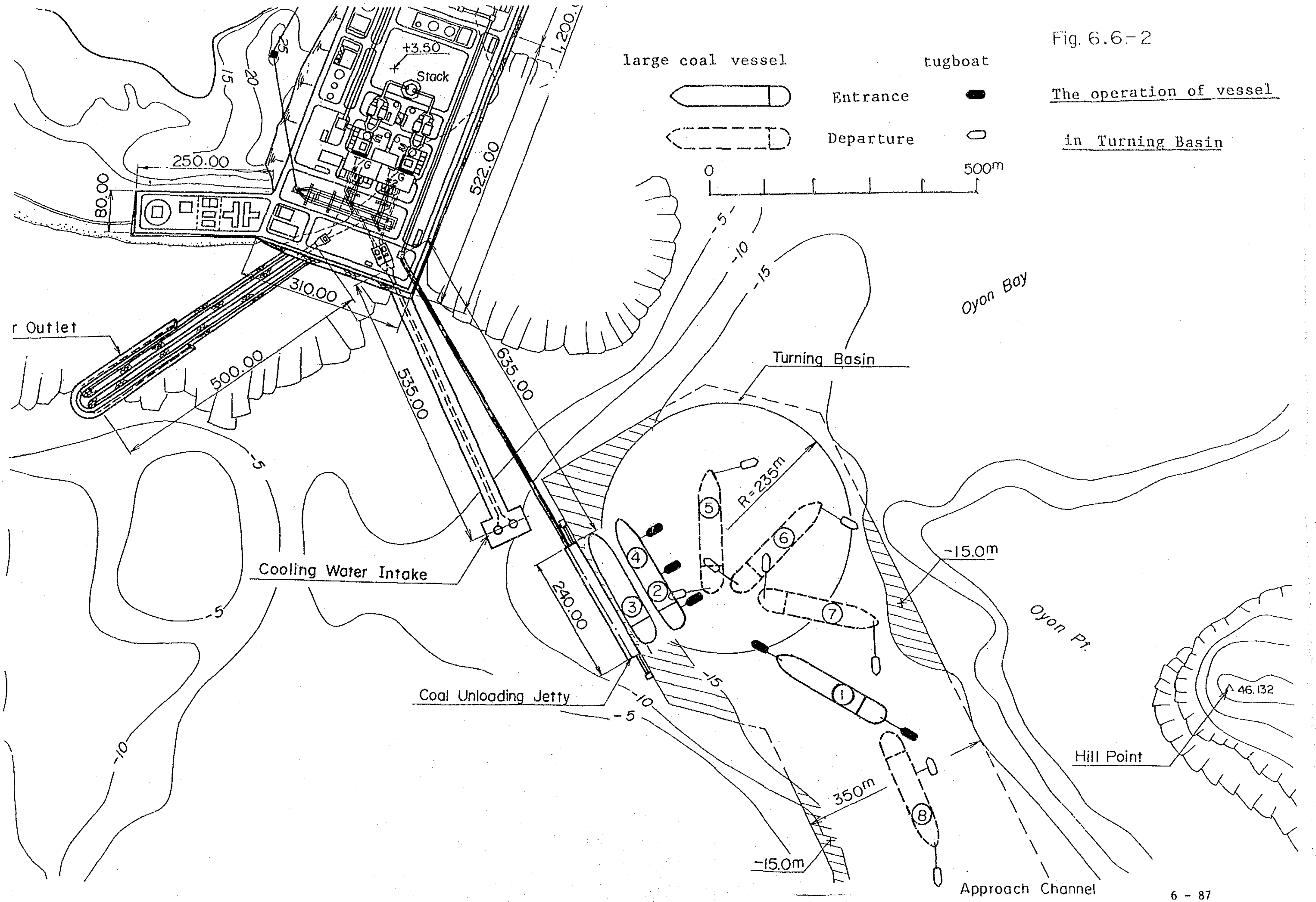


Fig. 6.6-2
The operation of vessel
in Turning Basin
large coal vessel
tugboat
Entrance
Departure
0
500m
+3.50
Stack
T/G
250.00
80.00
310.00
500.00
535.00
635.00
522.00
1,200.0
r Outlet
Cooling Water Intake
Coal Unloading Jetty
240.00
Turning Basin
R=235m
Oyon Bay
Oyon Pt.
-15.0m
350m
Hill Point
46.132
Approach Channel

TABLE 6.6-1 (1) PROCEDURE TO CALCULATE DESIGN WAVE

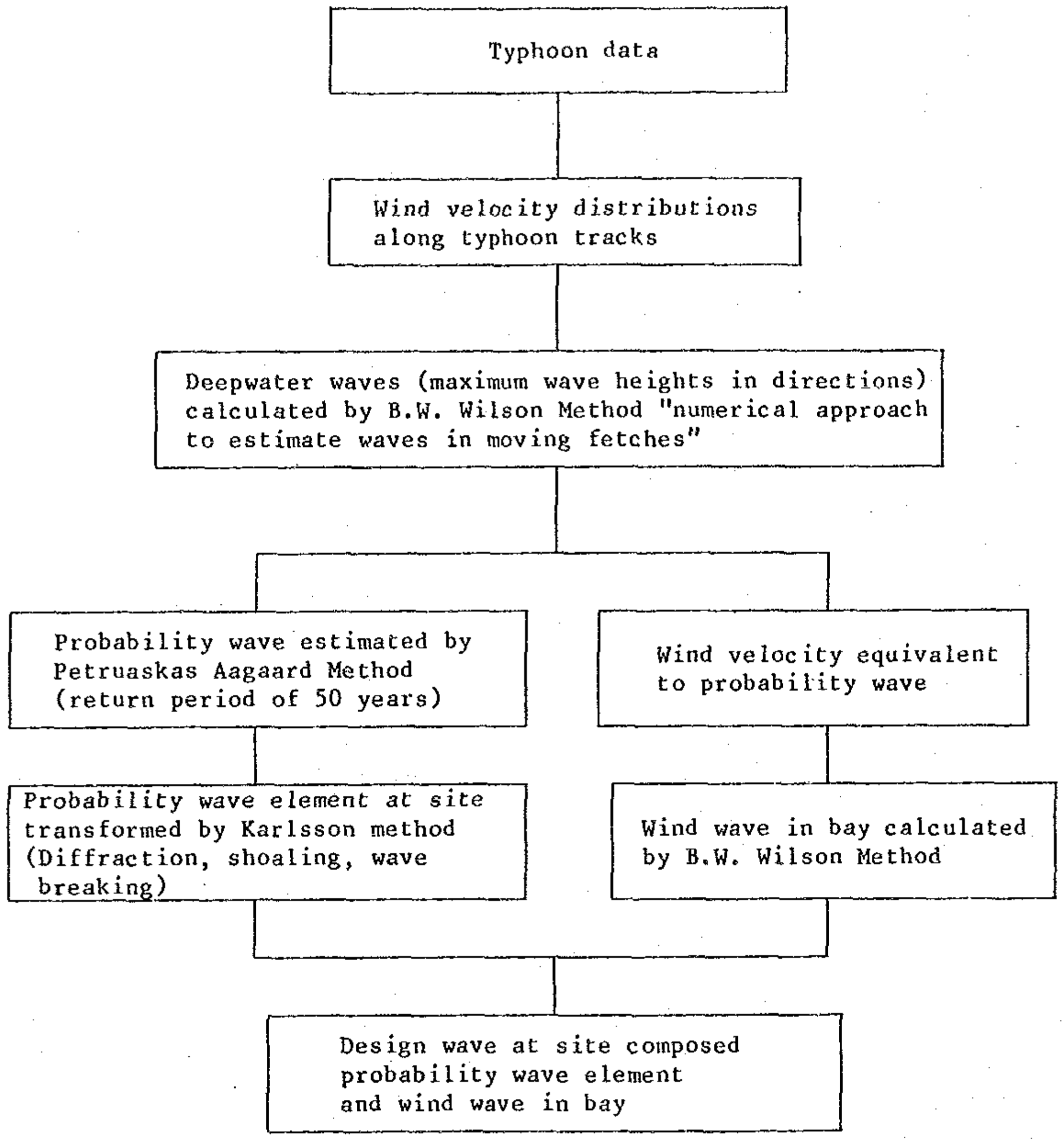
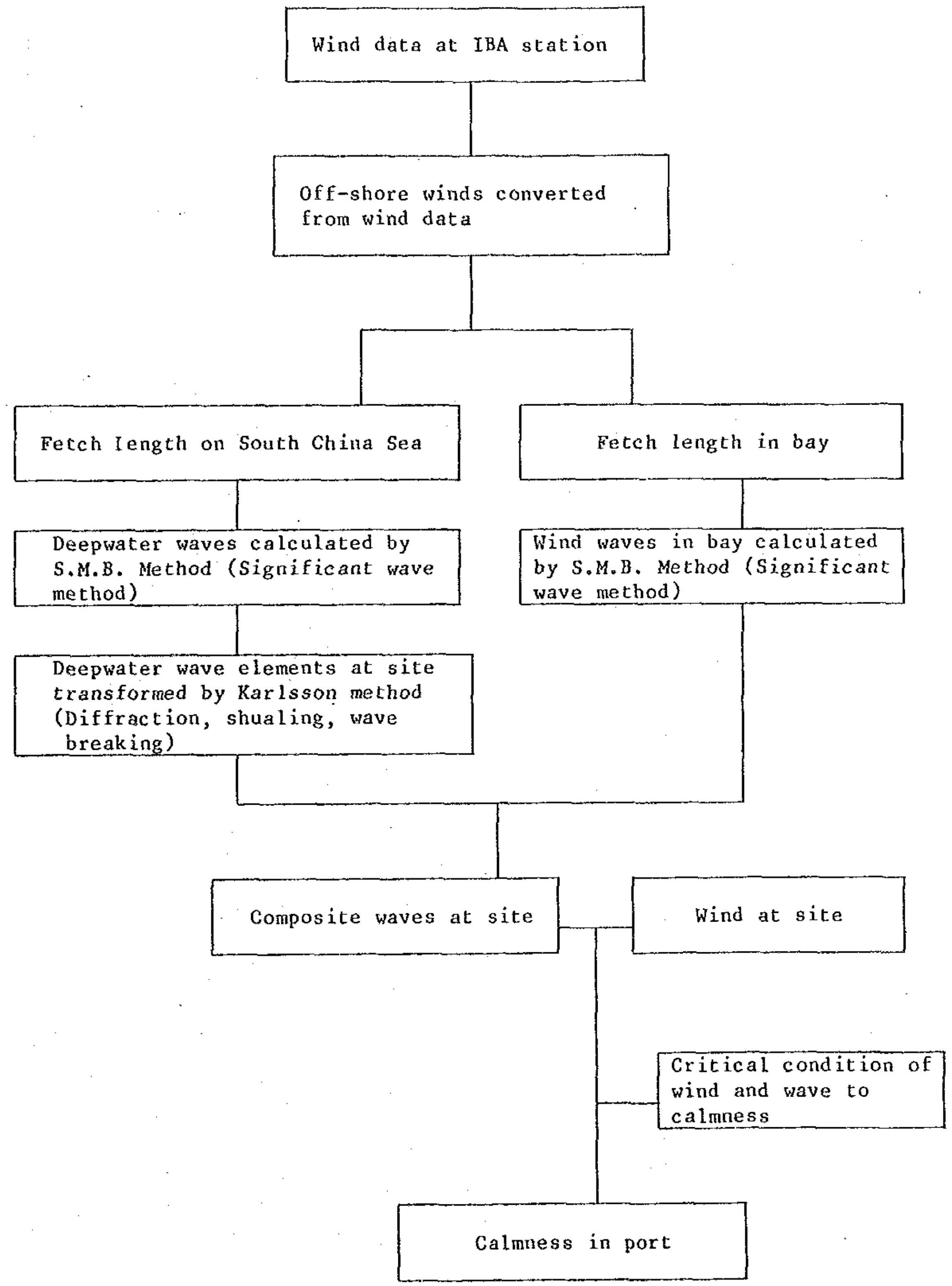



TABLE 6.6-1 (2) PROCEDURE TO CALCULATE CALMNESS IN PORT



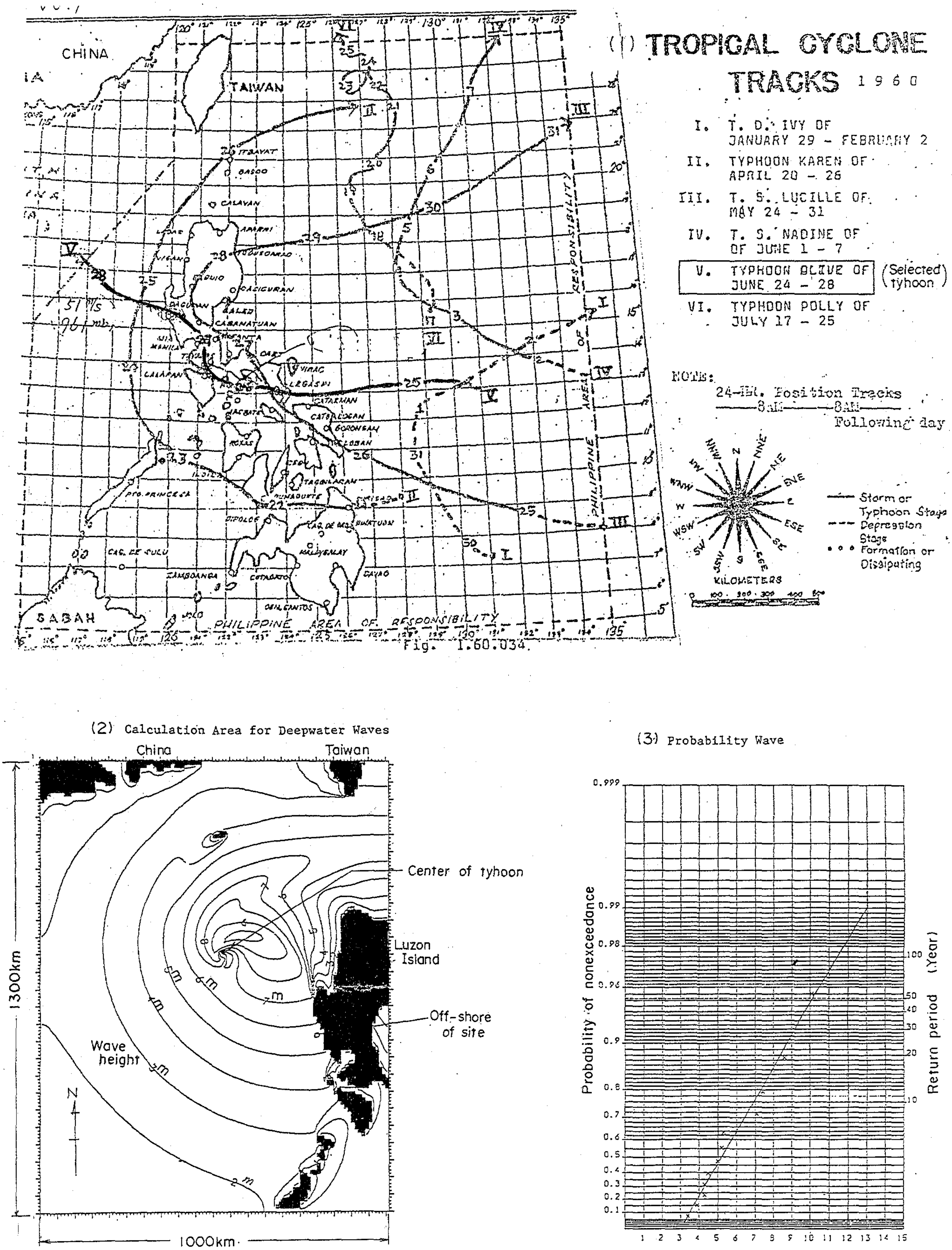
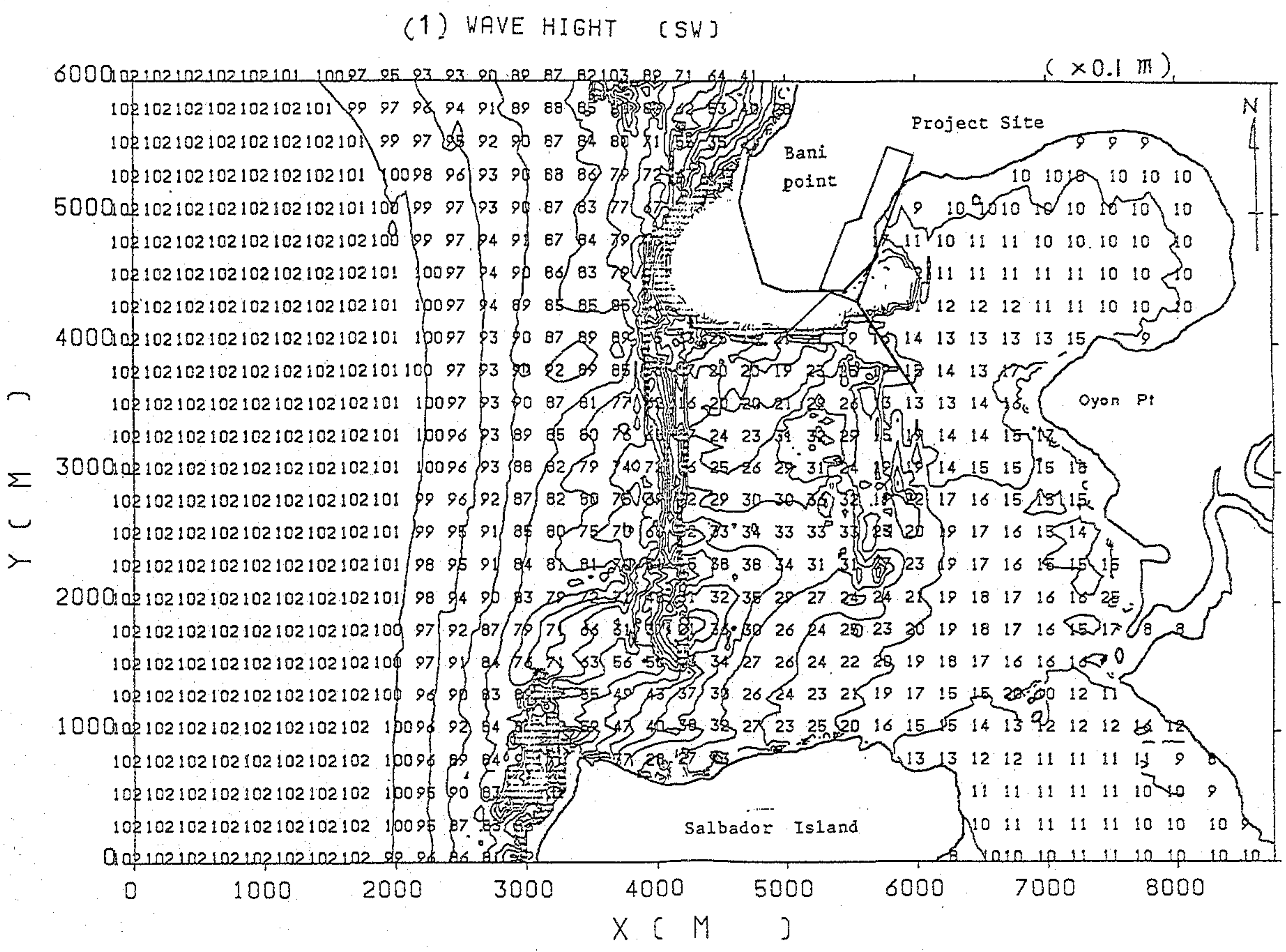



Fig.6.6-3(1) Calculation Method for Design Wave



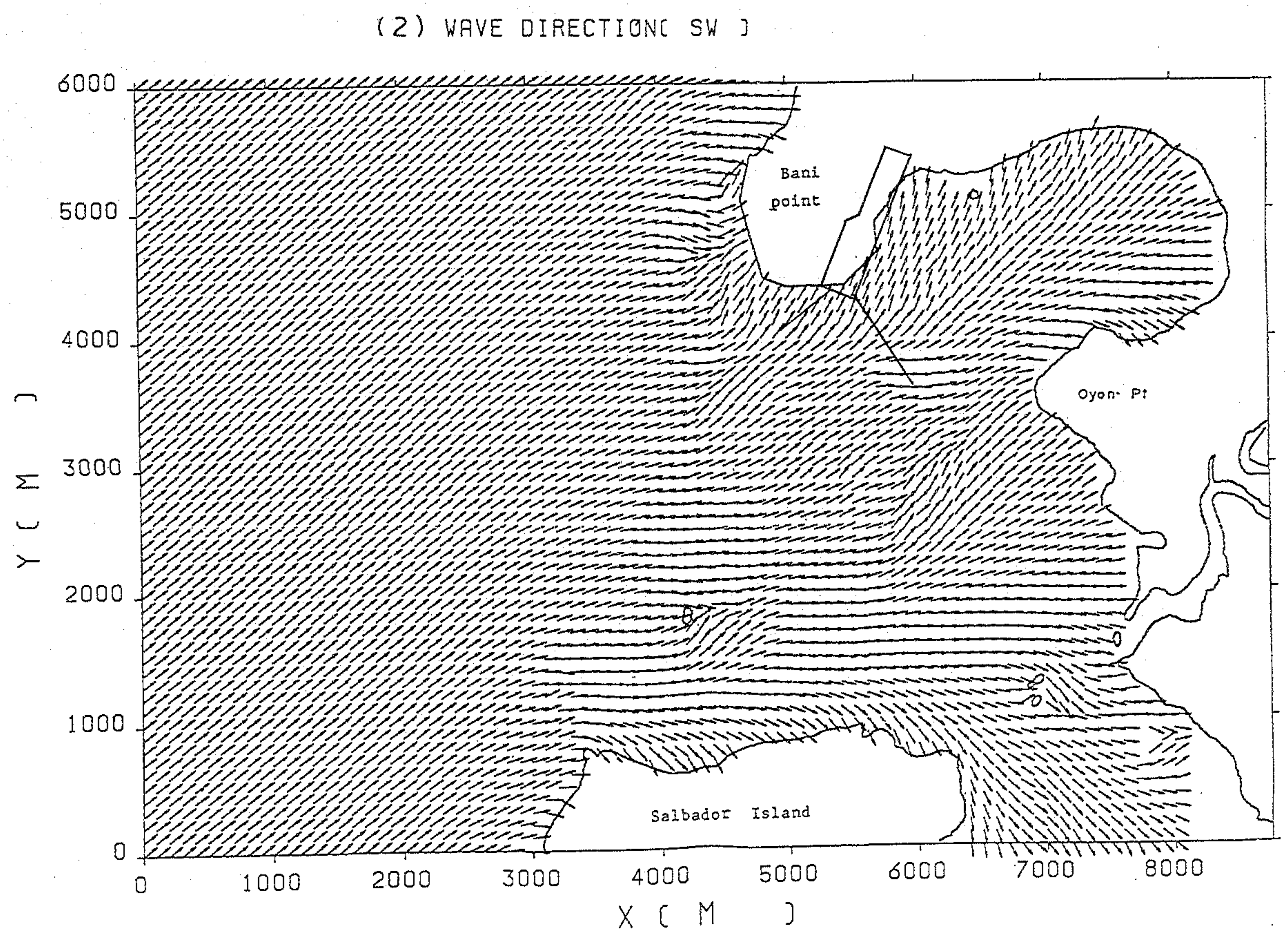




Fig. 6·6-3 (2) Calculation Result on Waves Combined Deepwater Waves with Wind Waves in Bay

Table 6.6-2 (1) Distribution of Wave Heights
(Wave Combined Deepwater Wave with Wind Wave in Bay)

LT 0.4 : All direction less than 0.4 m/s
Data period : Jan. 1981 to Dec. 1985
Number of data: 12,698

(%)

| Wave Height | LT0.40 | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 - 0.3 m | 11.4 | 6.2 | 3.4 | 9.2 | 1.4 | 19.9 | 4.6 | 5.8 | 0.8 | 3.2 | 1.1 | 3.2 | 1.0 | 4.3 | 1.1 | 10.0 | 0.8 | 87.37 |
| 0.3 - 0.5 m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.1 | 1.5 | 0.3 | 0.9 | 0.3 | 1.0 | 0.4 | 1.9 | 0.0 | 6.79 |
| 0.5 - 0.7 m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.6 | 0.2 | 0.3 | 0.2 | 0.4 | 0.0 | 2.14 |
| 0.7 - 1.0 m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.1 | 0.5 | 0.1 | 0.4 | 0.1 | 0.1 | 0.0 | 1.66 |
| 1.0 - 2.0 m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.2 | 0.5 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 1.70 |
| 2.0 - 4.0 m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.27 |
| 4.0 - MAX m | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.07 |
| TOTAL | 11.4 | 6.2 | 3.4 | 9.2 | 1.4 | 19.9 | 4.7 | 6.2 | 0.9 | 5.8 | 1.9 | 5.7 | 1.7 | 6.1 | 1.9 | 12.5 | 0.9 | 100.00 |

Table 6.6-2 (2) Calmness in Berthing Basin

Condition for calmness: Wind velocity < 13 m/s, Wave height < 0.7 m
Data period : Jan. 1981 to Dec. 1985
Number of data : 12,698

(%)

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 94.1 | 91.1 | 100.0 | 100.0 | 100.0 | 97.9 | 91.1 | 74.6 | 90.8 | 96.4 | 91.7 | 97.4 | 93.5 |
| 1982 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.2 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 |
| 1983 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1984 | 100.0 | 98.3 | 99.2 | 98.3 | 96.8 | 91.1 | 96.7 | 75.4 | 98.3 | 95.2 | 98.7 | 98.3 | 95.5 |
| 1985 | 100.0 | 100.0 | 98.0 | 97.5 | 96.8 | 71.4 | 90.7 | 85.1 | 93.8 | 92.7 | 100.0 | 98.4 | 94.0 |
| TOTAL | 98.7 | 97.6 | 99.4 | 99.1 | 98.5 | 91.9 | 95.2 | 85.4 | 96.2 | 96.4 | 97.9 | 98.8 | 96.2 |

## 6.7 Coal Handling Facilities

Coal unloading, transporting and storing are composed of the following facilities:

i) Coal unloading jetty
ii) Ship unloader
iii) Receiving conveyor
iv) Stacking equipment
v) Coal storage yard
vi) Reclaiming equipment
vii) Discharging conveyor

The types and capacities of respective facilities are influenced by outside factors such as the quality and quantity of coal handled, meteorological conditions, environmental control, etc., and it is necessary to satisfy these conditions. Hereunder, the basic conditions for the preliminary design have been established and the types and capacities of the respective facilities have been studied.

### 6.7.1 Study Conditions

(1) Annual Coal Consumption

One unit base: 840,000 tons
Two unit base: 1,680,000 tons

(2) Daily Coal Consumption

One unit base : 3,312 tons/day (138 t/h x 24 h)
Two units base: 6,624 tons/day (138 t/h x 24 h x 2)

(3) Coal Unloading Berth

1 berth - 60,000 DWT class

(4) Vessel Size

60,000 DWT and 5,000 DWT

(5) Coal Storage Capacity and Number of Stock Piles

| | | |
|---|---|---|
| Coal storage capacity | : | About 300,000 tons (45 days requirement) |
| Indigenous coal storage capacity | : | 150,000 tons |
| Overseas coal storage capacity | : | 150,000 tons |
| Number of stock piles | : | 2 |

(6) Daily Working Hours

Unloading time: 0:00 - 24:00 (actual working hours: 20 hours)
Discharge time: 8:00 - 22:00 (actual working hours: 12 hours)

(7) Annual Working Condition

No day-off during unloading and discharge

(8) Expected Annual Available Working Days

300 days (10 days inspection and 55 days adverse weather)

(9) Annual Inspection Period for Power Generation Facilities

One unit base: 40 days
Two unit base: 1U -- 40 days
2U -- 40 days

(10) Blending Condition

Simultaneous blending of two sources

(11) Coal Property

Apparent specific gravity: 0.8 $t/m^3$ (Capacity calculation)
0.9 $t/m^3$ (Load calculation)

| | | | |
|---|---|---|---|
| Particle size distribution | : | Larger than 40 mm | 20% (Maximum 100 mm) |
| | | 40 to 2 mm | 54% |
| | | Under than 2 mm | 26% |

Moisture : Maximum 29%

Repose angle : 40°

Hardgrove Index (HGI) : Maximum 50

### 6.7.2 Unloader

(1) Selection of Unloader Type

There are four types of unloader used for coal handling, namely: bucket-chain type continuous unloader, level ruffing unloader, rope trolley type gantry unloader, and man trolley type gantry unloader.

Comparative results of these four types are shown in the Appendix 6-1.

Recently, unloaders have been strongly required to be efficient in unloading operations, excellent in terms of environmental countermeasures against dust emission and noise and advanced in manpower saving, energy conservation and economy. As a comparative result of these four types, bucket-chain type continuous unloader is considered to be the most suitable.

(2) Calculation of Unloader Capacity

Overseas coal is transported by 60,000 DWT class coal vessel, while indigenous coal is transported by 5,000 DWT class vessel. In consideration of inspection and operational needs, two units of unloader shall be installed.

The capacity of unloaders will be computed on the basis of the following two viewpoints and the capacity meeting the requirements from such viewpoints will be selected.

i) Average unloading rate per day
ii) Annual unloading quantity and berth occupancy

Calculation formula for method i)

$$\frac{Qt}{2\ \text{units} \cdot T \cdot \eta w}$$

Qt: Average unloading rate per day

T : Daily unloading hours (Actual working hours)

$\eta$w: Working efficiency of unloader

Calculation formula for method ii)

$$\frac{Qy}{2\ \text{units} \cdot \rho t \cdot T \cdot \eta w \cdot N}$$

Qy: Annually handled quantity

$\rho$t: Nominal berth occupancy

N : Annual available working days

Calculation Sheet of Unloader Capacity

| | | |
|---|---|---|
| Vessel Size | 60,000 DWT<br>(Ocean-going vessel) | 5,000 DWT<br>(Coastal vessel) |
| No. of Unloaders | 2 units | 2 units |
| Type of Unloader | Continuous unloader | Continuous unloader |
| Working Efficiency of Unloader | 0.7 | 0.35 |
| Unloading Rate per Day | 15,000 t/d | 3,000 t/d |
| Daily Unloading Hours (actual working hours) | 20 h/d | 20 h/d |
| Unloader Capacity Required Based on Unloading Rate per Day | 15,000 / 2unitsx0.7x20h/dx1day<br>= 536 t/h | 3,000 / 2unitsx0.35x20h/dx1day<br>= 214 t/h |
| Annually Handled Volume | 840,000 tons | 840,000 tons |
| Available Working Days per Year | 300 day<br>Holidays 0<br>Inspection 10<br>Bad weather days 55 | 300 day<br>Holidays 0<br>Inspection 10<br>Bad weather days 55 |
| Berth Occupancy Rate | 0.2 | 0.3 |
| Unloader Capacity Required on the Basis of Annually Handled Volume | 840,000 t / 300dx0.2x2unitsx0.7x20h/d<br>= 500 t/h | 840,000 t / 300dx0.3x2unitsx0.35x20h/d<br>= 667 t/h |
| Required Unloader | 2 units x 500 t/h | 2 units x 667 t/h |

As calculated above, the required unloader capacity is more than 667 t/h. Accordingly, unloaders to be installed will be two 700 t/h bucket chain type continuous unloaders.

(3) Verification of Berth Occupancy

The berth occupancy in the case that two 700 t/h continuous unloaders are installed will be verified.

i) In case of 60,000 DWT vessel

$$\rho E = \frac{840,000 \text{ t/h}}{2 \text{ units} \times 700 \text{ t/h} \times 0.7 \times 20 \text{ h/d} \times 300 \text{ d/y}}$$

$= 0.143$

ii) In case of 5,000 DWT vessel

$$\rho D = \frac{840,000 \text{ t/h}}{2 \text{ units} \times 700 \text{ t/h} \times 0.35 \times 20 \text{ h/d} \times 300 \text{ d/y}}$$

$= 0.286$

iii) Overall berth occupancy

$$\rho = \rho_E + \rho D$$
$$= 0.143 + 0.286$$
$$= 0.429$$

The berth occupancy for exclusive mono-cargo wharf including coal-fired power plant is generally estimated at less than 60%. Therefore, two 700 t/h continuous unloaders are considered sufficient to smoothly carry out unloading at the port.

### 6.7.3 Unloading Jetty

(1) Basic Conditions

The basic conditions for the preliminary design of coal unloading jetty are shown below:

| | |
|---|---|
| . Ships to be moored | 60,000 DWT Coal vessel |
| | 5,000 DWT Coal vessel |
| | 500 DWT Oil tanker |
| . Tidal level | H.W.L; D.L + 1.3 m |
| | L.W.L; D.L ± 0.0 m |
| . Wave height | H 1/3 = 2m |
| . Seismic coefficient | $K_H = 0.20$ |

- Wind velocity — 13 m/sec. at the time of operation
  49 m/sec at the time of storm
- Water depth of the berth — 15 m
- Unloader — No. of units: 2
  Capacity : 700 t/h
  Dead weight : 890 t/unit

(2) Geological Conditions

Judging from the geological profile at offshore borings No. 2 and No. 3, carried out by JICA around the planned unloading jetty site, silt and clay are deposited from the sea bottom to a depth of 10 m to 23 m, and its N value is 15 to 24. Beneath the clay layer, there is a sand silt layer with N value of more than 60, which will be the supporting stratum for the piles of the unloading jetty.

(3) Facilities Arrangement

The facilities and layout for the ships to be moored are shown in Fig. 6.7-1:

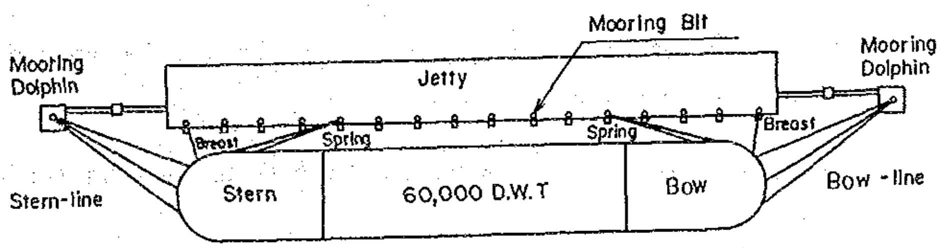



Fig. 6.7-1 Jetty and Coal Vessel Mooring

Bow line and stern line have the purposes of preventing forward and backward movement of ship and at the same time laterally supporting it, so that it is necessary to stretch them at an angle of 30 degrees to the face line of the jetty. Since it is uneconomical to include the facilities for bow and stern mooring ropes in the jetty itself, mooring dolphines were designed at both ends of the jetty for mooring only.

Jetty length of 240 m which is almost equal to the length of a 60,000 DWT vessel is adopted as it is the largest vessel planned to be moored. This jetty size takes into consideration ship length, location of hatch, traveling range of unloaders, etc.

Mooring dolphins are provided at both ends 45 m apart from the jetty, and a connecting walkway is installed between the jetty and the dolphins.

Regarding 5,000 DWT coal vessel and a 500 DWT oil tanker, when 60,000 DWT coal vessel is not berthed, 5,000 DWT vessel and 500 DWT tanker can be berthed at the same time on the north and south sides of the jetty, respectively.

The width of the jetty was determined taking into consideration the following conditions:

- Gauge of unloader rails and loading conditions;
- The number of piles and pile spacing are decided on the basis of design force, and
- Installation space for attached facilities such as fenders and bitt.

The gauge of unloader rails is 20 m. Based on these conditions, the width of the jetty was set at 25 m. The size of one block for the 240 m-long jetty was decided in consideration of the following conditions:

- The berthing energy by the ship should be safely transferred to the jetty by installing fenders in the center of the blocks.

- The ships to be moored will be 60,000 DWT, 5,000 DWT and 500 DWT class, and the distance between fenders suitable for the berthing of these classes of ships is about 15 m, and

- The bigger the size of one jetty block, the stronger the stiffness versus such design forces as ship's berth pressing force and tractive force, and therefore, the more desirable. However, it is necessary to limit the size of one block so that the required volume of concrete can be placed in one day.

Based on the above conditions, the length of one block was set at 15 m, while the number of blocks was fixed at 16 (see Fig. 6.7-2).

(4) Structure and Crown Height of Jetty

As for the structure of the jetty, it was decided for reasons shown below to adopt the pile type jetty with reinforced concrete slab and beam for the upper structure, and using steel piles:

- It is required for the jetty to have a structure to withstand the unloader weight of 890 tons without occurrence of differential settlement.

- As stated in the above geological conditions, a heavy structure such as a caisson is not suitable for the jetty site because of the thick deposit. This being the case, pile structure to be supported by a layer with N value of more than 60 was adopted.

- As regards the kind of piles, steel pipe piles were adopted because of their characteristics of ensuring the driving of long piles in the sea, penetration of piles into hard supporting stratum and having considerable durability.

The deck height of the jetty was set at D.L. + 5.0 m in order to secure a height sufficiently safe against uplift force acting on the superstructure slab.

In consideration of the above points, structural calculations of the planned jetty was carried out based on the basic conditions and the standard section shown in Fig. 6.7-3.

For anti-corrosion measures of steel pipe piles of the jetty, it was decided to apply mortar to the surface of the piles to be washed with sea water or exposed/submerged depending on the tidal changes and to employ aluminum alloy anodes for cathodic protection for portions of piles submerged in water.

(5) Ancillary Facilities

The main facilities attached to the jetty are as follows:

i) Fender

A rubber fender will be installed at each block of the jetty. Since the dimension of the freeboard is different between a 60,000 DWT vessel and a 500 DWT tanker, the fender was decided to be of a size and installed at a position that will accommodate all sizes of vessel to be moored.

ii) Bitt

For mooring a ship berthed at the jetty, a mooring bitt will be installed in each block. Also, a mooring bitt will be provided at the place of each mooring dolphin.

iii) Ladder

As passage facilities from a ship to the jetty, two ladders will be installed at both ends of the jetty.

### 6.7.4 Receiving Conveyor Facilities

(1) Study of the Number of Conveyor Lines

For combining unloaders and receiving conveyors, an appropriate method should be selected from among the following methods:

a. One conveyor for one unloader. Two conveyors will be installed in parallel with two unloaders.

b. Only one conveyor will be installed for two unloaders.

c. One conveyor for two unloaders, and one conveyor will be installed as a spare.

Due to technological improvement, transport capacity of belt conveyor has increased greatly to 4,000 t/h or more. As for the width of belts, many conveyors are equipped with those with width of about 2,000 mm enhanced, and their reliability has been considerably. Although hardly conceivable at the time of normal maintenance, if a belt should be damaged, it could be repaired in several hours, and its influence to the operation of the entire facilities would be slight.

In terms of economy, it would be better to have the least number of conveyor lines.

For these reasons, it was decided to employ method item b, providing one conveyor for two unloaders.

(2) Capacity of Receiving Conveyor

i) Conveyor capacity

Since the unloader capacity is 700 t/h, the transport capacity is set as follows with the peak unloading rate assumed to be about 1.15 times.

2 units x 700 t/h x 1.15 = 1,600 t/h

ii) Foundation for offshore conveyor

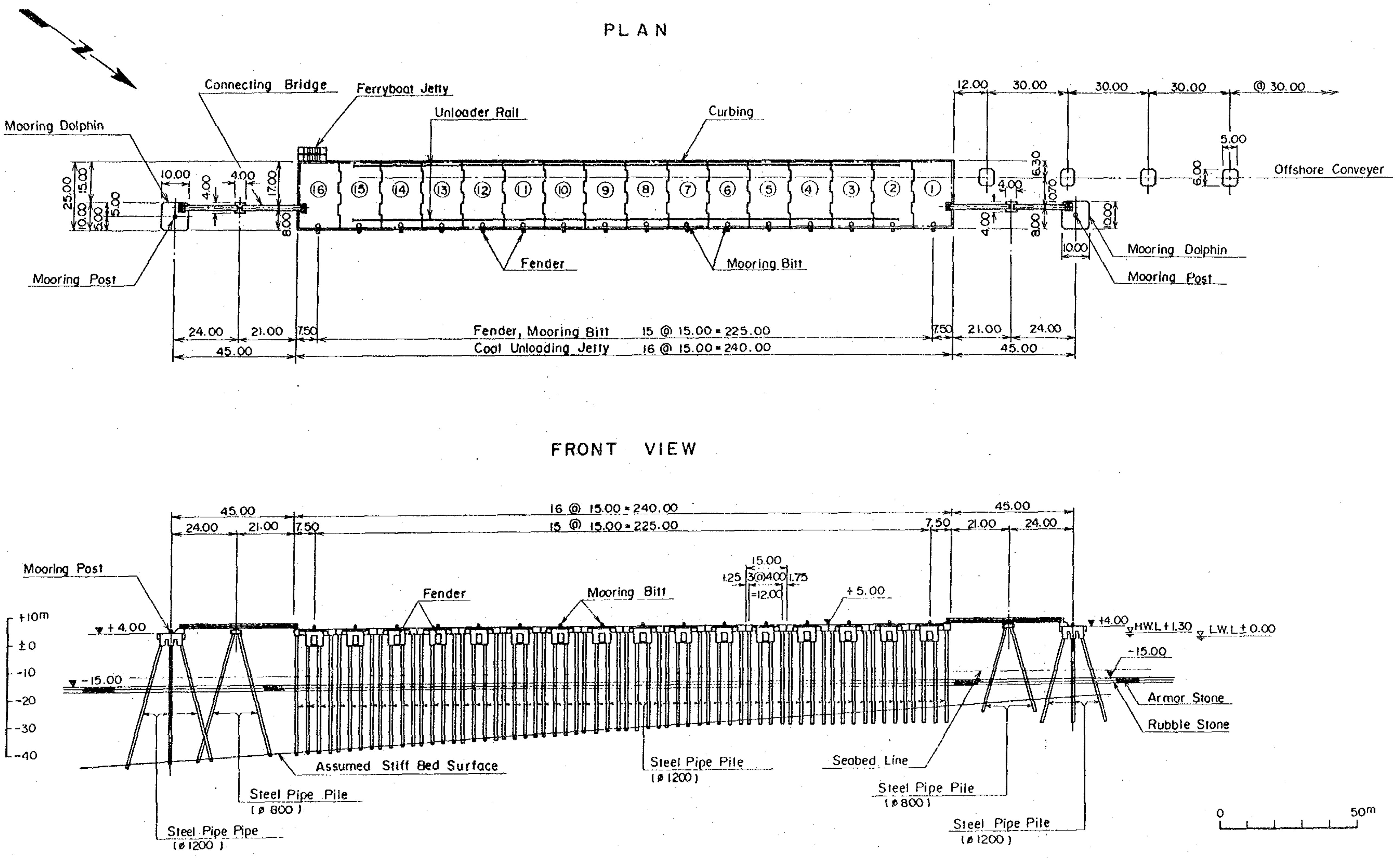
A conveyor will be installed offshore over a distance of 635 m between the jetty to the power station site to carry coal unloaded at the jetty.

The load to be applied to the conveyor foundation will be the total of tidal force, wind force and dead weight of conveyor. Based on the assumption of such load and with consideration given to the following points, the dimension of the conveyor was decided as follows:

i) The height of the offshore conveyor foundation was set at D.L. + 5 m in consideration of maximum design wave height.

ii) For the standard distance in the longitudinal direction of the offshore conveyor foundation, a value of 30 m was adopted as it is a standard decided on the basis of the strength of the belt conveyor gallery.

iii) Steel piles will be used for foundations of conveyor. Of the total of 20 foundations, 6 will be constructed in deep water. Since the wave force acting on the piles is substantial and the free length of piles (the length from the sea bed to the tip of piles) is long, all piles will be inclined in order to prevent lateral movement. The piles in shallow water will be driven vertically. (See Fig. 6.7-4).

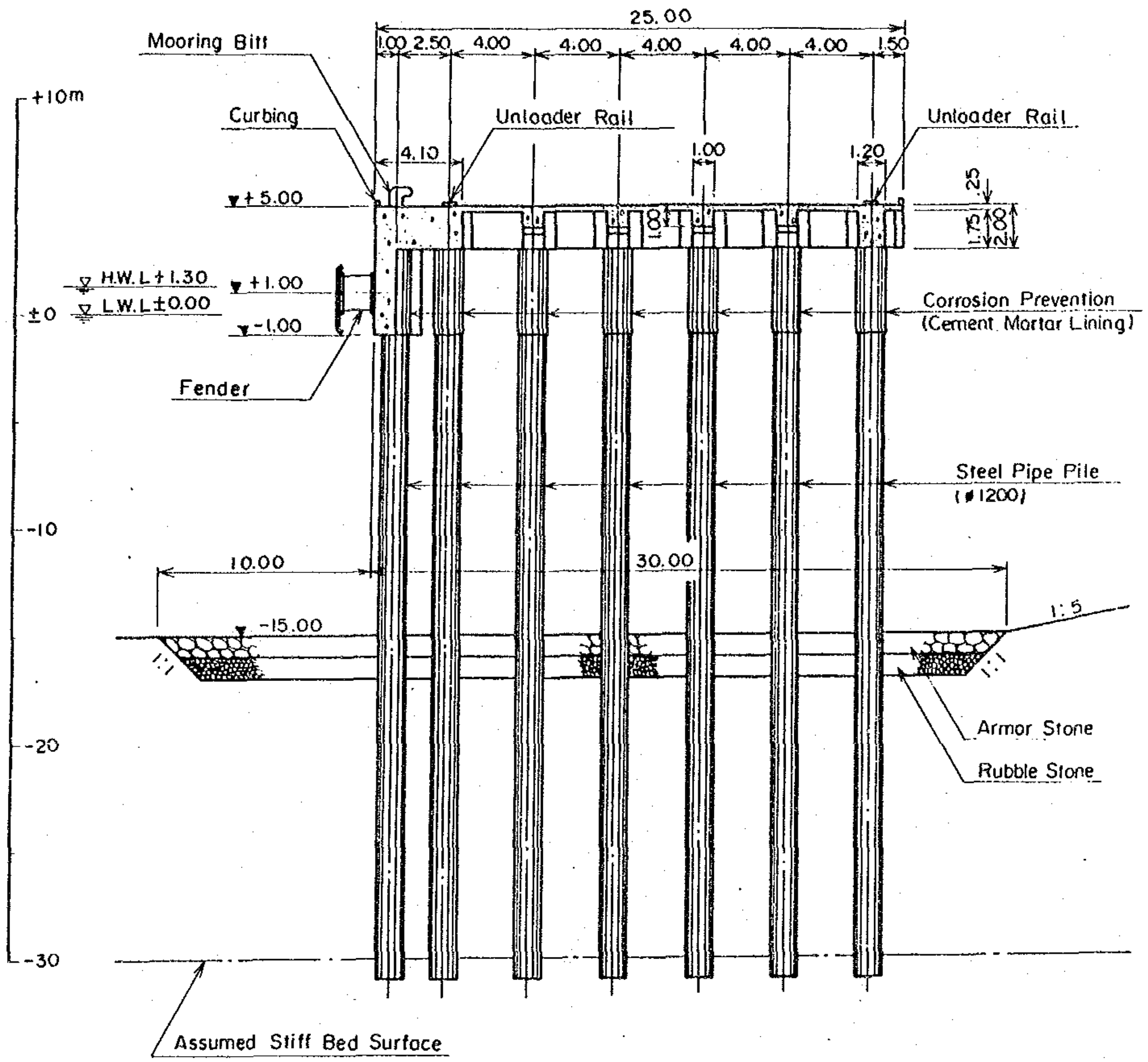



ZAMBALES COAL-FIRED POWER PROJECT

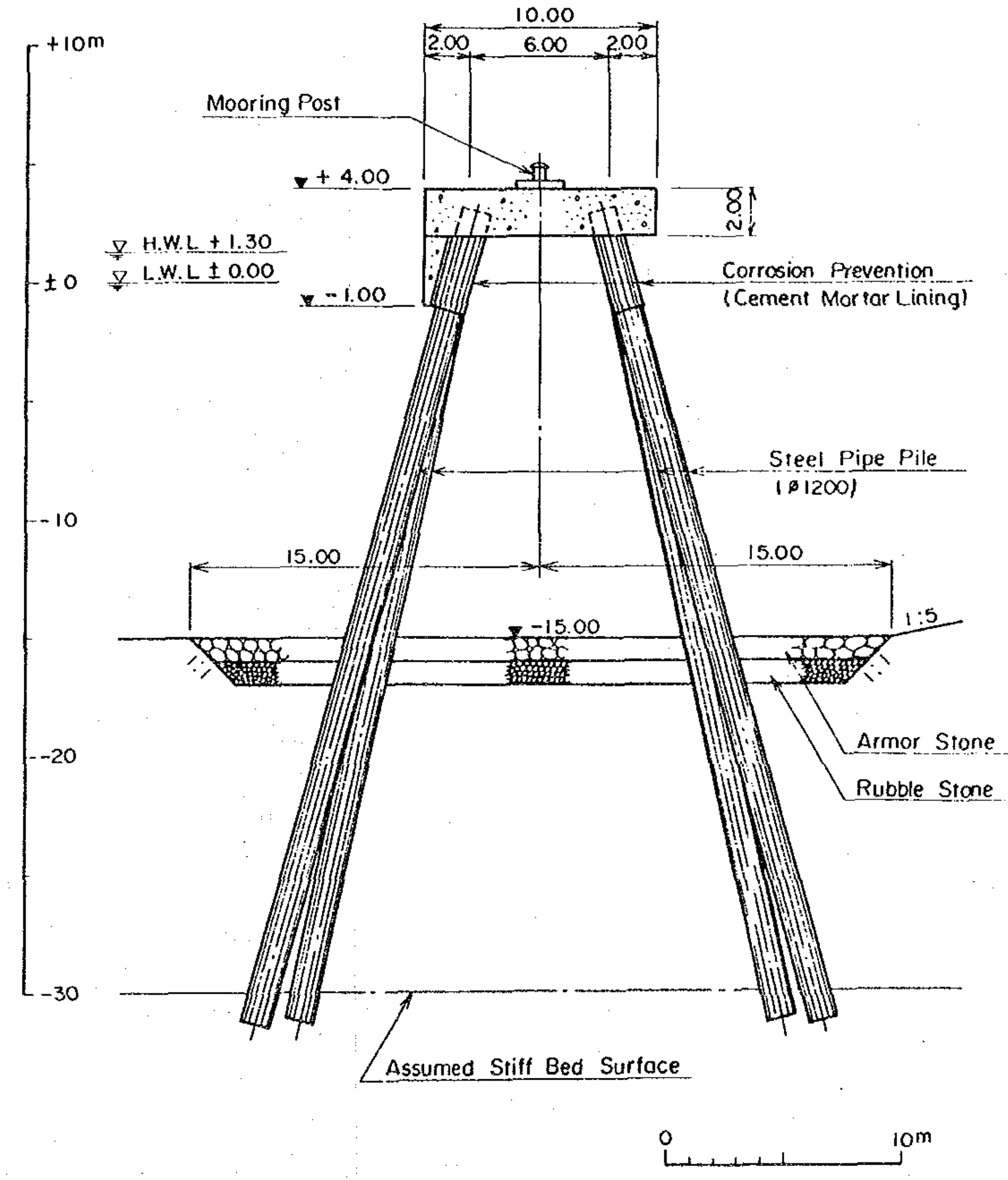
COAL UNLOADING JETTY (2-1)

| | |
|---|---|
| | JAPAN INTERNATIONAL COOPERATION AGENCY |
| Fig. 6.7-2 | D.R.; SUBMITTED; C.R.; RECOMMENTED; C.K.; APPROVED; |

## COAL UNLOADING JETTY




## MOORING DOLPHIN

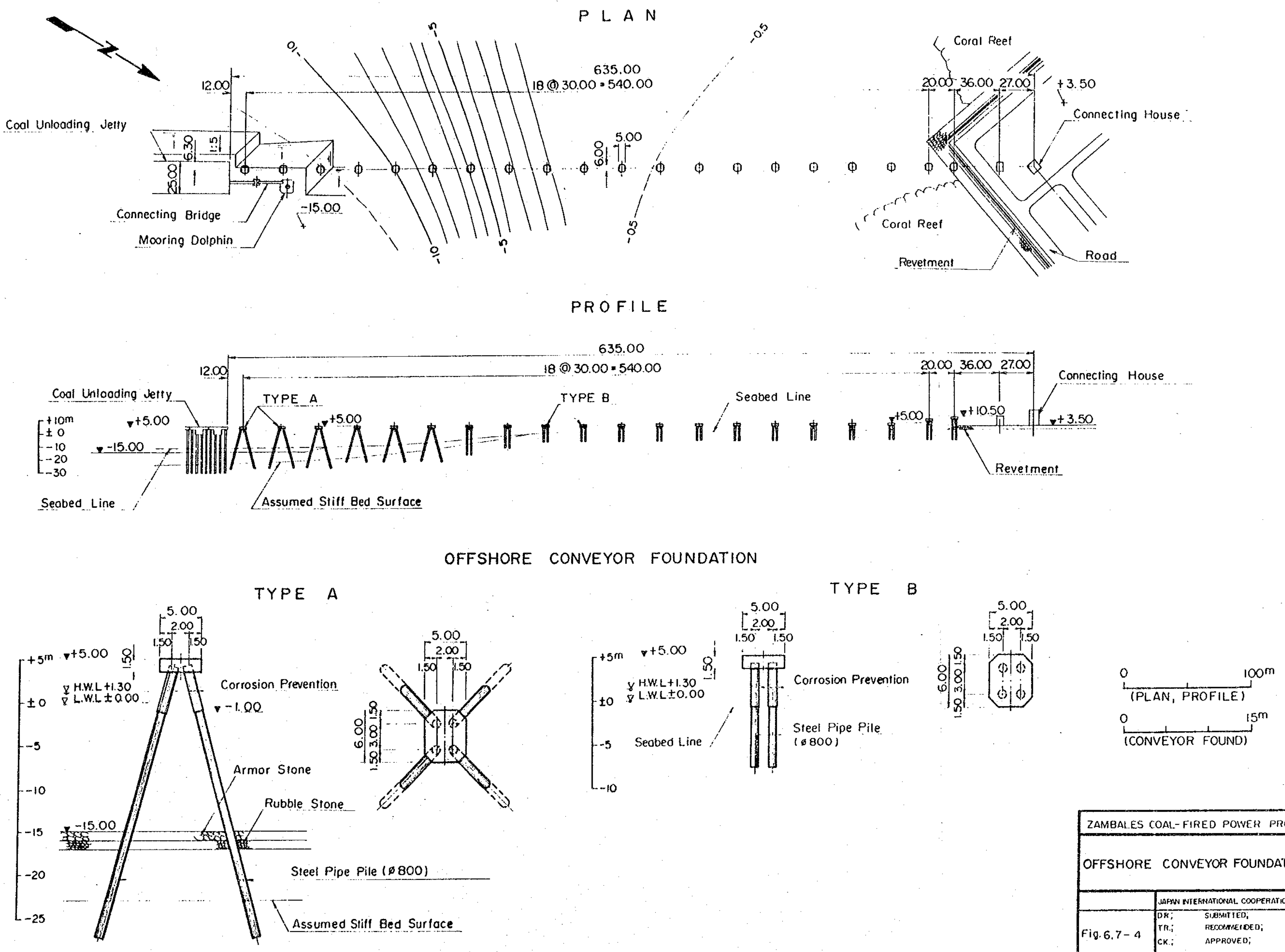



ZAMBALES COAL-FIRED POWER PROJECT

COAL UNLOADING JETTY (2-2)

JAPAN INTERNATIONAL COOPERATION AGENCY

| | | |
|---|---|---|
| Fig. 6.7-3 | D.R.: | SUBMITTED: |
| | T.R.: | RECOMMENDED: |
| | C.K.: | APPROVED: |




| | | |
|---|---|---|
| ZAMBALES COAL-FIRED POWER PROJECT | | |
| OFFSHORE CONVEYOR FOUNDATION | | |
| Fig. 6.7-4 | JAPAN INTERNATIONAL COOPERATION AGENCY | |
| | DR.; | SUBMITTED; |
| | TR.; | RECOMMENDED; |
| | CK.; | APPROVED; |

### 6.7.5 Coal Handling System for Open Storage System

(1) Open Storage Yard

As for coal storage methods, there are open and indoor storage methods. The open storage method is evidently more economic and study was conducted solely for the open storage method.

As coal handling method for open coal storage yard, there are stacker and reclaimer method and underground hopper method (bulldozer method).

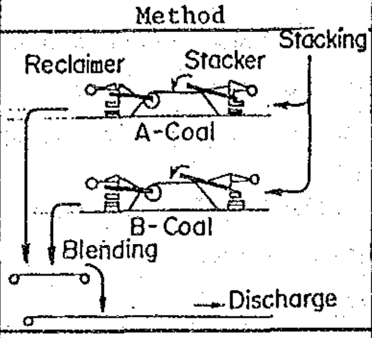
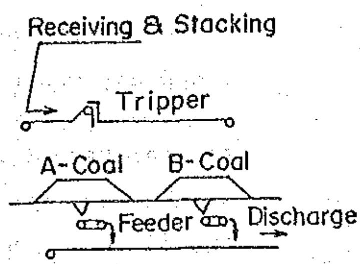
Comparative results of these two methods are shown in Table 6.7-1.

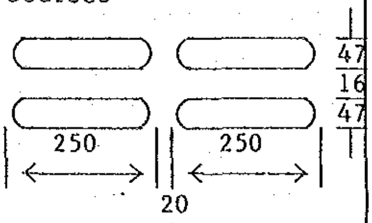
Based on this comparative table, the stacker and reclaimer method has been chosen.

The coal storage capacity has been set at 300,000 tons based on the following formula:

Coal storage capacity = Fluctuation of consumption (1 month equivalent) + Minimum coal storage capacity (0.5 month equivalent)
= 1.5 months
= 2 units x 136.2 t/h units x 24 h x 45 days
= 294,200 tons —> 300,000 tons

Table 6.7-1 Comparison of Coal Storage System

| Item | Stacker・Reclaimer Method | Underground Hopper Method(Bulldozer Method) |
|---|---|---|
| System Configuration |  |  |
| Constituent Equipment and Unloading Operation Flow | Receiving conveyor<br>│<br>Stacker<br>│<br>(Coal storage pile)<br>│<br>Reclaimer<br>│<br>Blending conveyor<br>│<br>Discharging conveyor | Receiving conveyor<br>│<br>Tripper<br>│<br>(Coal storage pile)<br>│<br>Bulldozer<br>│<br>Feeder<br>│<br>Discharging conveyor |
| Pile Shape | Stacking Height:<br>Generally 10 to 16 m. Decision made will be based on the bearing force of the ground, operability of the machine and pile width.<br>Pile Width:<br>Generally 30 to 50 m. The following size should be determined in consideration of the bearing force of the ground and yard area:<br>13 m (H) x 47 m (W) | Stacking Height:<br>The height of about 5 m should be adopted in consideration of the operation of a bulldozer. |

| Item | Stacker·Reclaimer Method | Underground Hopper Method(Bulldozer Method) |
|---|---|---|
| Yard Area | In consideration of blending two coal sources<br><br><br>(47+16+47)x(250+20+250)<br>= 59,400 $m^2$ | In consideration of blending two coal sources<br>$\frac{300{,}000\ t}{0.8t/m^3 \times 5\ m} \times 1.5$<br>$= 112{,}500\ m^3$<br>(Stowage factor is low) |
| Control of Source | Multi coal source can be dealt with. | Same as left. (It is necessary to study the location of the underground hopper and the discharge conveyor.) |
| Operability | Stacker:<br>Possible to automate (no-man operation)<br>Reclaimer:<br>Semi-automatic operation is possible | Stacking tripper can be operated through remote control. Because of using bulldozer, however, impossible to automate. |
| Dust Emission | Installation of water sprinklers and other countermeasures are necessary. | Same as left.<br>Since the surface area of the pile is bigger than stacker reclaimer method, dust emission is larger. |
| Noise | Since it comprises the sound from the driving equipment and the shooting sound, its level is lower than in the case of the bulldozer method. | Since it is the engine sound of a bulldozer, the noise level is higher than stacker reclaimer method.<br>No substantial effect can be expected even in the case of a low noise-type bulldozer. |

| Item | Stacker•Reclaimer Method | Underground Hopper Method(Bulldozer Method) |
|---|---|---|
| Yard Cleaning | Supplementary work by a bulldozer is required. | This shall be implemented with a discharging bulldozer. |
| Equipment Cost | Medium | Low |
| Operation Cost | Medium | Medium |

(2) Stacker

As for the capacity and number of units, one unit was adopted based on the same concept as that for the receiving conveyor, with a capacity of 1,600 t/h.

(3) Reclaimer

i) Study of the number of reclaimers

It is a general practice to install a number of reclaimers so that coal transshipment to a coal bunker will not be disrupted due to reasons of machine trouble. The number of reclaimers is decided in accordance with the layout of the coal storage piles.

ii) Study of reclaimer capacity

a) Conditions

One (1) reclaimer will have sufficient discharging capacity to meet the required consumption volume.

| | | |
|---|---|---|
| Daytime discharging volume: (at MCR) | : | 3,270 t/d in the case of one unit<br>6,540 t/d in the case of two units |
| Discharging time | : | 12 h/d |
| Blending | : | Blending of two types of coal blending ratio is 50/50 |

b) Capacity calculation

$$\frac{\text{Daily discharge volume}}{\text{Actual coal feeding time}} \times \frac{1}{\eta}$$

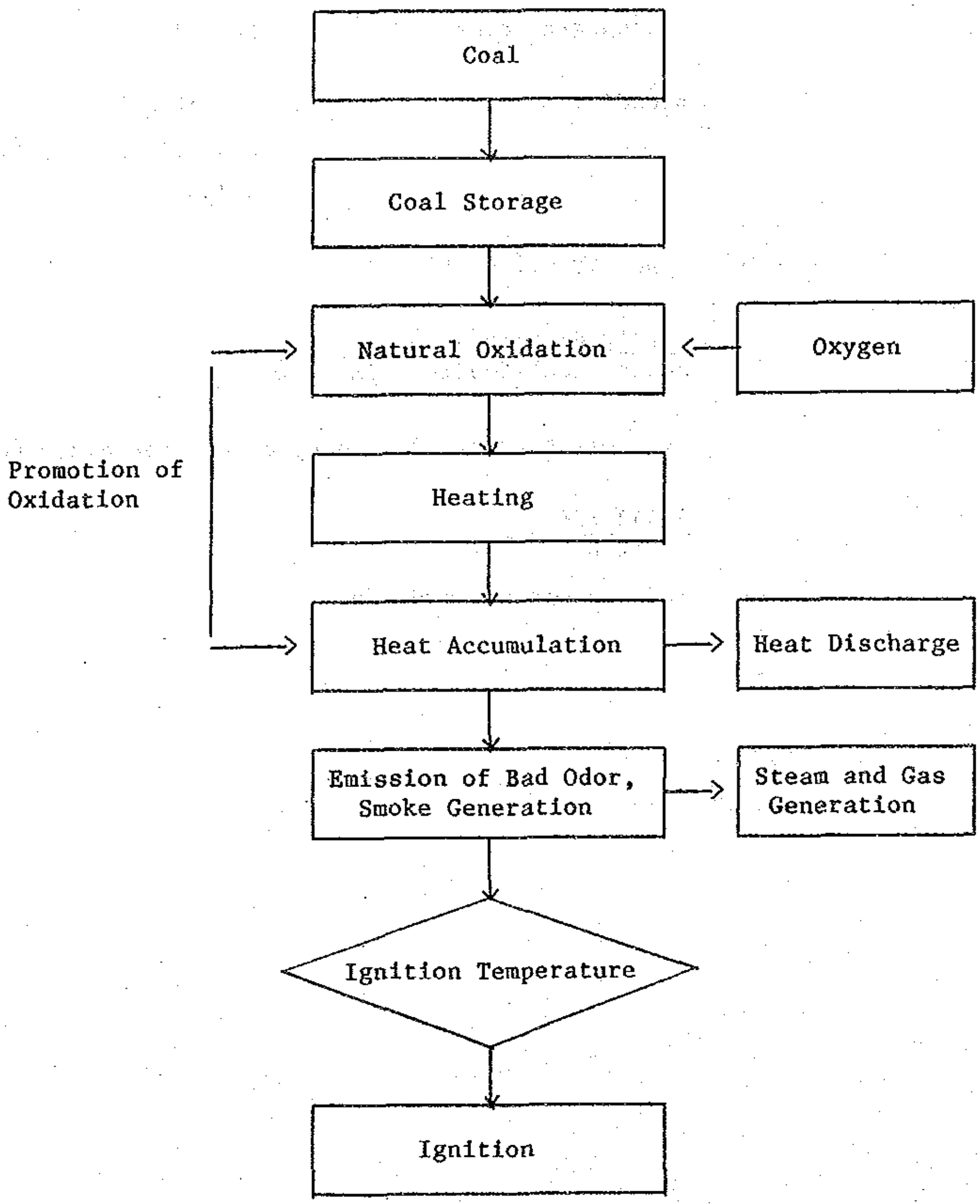
$\eta$: Discharging efficiency of the reclaimer (0.7)

$$\frac{6{,}540 \text{ t/d}}{12 \text{ h}} \times \frac{1}{0.7}$$

$= 778.6$ t/h —> 800 t/h

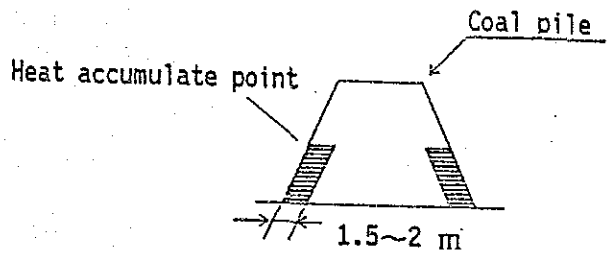
(4) Spontaneous Combustion Countermeasures

i) Spontaneous Combustion Process



ii) Spontaneous Combustion of Open Piles and Examples of Specific Countermeasures

(a) Heat accumulating point: Heat accumulate mainly in the coal pile 1.5 to 2 m under the surface of the lower half of the pile slope.




(b) Process of spontaneous combustion

Slight, smoldering smell
↓ 3 to 7 days then pass
Light smoke is generated

(c) Measures

- Slight, smoldering smell is scented ⟶ The pile portion concerned should be compacted with a bulldozer, and the smell will vanish ⟶ The coal near the part concerned should be discharged promptly

- Smoke is generated ⟶ The surface layer should be dug out, and the fire should be extinguished by opening a hydrant ⟶ The coal near the part concerned should be discharged promptly

iii) Countermeasures

Countermeasures against spontaneous combustion can be broadly classified into preventive measures, precognitive measures and combustion countermeasures. Of the three (3) countermeasures, precognitive measures are important.

**Preventive Measures**

- Operation within the safe coal storage period

  The safe coal storage period varies with coal property and surrounding environmental conditions, but it is generally regarded as 1.5 to 2 months.

- If long-term storage is required, the compacting of coal with a bulldozer (or surface coating) and other steps are to be implemented.

↓

**Precognitive Measures**

- Stored coal temperature monitoring

  An artificial and scientific temperature monitoring setup should be adopted to watch changes in temperature.

- A coal storage control temperature (60 to 70°C) should be set and temperature monitoring should be strengthened if the temperature surpasses that level.

- If the coal storage temperature exceeds 90°C, the heat accumulated part should be partially cooled (through digging up, water sprinkling or re-piling).

↓

**Ignition Countermeasures**

- The ignition temperature of coal is about 200 to 300°C and if combustion occurs, the fire should be put out through air shielding and other methods, and partial discharge shall be promptly conducted.

  Non-combustible covers, hydrants and fire extinguishers should be installed.

In this project study, the facilities are so arranged that relocation of coal can be implemented through the operation of the conveyor. Also, water sprinking facilities will be equipped as measures against rise of pile temperature and extinguish it if spontaneous combustion occurres.

See Fig. 6.7-7 "Coal Handling Diagram".

(5) Foundation for Stacker and Reclaimer

i) Geological conditions

The ground height of the planned coal storage yard changes from DL +10 m in the hilly land to DL -0.5 m at the seashore to be reclaimed and the average ground height is about DL+1.0 m. Therefore, the average banking height is about 2.5 m. The rock (sandstone and shale) excavated from the hilly land is used as the banking material. This material is suitable for banking and believed to have sufficient bearing capacity.

According to exploratory boring (DH-3) carried out in the coal storage yard site, the geology is composed of silty fine sand down to 7 m depth from the surface and the N value is about 6, and of sandstone and shale below 7 m depth and the bearing capacity is sufficient.

ii) Foundation for stacker and reclaimer

The plane and cross section of the foundation for the stacker and reclaimer are shown in Fig. 6.7-5. Features of the foundation are as follows:

- The foundation for the stacker and reclaimer was determined to be ballast foundation using sleepers because the subsoil for foundation consists of comparatively shallow bedrock, deposit of sandy soil which has small settlement and is good banking material.

- The foundation height was raised by 1 m from the ground level to DL +4.5 m to prevent coal flowing into the drainage and foundation.

- The ballast foundation is composed of sleepers, ballast and subbase course to disperse and decrease the wheel load of the stacker and reclaimer.

- Some settlement at sleepers will occur at early stage of operating the stacker and reclaimer but this settlement can be corrected simply by supplementing ballast under the sleepers.

- Three assembling and mooring foundation were prepared at the south side of the coal storage yard to erect the stacker and reclaimer and to moor the machines in case of storm.

  The foundation is of pile structure because of the large jacking up load when assembling and to prevent differential settlement during assembling.

(6) Foundation of Coal Piling Part

The maximum coal piling height is 13 m and the load is about 12 $t/m^2$.

Since the foundation ground is good as above mentioned, lateral flow does not occur and adverse effect on the foundation of the stacker and reclaimer is not articipated, though some settlement may occur. Special foundation work shall not be performed except that coal layer of 10 cm thickness is prepared to facilitate handling of coal.

(7) Drainage of Coal Storage Yard

Rainwater in the coal storage yard is collected by water channel installed around the yard to prevent direct discharge to the outside.

The collected water is discharged to Oyon Bay after coal particles have settled in the sediment pond prepared at the east of the yard.

Drain water is discharged after collecting water in two sediment pond by dividing the drainage system at the yard center because the yard is long in the northern and southern directions. The side wall of the yard was raised by 1 m at the northern and southern parts of the water channel to prevent coal flowing into the water channel.

### 6.7.6 Discharging Conveyor

(1) Study of Number of Conveyor Lines

The discharging conveyor, i.e. coal flow from coal yard to bunkers, was decided to be two-line in consideralton of the need for coal blending and steady supply to coal bunkers.

(2) Determination of Discharging Conveyor Capacity

(a) Discharging Line

The conveyor capacity will correspond to the reclaimer capacity. Therefore, it will be 800 t/h.

(b) Coal Supply Line to Bunkers

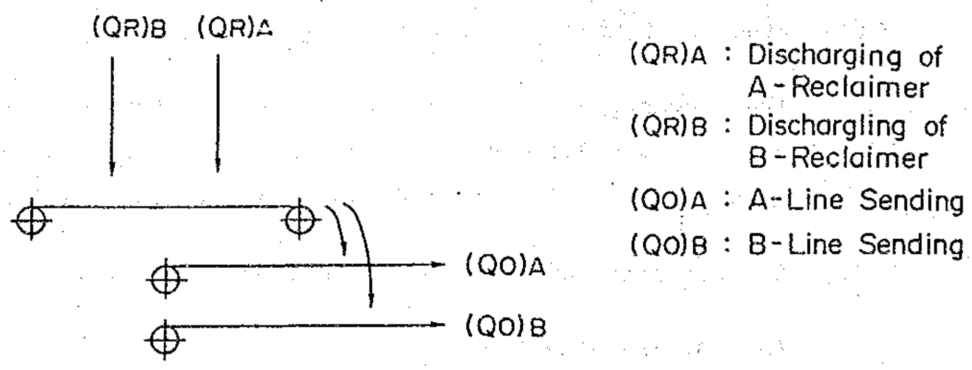
The conveyor for the blended coal from two sources should be operated every day in conformity with each unit, except for the time of the annual inspection of the plant. The conveyor capacity was decided to correspond with daily coal consumption for one unit. This is because the reliability of the belt conveyor has improved and also because machine trouble can be dealt with by extending the operation hours.

Therefore, the conveyor capacity will be 400 t/h.

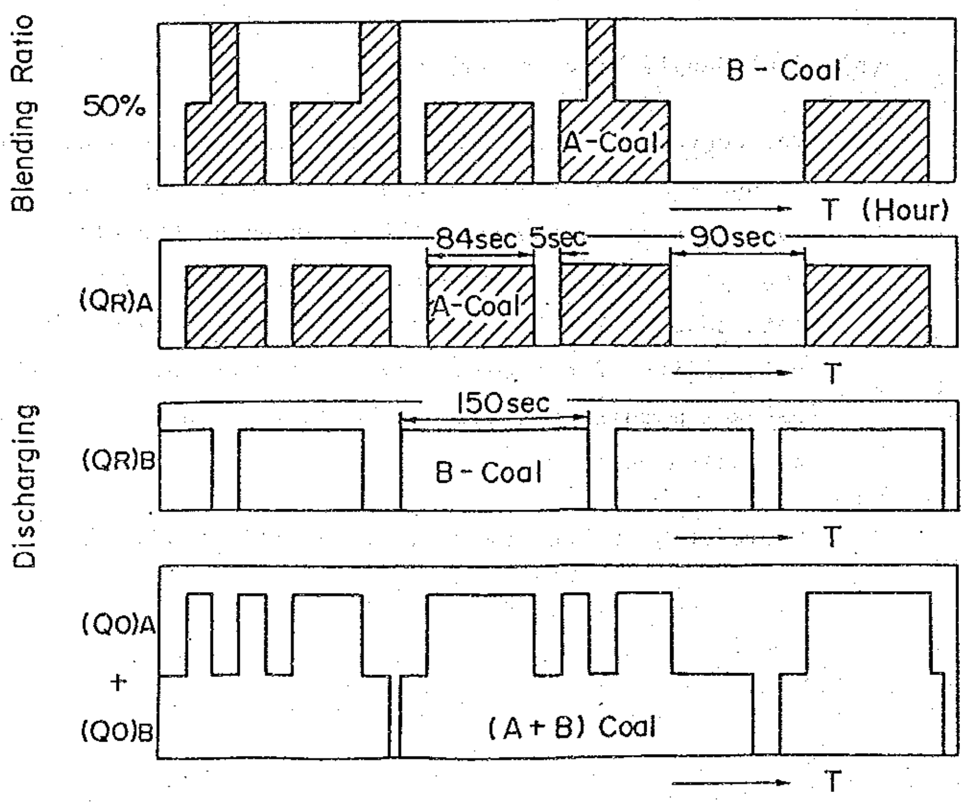
### 6.7.7 Coal Blending Method

Coal discharge from the coal storage yard will be carried out by means of two reclaimers.

A system for blending coal on a conveyer without installing a coal blending facility (blending hopper) is shown below:




Example of Blending State with Time.



In case a coal blending facility is not installed, coal blending ratio incessantly changes in accordance with the alteration of the discharge volume from the reclaimer. For this reason, if a constant blended quality is required, a blending device will be necessary.

If each reclaimer is operated while the total discharge volume is monitored, discharge at some specific blending ratio can be obtained in an hour (Since the control depends on reclaimer operation, precision will be about ±10%).

However, if the blending ratio is extreme as 10:90, this blending method is not applicable since corresponding reclaimer operation is almost impossible.

In conclusion, if the blending ratio changes between 30:70 and 50:50, and blending precision is about +10%, and if partial uniform blending is not required, on-the-belt blending or line-blending method without blending equipment will serve the purpose.

### 6.7.8 Coal Bunker

The capacity of a coal bunker is determined on the basis of the non-feeding time and the coal consumption volume during that time.

(1) Study Conditions

i) Non-feeding time of a day : 12 h/d
Tolerance time for trouble: 1 h/d
Total 13 h/d

ii) Coal consumption volume (at MCR) : 138 t/h

iii) Specific gravity of coal : 0.8 $m^3/t$

iv) Efficiency of bunker capacity : 0.8

v) No. of bunkers : 5 units including 1-stand-by.

(2) Capacity Calculation

$$\frac{138 \text{ t/h} \times 13 \text{ h}}{0.8 \text{ ton/m}^3 \times 4 \text{ units} \times 0.8}$$

$\fallingdotseq 700 \text{ m}^3/\text{unit}$

Accordingly, appropriate bunker facilities will be 5 units x 700 $m^3$/unit.

(3) Coal Dumping Method into Bunker

The coal dumping methods into bunker and their respective characteristics are as follows:

i) Shuttle Conveyor Method

- Suitable for coal bunkers ranging from large-sized bunkers to small-sized ones.
- Control system will be somewhat complicated.
- Maintainance is good.
- The mounting of a slide-type steel cover is required to control dust emission.
- Equipment cost is somewhat high.

ii) Travelling Tripper Method

- Applicable to coal bunkers ranging from large-sized bunkers to small-sized ones.
- Control system is simple.
- Maintainance is good.
- The mounting of a rubber belt seal is required for countermeasure against dust emission.
- Equipment cost is average.

iii) Scraper Method

- Suitable for coal bunkers ranging from medium-sized bunkers to small-sized ones.
- Control system is very simple.
- Abrasion control maintenance is necessary.
- No special dust emission countermeasures are required.
- Equipment cost is low.

iv) Fixed point method

- Applicable to coal bunkers ranging from medium-sized bunkers to small-sized ones.
- Control system is simple.
- Maintenance and inspection required will be the same as that for other conveyors.
- No special dust emission countermeasures are required.
- Equipment cost is somewhat high.

An overall evaluation, based on the above study and especially from the point of view of economy, reveals that the scraper method is better, and this method is adopted.

### 6.7.9 Verification of Optimization

To verify whether the coal unloading and coal storage facility plan has been optimized or not, simulation was carried out. The program used for the simulation has been one developed by EPDC.

(1) Simulation Model

In importing coal from overseas, the arrival of coal vessels will be at random. This is because user cannot control ship arrival schedules. However, the number of annual arrival of vessels is almost constant. For this reason, Poisson distribution is used as the probability model.

(2) Results of Simulation

Details of the simulation are given in the Appendix 6-2.

Results of the simulation are as below:

i) The number of waiting vessels for vacancy at the berth is on an average 1.0/day. This signifies an ideal state.

ii) The overseas coal storage capacity ranges from a maximum of 270,000 tons to a minimum of 120,000 tons, with a range of variation being 150,000 tons. Accordingly, overseas coal storage volume of 45 days use is considered appropriate.

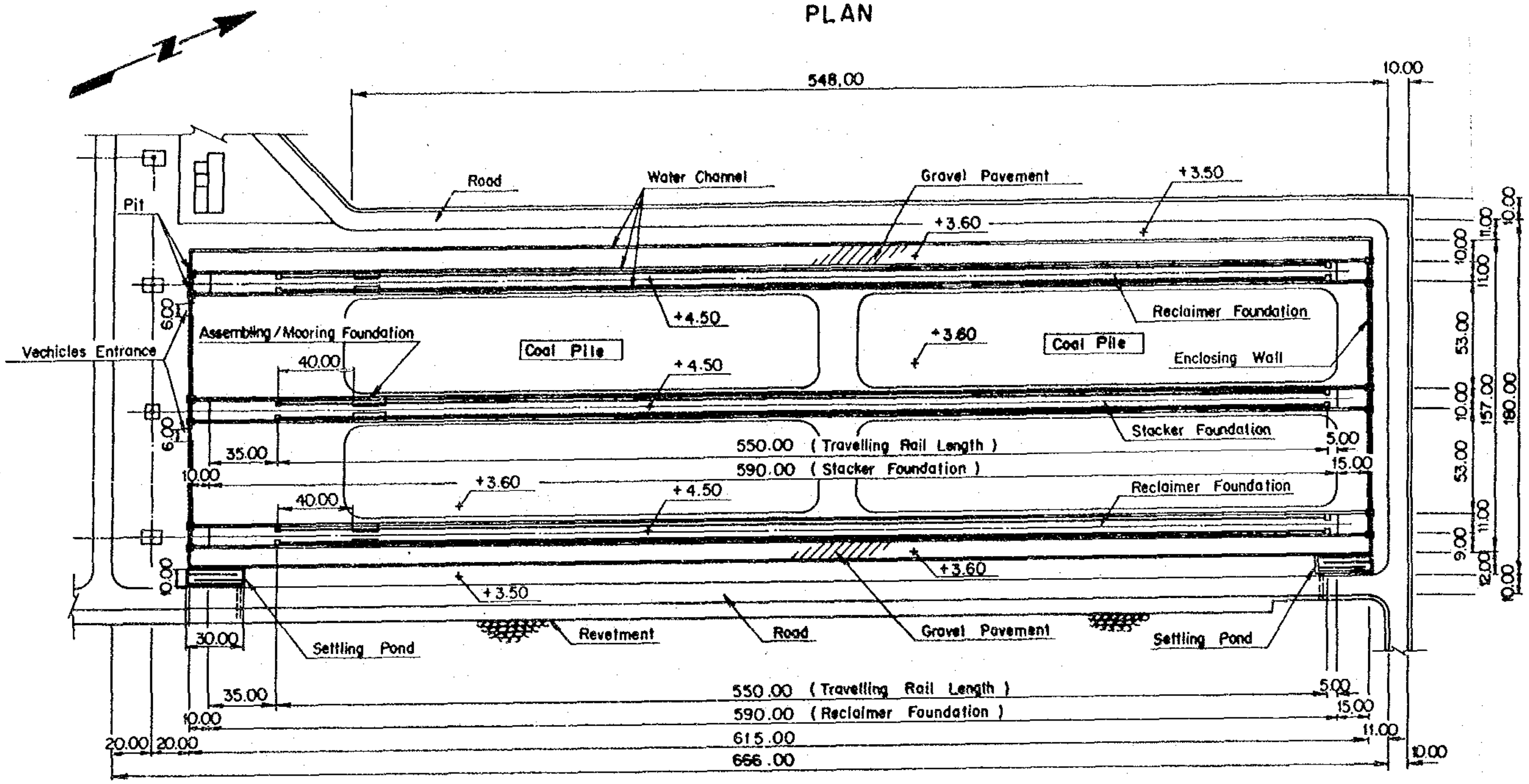
iii) The indigenous coal storage capacity ranges from a maximum of 120,000 tons to a minimum of 80,000 tons with a range of variation being 40,000 tons. Therefore, indigenous coal storage volume of 45 days use can be considered as excessive.

iv) Since indigenous coal will be brought in by 5,000 DWT coal carriers, the number of vessels entering the port in a year will be 168. If simply averaged, a ship will enter the port in almost every two days. In other words, coal carriers will play the role of coal storage yards as far as indigenous coal is concerned.

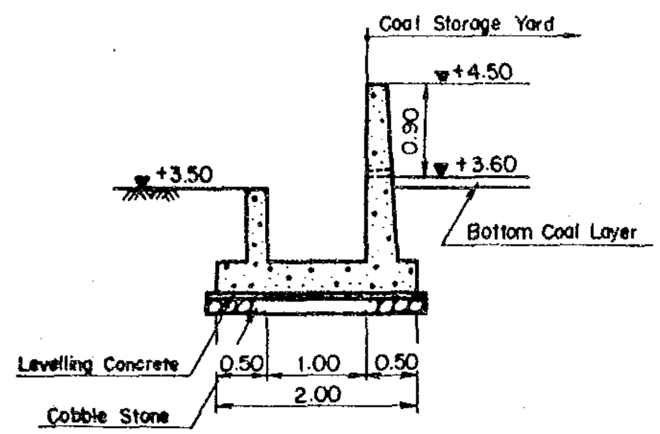
v) In consideration of problems in control of stored coal, such as spontaneous combustion of indigenous coal, it is necessary to study the need to limit the indigenous coal storage capacity to about 50,000 tons in the future.

vi) In view of the simulation results, two 700 t/h unloaders are considered appropriate.

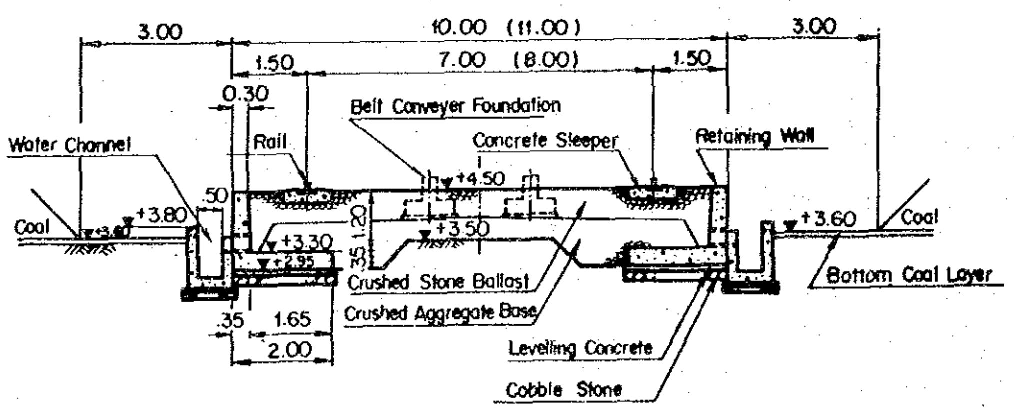
## PLAN



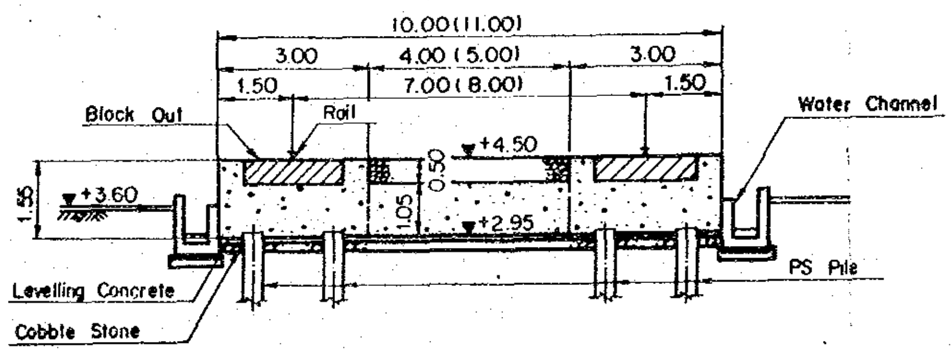

## ENCLOSING WALL

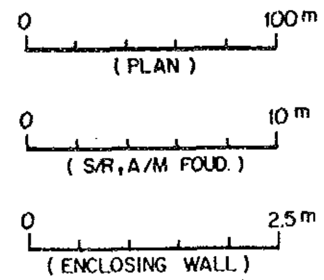



## STACKER, RECLAIMER FOUNDATION




## ASSEMBLING, MOORING FOUNDATION




ZAMBALES COAL-FIRED POWER PROJECT

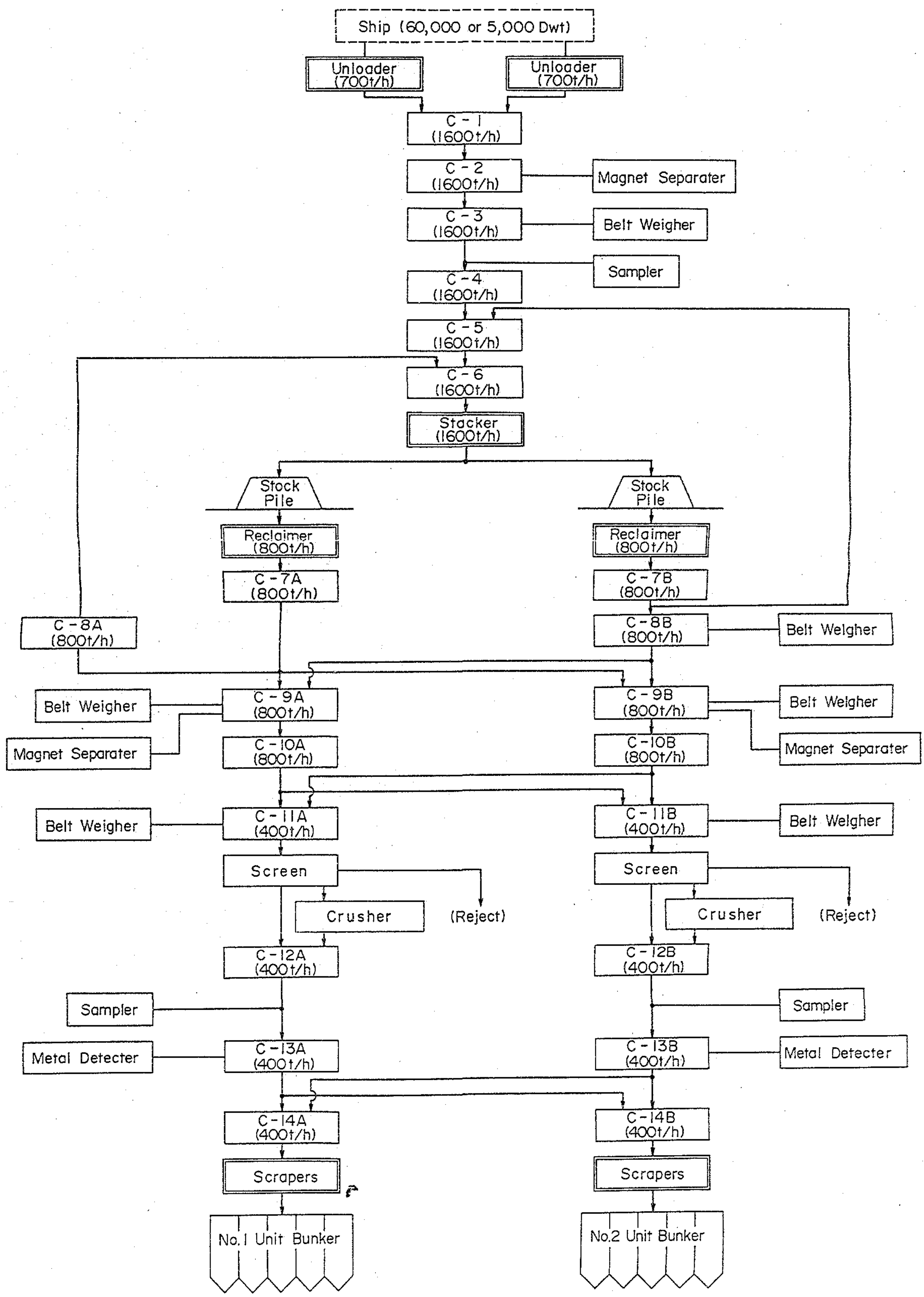
COAL STORAGE YARD

JAPAN INTERNATIONAL COOPERATION AGENCY

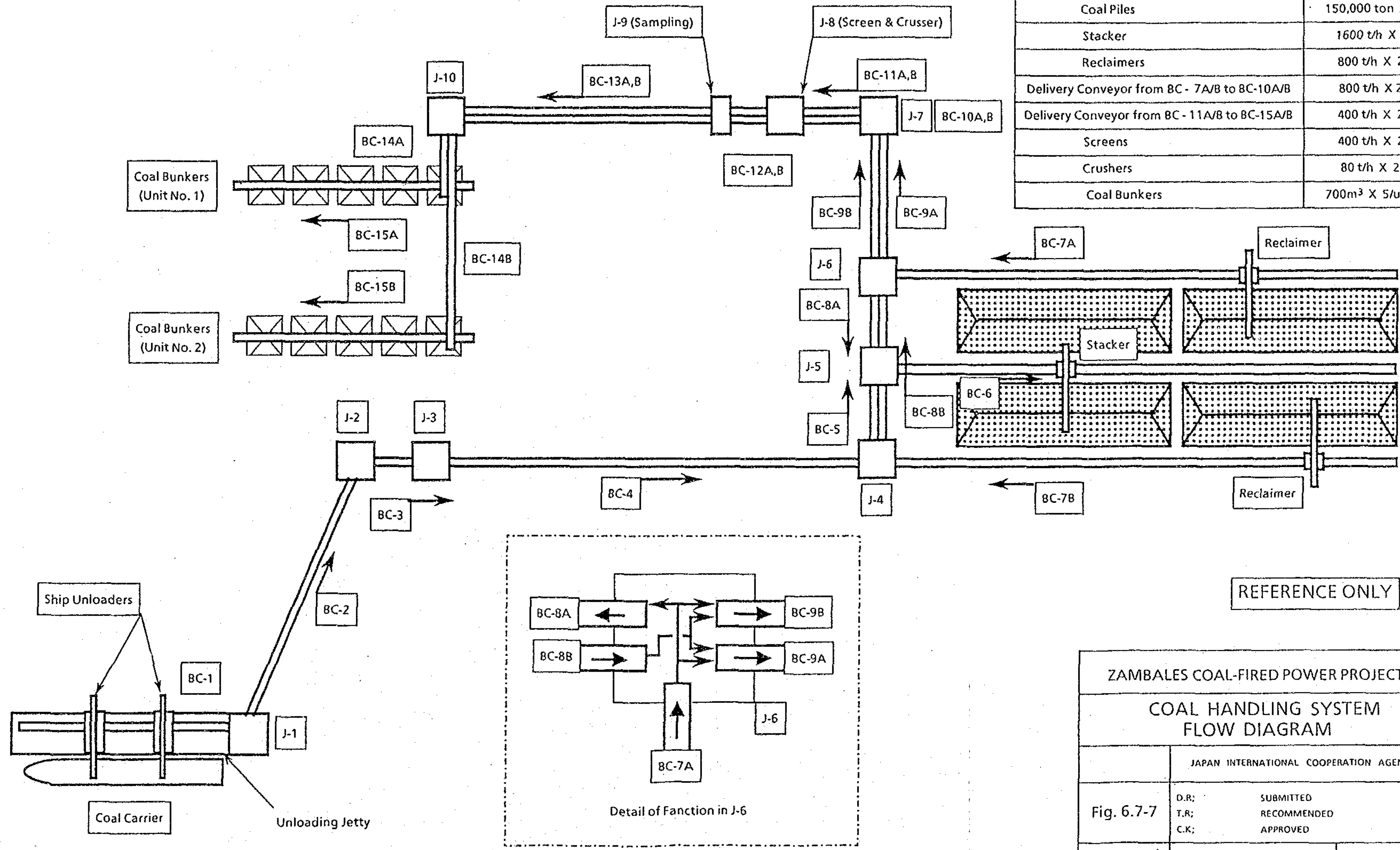
Fig.6.7-5

D.R. ; SUBMITTED ;
T.R. ; RECOMMENDED ;
C.K. ; APPROVED ;

Fig. 6.7-6 Coal Handling Flow Diagram



| ITEM | CAPACITY |
|---|---|
| Unloading Jetty | 60,000 DWT |
| Ship Unloaders | 700 t/h X 2 |
| Receiving Conveyors from BC - 1 to BC - 6 | 1600 t/h X 1 |
| Coal Piles | 150,000 ton X 2 |
| Stacker | 1600 t/h X 1 |
| Reclaimers | 800 t/h X 2 |
| Delivery Conveyor from BC - 7A/B to BC-10A/B | 800 t/h X 2 |
| Delivery Conveyor from BC - 11A/B to BC-15A/B | 400 t/h X 2 |
| Screens | 400 t/h X 2 |
| Crushers | 80 t/h X 2 |
| Coal Bunkers | 700m³ X 5/unit |




REFERENCE ONLY

ZAMBALES COAL-FIRED POWER PROJECT

COAL HANDLING SYSTEM
FLOW DIAGRAM

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.7-7

D.R; SUBMITTED
T.R; RECOMMENDED
C.K; APPROVED

## 6.8 Fuel Oil Storage Facilities

### 6.8.1 Capacity of Heavy Oil Storage Tank

(1) Basic Concept of Tank Capacity

i) The storage capacity of heavy oil is considered on the basis of maximum daily consumption at the time when two 300 MW units are in operation.

ii) Comparing the computed maximum daily consumption and the storage capacity of existing plants, the storage capacity for this project is decided.

iii) As for the number of heavy oil tanks to be installed, one tank will be provided for each unit in consideration of inside inspection of the tank.

(2) Oil Tanker Size

500 DWT class tanker is considered.

(3) Calculation of Heavy Oil Consumption

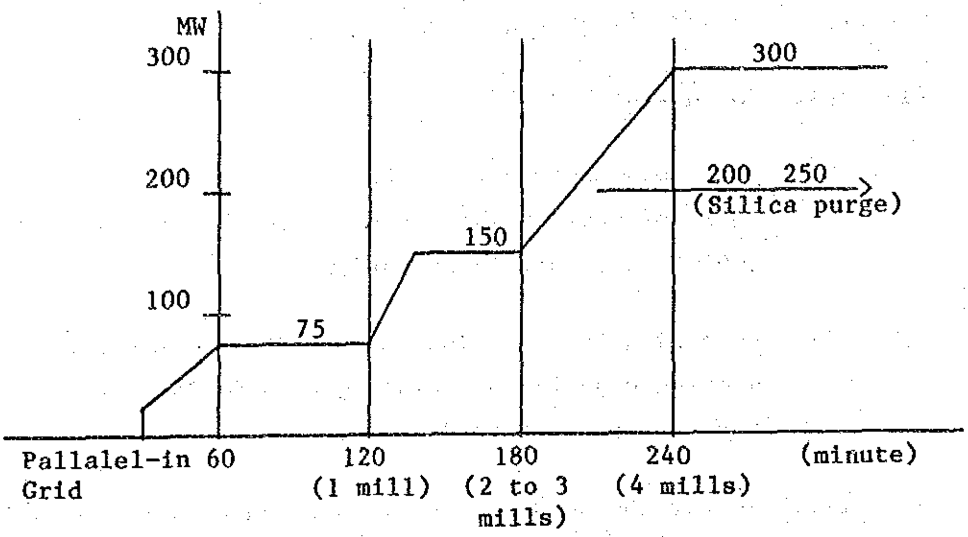
i) Case 1 : At the time of 50% oil mixed combustion at MCR
Load pattern: 17 Hr. x 300 MW load
7 Hr. x 150 MW load

$$Q = \text{Coal consumption at MCR} \times \frac{\text{Heating value of coal}}{\text{Heating value of heavy oil}} \times 0.5 \times \text{operating hours}$$

$$= 138 \text{ t/h} \times \frac{5,262}{10,000} \times 0.5 \times (17 + \frac{7}{2}) \text{ h/day}$$

$$= 744 \text{ ton/day}$$

ii) Case 2 : From Plant Start-up (Cold state) to 100% Load




It is assumed that mills shown in the diagram are used after the plant is paralleled in the grid, and heavy oil will be consumed for five (5) hours at 15 MW load on an average.

$$\text{Oil consumption} = \frac{\text{Output (kW) x hours x 860 kcal/kWh}}{\eta p \text{ x Heating value of oil}}$$

$$= \frac{15 \times 10^3 \times 5 \times 860}{0.36 \times 10{,}000} \doteqdot 18{,}000 \text{ kg}$$

$$\doteqdot 18 \text{ ton}$$

The consumption of heavy oil in this case is assumed to be 18 tons.

iii) Case 3 : Heavy oil consumption based on 8% annual forced outage for each start-up is assumed to be the same as Case 2 (18 tons).

(4) Capacity of Heavy Oil Tank

Based on Case 1 to Case 3, the maximum daily consumption is calculated as 750 tons.

Based on the conditions of 50% mixed combustion, ECR and two units in service, storage capacity for 4 to 5 days use is considered appropriate.

750 t/d x 4 to 5 days = 3,000 to 4,000 KL

Therefore, 2 x 4,000 KL tanks will be provided.

(5) Tank Foundation and Oil Retaining Wall

Fig. 6.8-1 shows the layout and cross section of heavy and light oil tank.

i) Tank layout and oil retaining wall

The tank layout and the height of oil retaining wall were determined by considering the following points:

- The space between the tank and the oil retaining wall was determined to be 1/2 or more of the height of the tank (H = 15 m).
- In principle, the distance between tanks was determined to be the tank diameter (D = 19.4 m) or more.
- The capacity of the oil retaining wall was determined to be 110% or more of the maximum tank (heavy oil tank) capacity.
- Approximately 10 cm gravel pavement is provided inside the oil retaining wall to prevent disaster.
- The oil retaining wall should be provided with steps to enable access for routine check, inspection, and fire-fighting activity.

ii) Tank foundation

The original ground surface of the tank foundation is DL+0.8 m and the assumed rock surface is approximately DL-3.2 m. This is in accordance with the result of drillholes DH-2 and DH-3. Thus, the tank foundation rests on 4 m thick sand layer and 2.7 m thick embankment.

The features of the tank foundation construction are as follows:

- Tightly compacted sand layer and embankment material.
- Crushed rock is placed directly below the tank-side plate and construct a reinforced concrete ring surrounding the tank to reinforce the tank foundation.
- Provides asphalt sand in the area in contact with the bottom of the tank to prevent corrosion of the bottom plate of the tank.

iii) Drainage

Rainwater inside the retaining wall is collected by a water channel provided inside the oil retaining wall and at the periphery of the tank. Water is drained to an oil separation pond provided outside the oil retaining wall where oil is removed, and then drains into a drain duct along the road within the power station premise.

6.8.2 Capacity of Light Oil Storage Tank

(1) Basic Concept of Tank Capacity

i) To be able to receive oil delivered by one light oil tanker

ii) To consider the maximum consumption rate and duration

(2) Oil Tanker Size

300 DWT class

(3) Estimation of Light Oil Consumption

Light oil consumption is the greatest during plant commissioning test.

Light Oil Consumption during Plant Commissioning Test

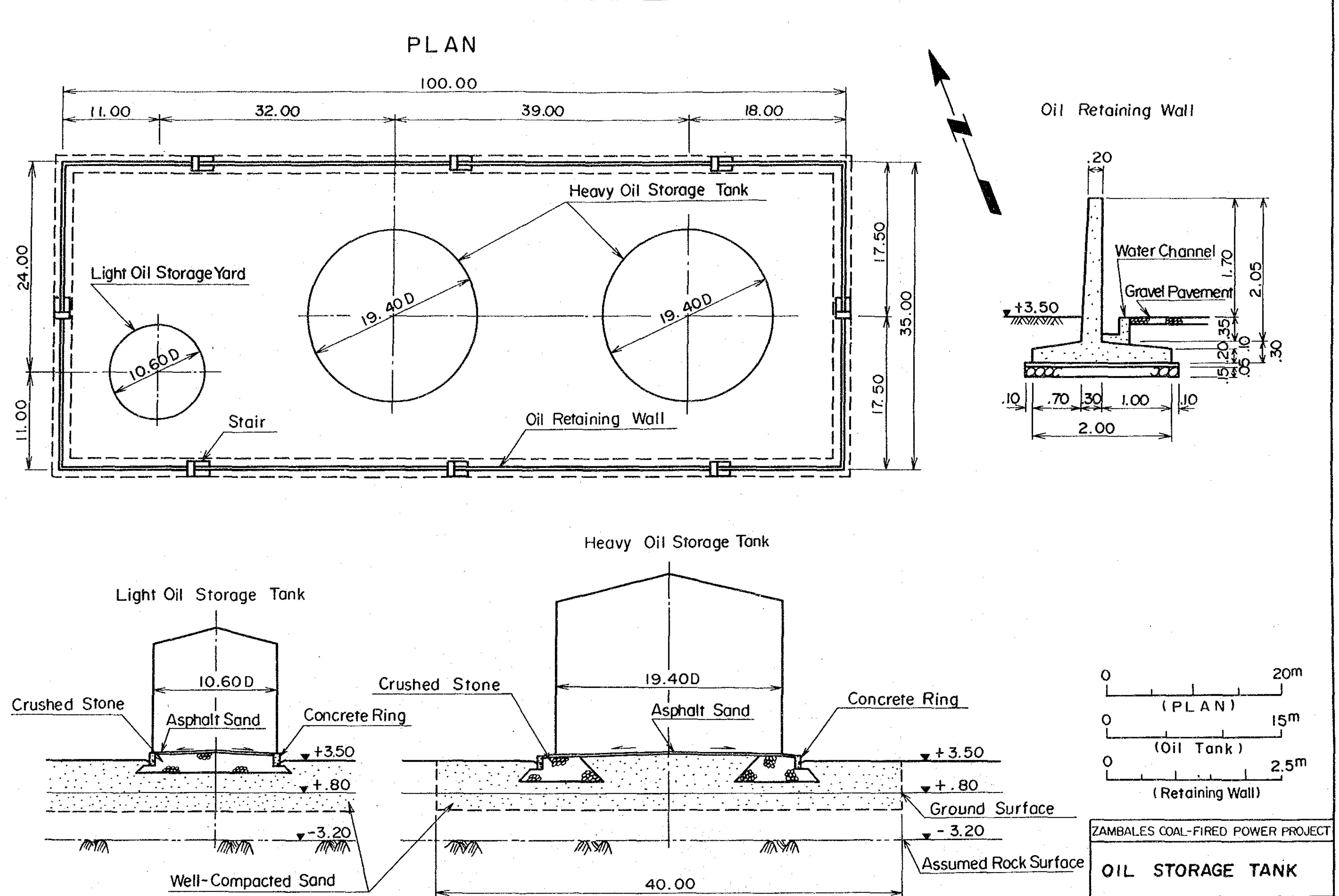
| | | |
|---|---|---|
| 1) | Boiler boiling out | 30 kL x 3 days = 90 kL |
| 2) | Boiler chemical cleaning | 25 kL x 3 days = 75 kL |
| 3) | Boiler blowing out | 100 kL x 4 days = 400 kL |
| 4) | Safety valve test | 100 kL x 3 days = 300 kL |
| | | Total 865 kL |

(4) Capacity of Light Oil Storage Tank and Number of Tanks

Capacity: Tank capacity is 1,000 kL calculated in (3) above.

No. of Tanks: One tank for 2 x 300 MW

Light oil will be consumed most frequently during the plant commissioning test. The number of tank is one because this test comes in intervals of six (6) months.




ZAMBALES COAL-FIRED POWER PROJECT

OIL STORAGE TANK

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.6.8-1

D.R.; SUBMITTED;
C.R.; RECOMMENDED;
C.K.; APPROVED;

## 6.9 Fresh Water Supply System

### 6.9.1 Fresh Water Consumption

(1) Calculation of Fresh Water Consumption

Fresh water required for a power plant consist of water to be supplied to boiler and water to be provided to various kinds of facilities that support plant operation.

In terms of water purity, the water, on the other hand, can be classified into raw water, filtered water, demineralized water and potable water. These kinds of water are provided for their respective application.

Water necessary for the proposed two 300 MW coal-fired thermal power plants under this project will be classified in accordance with their respective application, and the required water volume, storage capacity and a system allowing rational operation of water systems will then be studied.

As for the water volume that is required for each application, calculation results are summarized in Table 6.9-1. In the calculation of required water volume, consumption at existing plants were used as reference. Consequently, the fresh water consumption for this project can be computed as follows:

$$Q_T = Q_P + Q_F + Q_R$$
$$= 2,600 \ m^3/D$$

$Q_P$ = Demineralized water
$Q_F$ = Filtered water
$Q_R$ = Raw water

(2) Operating System of Water for Power Plant

The operating systems for demineralized water, filtered water and raw water calculated in (1) is shown in Fig. 6.9-1. This is based on the study directed to efficient operation of the plant.

(3) Storage Tank

In order to smoothly operate the amount of water studied in section (1) and the water application systems, it is required to construct a storage tank within the water system. The effective storage capacity of the tank is 80%.

i) Fresh Water Tank

This tank will store three days consumption of the total water volume calculated in section (1). The number of raw water tank will be one.

$$\text{Fresh water tank capacity} = 2,600 \text{ m}^3/\text{d} \times 3 \text{ days} \times \frac{1}{0.8}$$

$$= 9,750 \text{ m}^3$$

$$\fallingdotseq 10,000 \text{ m}^3$$

ii) Filtered Water Tank

Filtered water tank will store a volume equivalent to the daily consumed portion of filtered water. The number of filtered water tank to be installed will be one.

Make-up water 500 $m^3/d$ + Potable water 150 $m^3/d$ + Filtering equipment and Regenerated water of demineralizer 165 $m^3/d$ + Others 310 $m^3/d$

$$\text{Filtered water tank capacity} = 1,125 \text{ m}^3/\text{d} \times 1 \text{ day} \times \frac{1}{0.8}$$

$$\fallingdotseq 1,400 \text{ m}^3$$

iii) Demineralized Water Tank

The tank capacity is determined using as a basis the case in which demineralized water consumption by two 300 MW coal-fired thermal power plants becomes maximum.

One tank is to be installed for each unit.

The following conditions are conceivable for the case in which demineralized water consumption becomes maximum:

<u>No. 1 Boiler Plant</u>

| | | |
|---|---|---|
| Make-up water | : | 990 t/h x 24 h x 1% x 5 days = 1,190 $m^3$ |
| Silica blow use | : | 990 t/h x 24 h x (5% x $\frac{5}{7}$) = 850 $m^3$ |

<u>No. 2 Boiler Plant</u>

| | | |
|---|---|---|
| Blowing out | : | 800 $m^3$/d x 5 days = 4,000 $m^3$ |
| Regenerated water of demineralizer | : | 20 $m^3$/d x 5 days = 100 $m^3$ |
| Total | | 6,140 $m^3$ |

Demineralizer capacity : 1,000 $m^3$/d x 5 days = 5,000 $m^3$

Storage capacity = Total consumption volume - Demineralizer capacity
= 6,140 $m^3$ - 5,000 $m^3$
= 1,140 $m^3$

Demineralized water tank volume = 1,140 $m^3$ x $\frac{1}{0.8}$ = 1,425 $m^3$

Tank capacity for each unit = 1,425 x $\frac{1}{2}$ = 720 $m^3$

In consideration of the demineralizer operation, 1,000 $m^3$/unit is recommended.

iv) Make-up Water Tank

The capacity of this tank is to be for one day requirement of make-up water during continuous operation. The number of tanks to be installed will be one for each unit.

Make-up water tank capacity $= 990\ t/h \times 24\ h \times 1\% \times \frac{1}{0.8} = 300\ m^3$

v) Other Water Storage Tank

a. Potable water tank

The capacity is to be half-day consumption of normally required potable water. The number of tank to be installed will be one.

Potable water tank capacity $= 63\ m^3/d \times 0.5\ d \times \frac{1}{0.8} = 40\ m^3$

b. Service water head tank

The capacity shall be equivalent to the volume to be supplied to the equipment usually provided with such water when operation of the power plant stops due to an accident. The number of the tank to be installed will be one.

Equipment provided with filtered water:

| | |
|---|---|
| Sampling system | 18 $m^3$ |
| CWP cooling water | 2 $m^3$ |
| Others | 6 $m^3$ |
| | 26 $m^3$ |

Service water head tank capacity $= 26\ m^3 \times \frac{1}{0.8} = 40\ m^3$

(4) Study of Water Treatment Equipment Capacity

i) Clari-flocualator

The capacity is to be at a level allowing production of filtered water required during normal operation.

Based on water balance, 1,070 $m^3/d \doteqdot$ 1,100 $m^3/d$ is recommended.

ii) Demineralizer

The capacity is to be at a level allowing production of the required demineralized water, and 100% capacity stand by system is to be also installed.

Based on water balance, two systems of 500 $m^3/d$ are recommended.

iii) Sterilizer

This plant is to have a capacity to be able to treat the maximum consumption volume of potable water.

Plant (during scheduled maintenance of one unit)

$0.2\ m^3/man\text{-}d \times 600\ men = 120\ m^3/d$

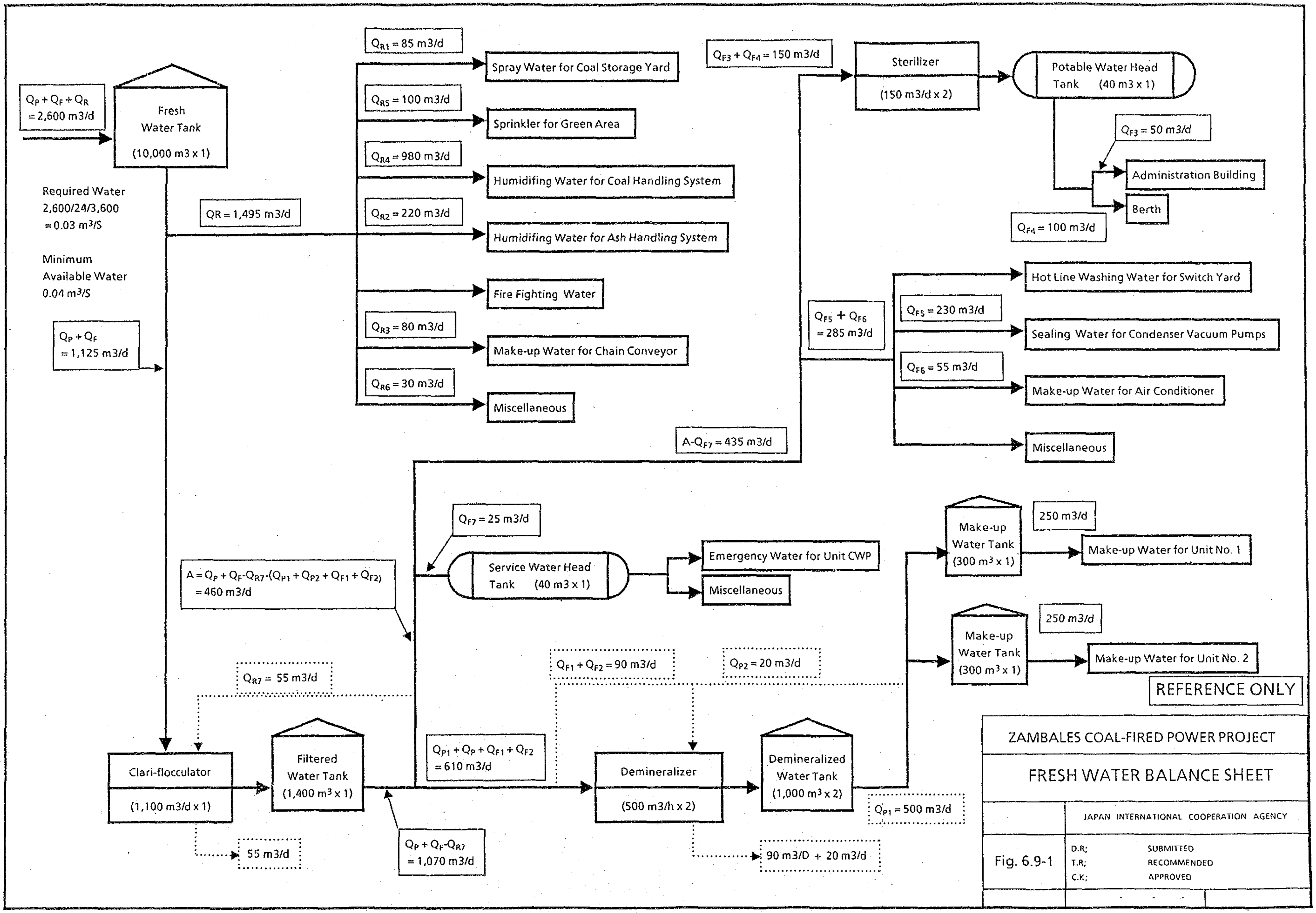
Water supply to ships

| | |
|---|---|
| 200 $m^3$/2 d | = 100 $m^3/d$ |
| Total | 220 $m^3/d$ |

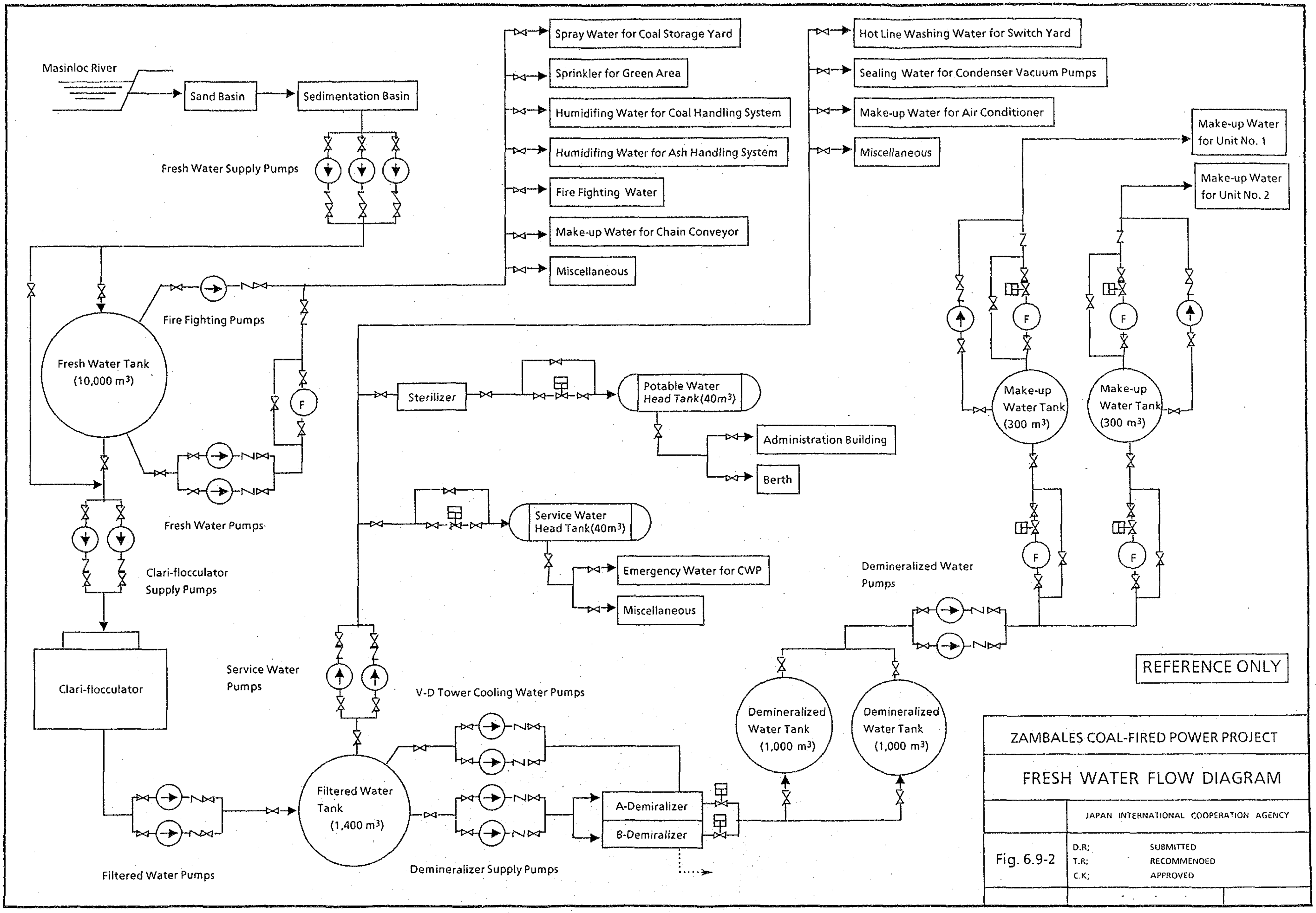
## Table 6.9.1 Volume of Water for Power Plant Use (2×300MW Basis)

| Water for Power Plant Use | | Water for Miscellaneous Application |
|---|---|---|
| **Demineralized water** | **Filtered water** | **Raw water** |
| (1) Plant make-up water $Q_{P1}$<br>$Q_{P1}$=boiler MCR evaporation volume<br>×1%×2 units<br>=990t/h×0.01×2 units ×24h/d<br>=500 m³/d<br><br>(2) Regenerating water of a demineralizer $Q_{P2}$ (Pharmaceutical resolution)<br>$Q_{P2}$=Equipment capacity×4%<br>=990t/h×0.01×2 units ×24h/d ×0.04<br>= 20 m³/d | (1) Regenerating water of a demineralizer $Q_{F1}$ (Backwash)<br>$Q_{F1}$=Equipment capacity× 6.2%<br>= 500 m³/d×0.062<br>= 30 m³/d<br><br>(2) Cooling water of a demineralizer (For vacuum deaeration)<br>$Q_{F2}$=Equipment capacity×12%<br>= 500 m³/d×0.12<br>= 60 m³/d<br><br>(3) Portable water $Q_{F3}$<br>$Q_{F3}$= 0.2m³/person・d × 250 persons<br>= 50m³/d<br><br>(4) Water for ships $Q_{F4}$<br>60,000DWT → 200m³<br>$Q_{F4}$= 200m³/2 d=100 m³/d<br><br>(5) Seal water for power plant pumps $Q_{F5}$*<br>Pumps related with condenser<br>$Q_{F5}$=230 m³/d<br><br>(6) Air conditioner make-up water $Q_{F6}$*<br>$Q_{F6}$= 55 m³/d<br><br>(7) Water for miscellaneous use in the administration office $Q_{F7}$<br>$Q_{F7}$=Water supply unit m³/person・d<br>× 250 persons<br>= 25 m³/d<br><br>(8) Regeneration water of clari-flocculator facilities $Q_{R7}$<br>$Q_{R7}$=Total filtered water×5%<br>=1,100 m³/d×0.05<br>= 55 m³/d | (1) Sprinkling water at a coal storage yard $Q_{R1}$ (3.6ℓ/m²)*<br>$Q_{R1}$=Sprinkled water unit volume<br>× Coal storage yard area<br>× Times of sprinkling×$10^{-3}$<br>=3.6 ℓ/m²× (500m×47m)<br>×1 Time/d ×$10^{-3}$<br>= 85 m³<br><br>(2) Humidifing water for ash treatment and transport $Q_{R2}$<br>$Q_{R2}$=Ash volume×30%×2 units<br>=138t/h×24h ×11.2%×30%×2 units<br>≒220 m³/d<br><br>(3) Chain conveyor make-up water $Q_{R3}$*<br>$Q_{R3}$= 40 m³/d×2 units<br>= 80 m³/d<br><br>(4) Humidifing water for unloading time $Q_{R4}$ (5% moistening)*<br>$Q_{R4}$=Unloading volume t/h×Unloading efficiency<br>×Moistening rate × Unloading time h/d<br>=1,400 t/h × 0.7×0.05×20 h/d<br>=980 m³/d<br><br>(5) Green area sprinkling $Q_{R5}$*<br>$Q_{R5}$=100 m³/d<br><br>(6) Working water $Q_{R6}$*<br>$Q_{R6}$=Unit water volume<br>× No. of working cases per day<br>= 3 m³/1 cases×10 cases/d<br>= 30 m³/d |
| Total volume of demineralized water<br>$Q_P = Q_{P1}+Q_{P2}$<br>= 520 m³/d | Total volume of filtered water<br>$Q_F = Q_{F1}+Q_{F2}+Q_{F3}+Q_{F4}+Q_{F5}+Q_{F6}+Q_{F7}+Q_{R7}$<br>=605 m³/d | Total volume of raw water<br>$Q_R = Q_{R1}+Q_{R2}+Q_{R3}+Q_{R4}+Q_{R5}+Q_{R6}$<br>=1,495 m³/d |

Note : * Mark indicates calculation based on actual values.



QP + QF + QR = 2,600 m3/d
Fresh Water Tank (10,000 m3 x 1)
Required Water 2,600/24/3,600 = 0.03 m3/S
Minimum Available Water 0.04 m3/S
QP + QF = 1,125 m3/d
QR = 1,495 m3/d
QR1 = 85 m3/d
Spray Water for Coal Storage Yard
QR5 = 100 m3/d
Sprinkler for Green Area
QR4 = 980 m3/d
Humidifing Water for Coal Handling System
QR2 = 220 m3/d
Humidifing Water for Ash Handling System
Fire Fighting Water
QR3 = 80 m3/d
Make-up Water for Chain Conveyor
QR6 = 30 m3/d
Miscellaneous
QF3 + QF4 = 150 m3/d
Sterilizer (150 m3/d x 2)
Potable Water Head Tank (40 m3 x 1)
QF3 = 50 m3/d
Administration Building
Berth
QF4 = 100 m3/d
QF5 + QF6 = 285 m3/d
Hot Line Washing Water for Switch Yard
QF5 = 230 m3/d
Sealing Water for Condenser Vacuum Pumps
QF6 = 55 m3/d
Make-up Water for Air Conditioner
Miscellaneous
A-QF7 = 435 m3/d
QF7 = 25 m3/d
Service Water Head Tank (40 m3 x 1)
Emergency Water for Unit CWP
Miscellaneous
A = QP + QF-QR7-(QP1 + QP2 + QF1 + QF2) = 460 m3/d
Make-up Water Tank (300 m3 x 1)
250 m3/d
Make-up Water for Unit No. 1
Make-up Water Tank (300 m3 x 1)
250 m3/d
Make-up Water for Unit No. 2
REFERENCE ONLY
QR7 = 55 m3/d
QF1 + QF2 = 90 m3/d
QP2 = 20 m3/d
Clari-flocculator (1,100 m3/d x 1)
Filtered Water Tank (1,400 m3 x 1)
QP1 + QP + QF1 + QF2 = 610 m3/d
Demineralizer (500 m3/h x 2)
Demineralized Water Tank (1,000 m3 x 2)
QP1 = 500 m3/d
55 m3/d
QP + QF-QR7 = 1,070 m3/d
90 m3/D + 20 m3/d
ZAMBALES COAL-FIRED POWER PROJECT
FRESH WATER BALANCE SHEET
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 6.9-1
D.R; SUBMITTED
T.R; RECOMMENDED
C.K; APPROVED



Masinloc River
Sand Basin
Sedimentation Basin
Fresh Water Supply Pumps
Spray Water for Coal Storage Yard
Sprinkler for Green Area
Humidifing Water for Coal Handling System
Humidifing Water for Ash Handling System
Fire Fighting Water
Make-up Water for Chain Conveyor
Miscellaneous
Hot Line Washing Water for Switch Yard
Sealing Water for Condenser Vacuum Pumps
Make-up Water for Air Conditioner
Miscellaneous
Make-up Water for Unit No. 1
Make-up Water for Unit No. 2
Fresh Water Tank (10,000 m3)
Fire Fighting Pumps
Fresh Water Pumps
Clari-flocculator Supply Pumps
Clari-flocculator
Sterilizer
Potable Water Head Tank(40m3)
Administration Building
Berth
Service Water Head Tank(40m3)
Emergency Water for CWP
Miscellaneous
Make-up Water Tank (300 m3)
Make-up Water Tank (300 m3)
Demineralized Water Pumps
Service Water Pumps
V-D Tower Cooling Water Pumps
Demineralized Water Tank (1,000 m3)
Demineralized Water Tank (1,000 m3)
REFERENCE ONLY
Filtered Water Tank (1,400 m3)
A-Demiralizer
B-Demiralizer
Filtered Water Pumps
Demineralizer Supply Pumps
ZAMBALES COAL-FIRED POWER PROJECT
FRESH WATER FLOW DIAGRAM
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 6.9-2
D.R;
T.R;
C.K;
SUBMITTED
RECOMMENDED
APPROVED

### 6.9.2 Selection of Fresh Water Intake Location

The Masinloc River was selected as the source of fresh water as mentioned in Chapter 4 "Site Selection Study:.

Site reconnaissance and data collection have been subsequently conducted, and the ideal site for fresh water intake from the Masinloc River was decided to be approximately 6 km upstream from the mouth of the river and on the east side of Babo Puti Hill for the following reasons. (Refer to Fig. 6.9-3)

- Sea water will not contaminate fresh water even at high tide.
- The water channel of the river is stable and the site is located where the intake of river water is feasible even during the dry season.
- The water intake and the proposed site of the pump pit are adjacent to Babo Puti Hill, and therefore, the foundation is assumed to be sound.
- The length of the pipe line will be short.

The results of runoff observation performed by the National Irrigation Administration for 10 years from 1978 to 1987 on Tinantapi River during the dry season were as follows:

| Year/Month/Day | Discharge ($m^3$/sec) |
|---|---|
| 1978. 3.28 | 0.126 |
| 78. 4.17 | 0.047 |
| 80. 1.16 | 0.223 |
| 80. 2.26 | 0.088 |
| 82. 1.13 | 0.284 |
| 83. 5.11 | 0.047 |
| 86.11. 6 | 0.756 |
| 87. 3.27 | 0.216 |

From the above results, it can be noted that the runoff during the driest period was 0.047 $m^3$/sec (≒ 4,000 $m^3$/day) and considering that the water from Lucan River is not included in the runoff and that the necessary water volume for the power station is 0.03 $m^3$/sec (= 2,600 $m^3$/day), this river can satisfactorily meet the requirement for water.

### 6.9.3 Water Intake Facilities and Pipeline

(1) Water Intake Facilities

As methods for water intake, ground water and directly drawing water from the river can be conceived, but based on the results of the site reconnaissance, river runoff intake was adopted considering the condition of the soil at the location of the water intake being fine grained silt and ground water intake would be difficult as well as the fact that water intake facilities for irrigation that are installed upstream on this river are surface water intake type.

Plan and sectional views of the water intake facilities are shown in Fig. 6.9-4. The structural features of the facilities are as follows:

- For the planned intake water volume, the water used in one day is 2,600 $m^3$/day and this volume of water is taken in during 24 hours. Therefore, runoff adopted was 0.03 $m^3$/sec.
- Water intake will be performed by a fixed weir which will be constructed across the entire 40 meter width of the river.
- The height of the weir was set at 50 cm so that the necessary water depth required to draw the planned amount of water can be maintained constantly without hindrance.
- As measures against silting, stop-log will be installed on a portion of the fixed weir so that sediment can be discharged downstream.
- In order to reduce seepage through the foundation of the weir and to prevent piping, cut-off sheet piles are to be driven in the foundation.

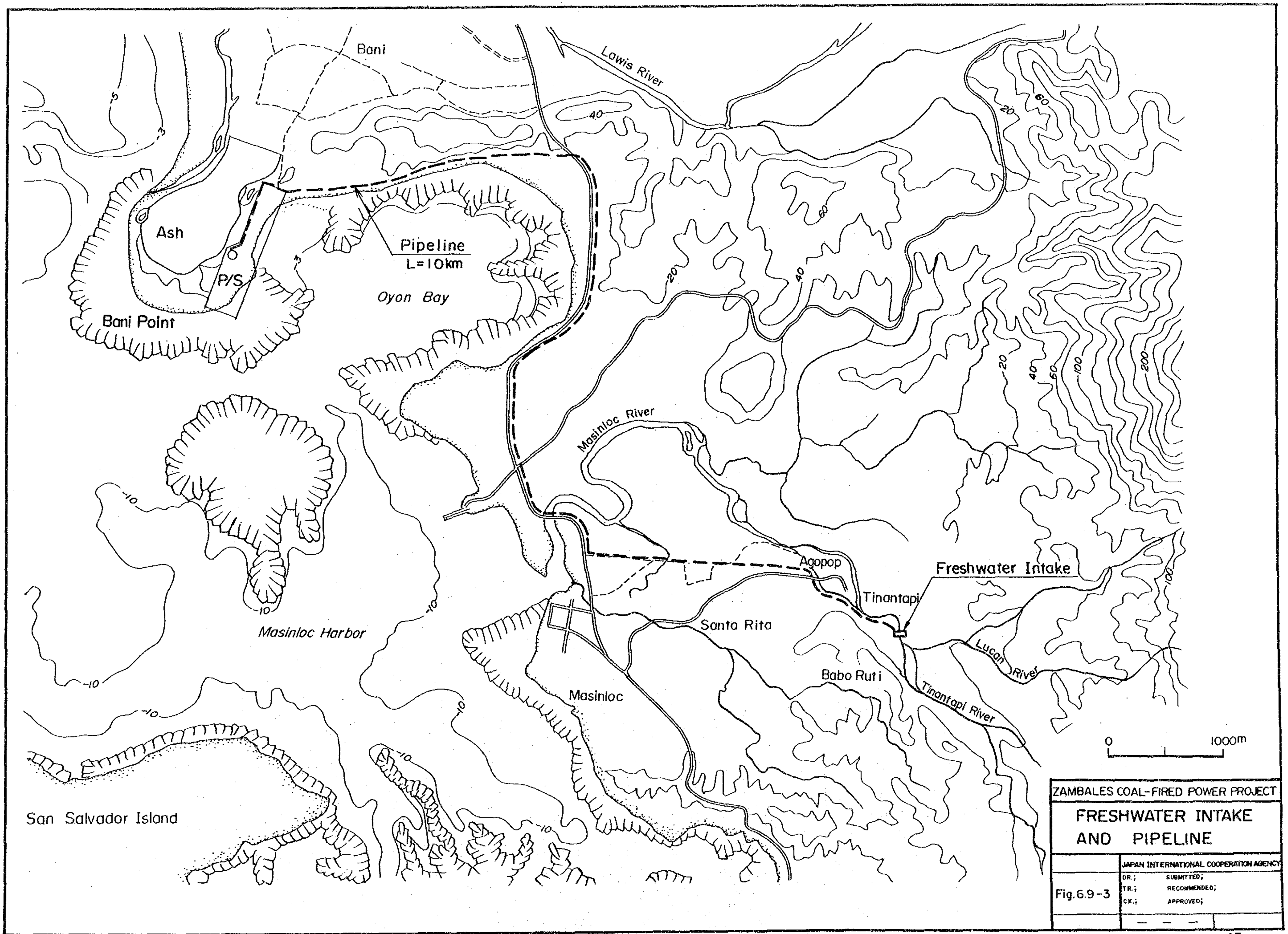
- The water that has been taken in at the weir passes through the intake, sand basin and sedimentation basin. The sedimentation basin will have a capacity of holding approximately 900 m3 which is equivalent to the volume for 8 hours, the time required for natural sedimentation.

- Water that has been treated in the sedimentation basin is pumped into the fresh water tank in the power plant compound by a pump.

(2) Pump Station and Pipe Line

The pump has been designed to pump water (1.81 $m^3$/min) required for one day use, 2,600 $m^3$/day, in 24 hours, and the capacity will be 0.95 $m^3$/min x 3 pumps (one pump to be on standby).

The pipe line route shown in Fig. 6.9-3 has been selected for the reason that the pipe line length will be short, topography of the ground has only limited rises and falls and excavation for pipe laying can be readily performed. The length of the pipe line is approximately 10 km. For economic reasons, the pipes of the pipe line will be 25 cm in diameter and made of cast iron.




ZAMBALES COAL-FIRED POWER PROJECT

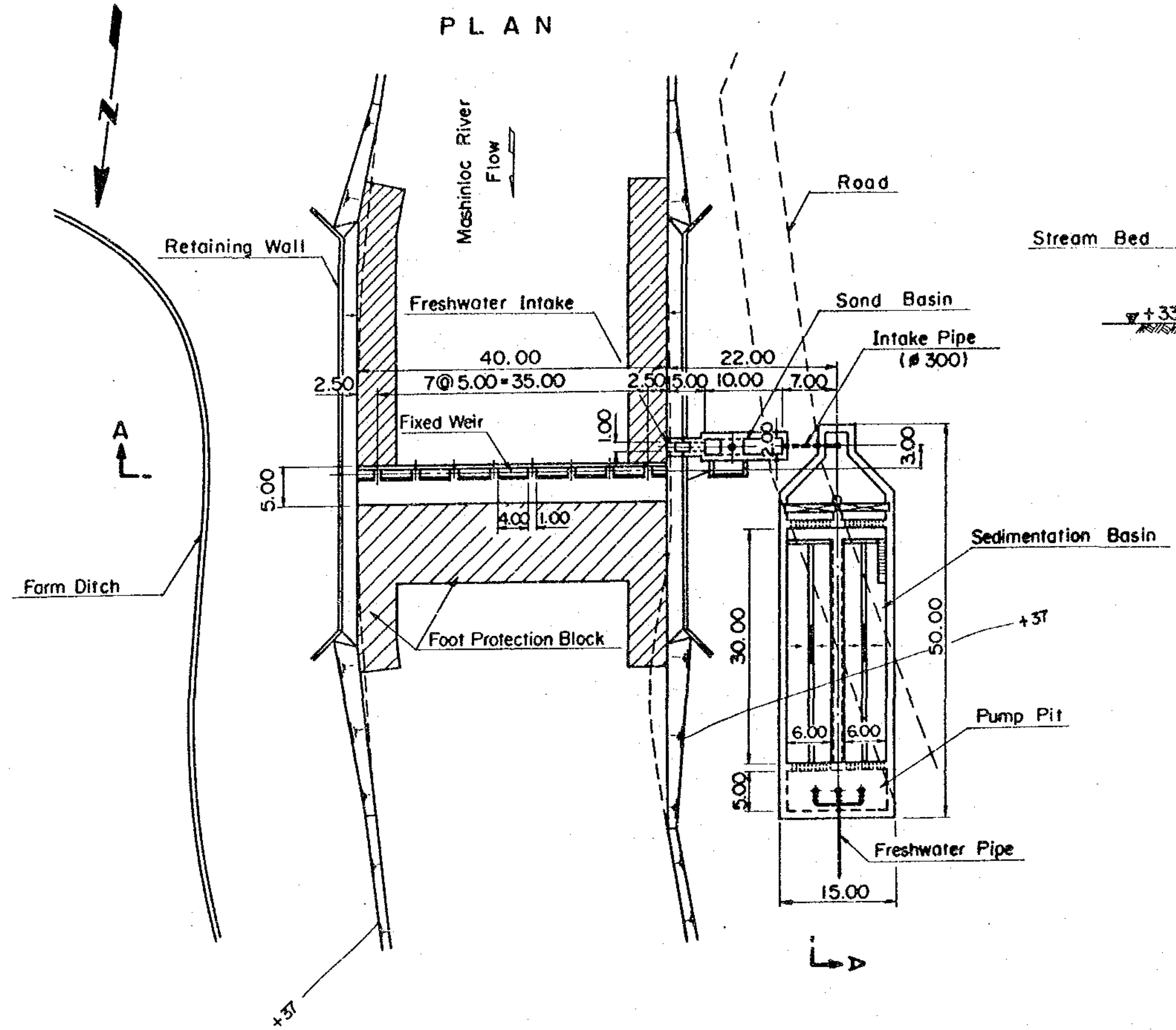
FRESHWATER INTAKE AND PIPELINE

JAPAN INTERNATIONAL COOPERATION AGENCY

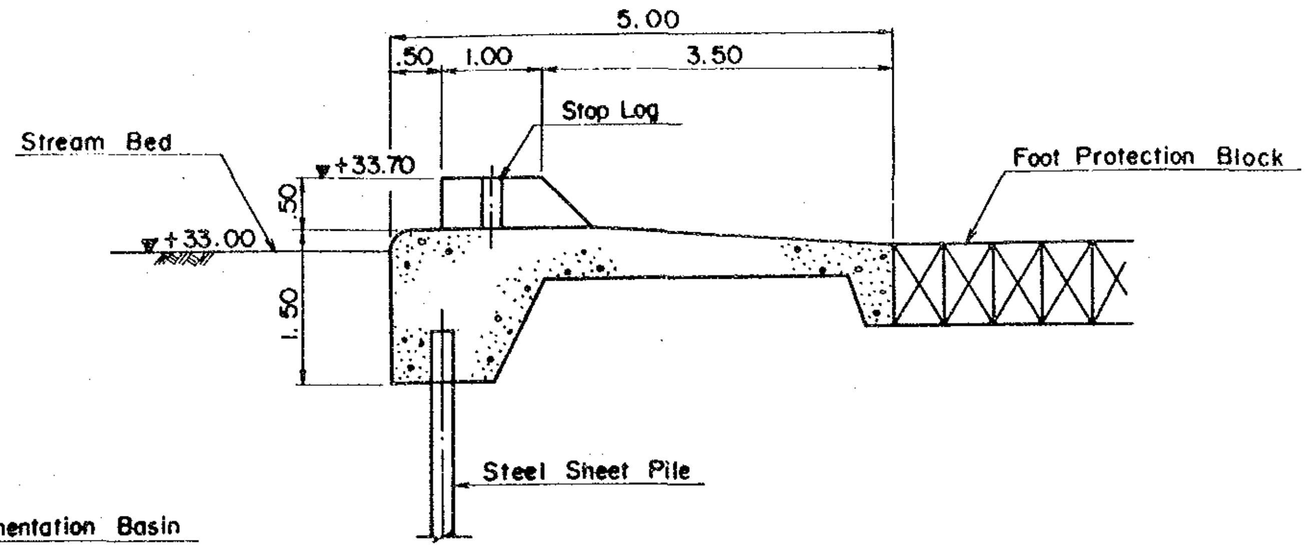
Fig.6.9-3

DR.; SUBMITTED;
TR.; RECOMMENDED;
CK.; APPROVED;

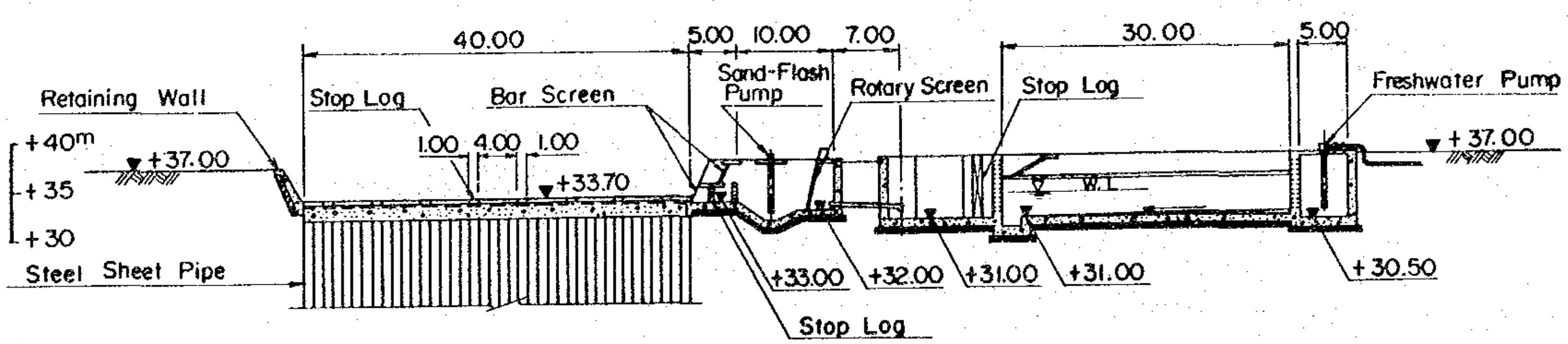
PLAN

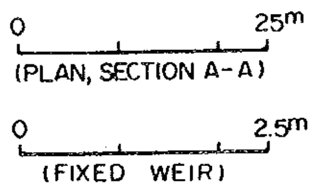



FIXED WEIR




SECTION A-A




| ZAMBALES COAL-FIRED POWER PROJECT | |
|---|---|
| FRESHWATER INTAKE | |
| | JAPAN INTERNATIONAL COOPERATION AGENCY |
| Fig.6.9-4 | DR.; SUBMITTED; TR.; RECOMMENDED; CK.; APPROVED; |

## 6.10 Boiler Facilities

### 6.10.1 Boiler Main

In case of coal firing boiler, the phenomena and influence of coal property, especially the characteristics of ash to the boiler were described in detail in Section 5.3 "Selection of Design Coal". We considered the following in preliminary design stage:

(1) Slagging Countermeasures

The slagging index of design coal (Semirara/Lemington = 50/50 wt%) of this project indicates "high" and the following countermeasures are available to prevent excessive slagging:

i) Reduce gas temperature near the water wall and decrease the amount of melted ash by reducing the heat load in furnace.

ii) Enlarge water wall area so that the cohesive ratio of ash per area and unit time may be reduced.

As a result, they are considered to be the compound result of both. However, it is effective to enlarge the furnace cross section for heavy slaggish coal. On the other hand, since excessive size of the furnace cross section results in difficulty in maintaining steam temperature, the furnace design should match the coal characteristics.

The value NHI/PA, which is obtained by dividing the net heat input (NHI) to the boiler by the plan area (PA), is used as a designing guide and the relationship with slagging characteristics is shown below:

| Slagging Characteristics | NHI/PA ($Btu/ft^2 \cdot h$) |
|---|---|
| Medium | $1.8$ to $2.2 \times 10^6$ |
| High | $1.6$ to $1.8 \times 10^6$ |
| Severe | $1.4$ to $1.6 \times 10^6$ |

From the above, we planned the furnace of this project as follows:

Plan Area (PA) : B 13.4 m x W 12 m = 161 $m^2$

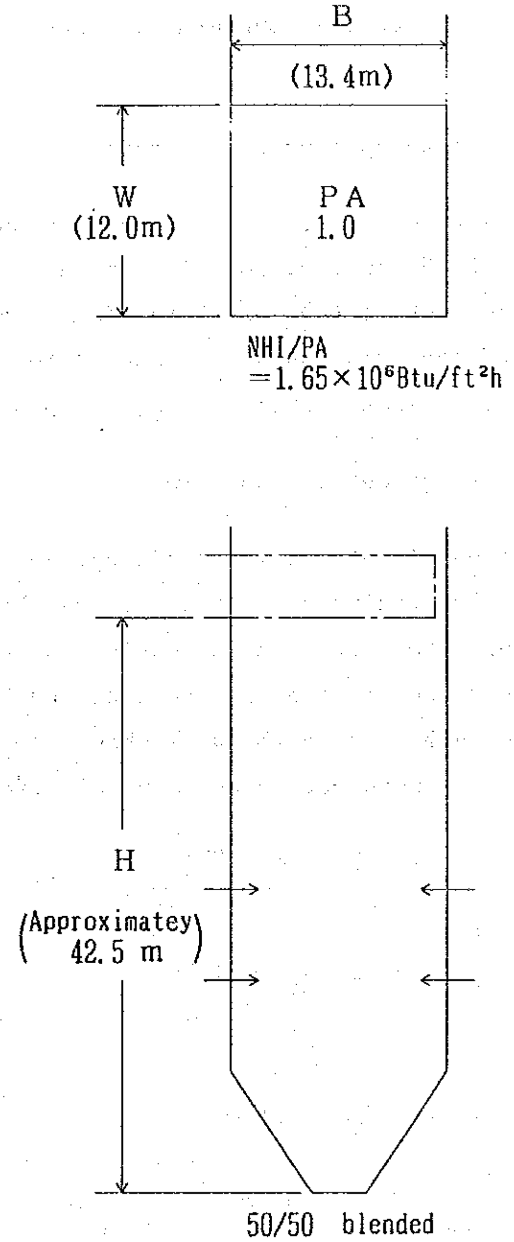
Net Heat Input (NHI): $724.5 \times 10^6$ kcal/h

NHI/PA $= 724.5 \times 10^6/161$

$= 4.5 \times 10^6$ kcal/$m^2$.h

$= 1.65 \times 10^6$ Btu/$ft^2$.h

Fig 6.10-1 Furanace dimensions in design coal



(2) Fauling Countermeasure

Countermeasure to slagging by ash can be done by furnace design but fauling cannot be avoided through boiler design. Thus, the following fauling countermeasures should be provided:

i) Selection of an optimum tube pitch:

If fauling tendency is high, reduce the outlet gas temperature of the furnace to below the ash melting point and the convection tube pitch in the furnace should be enlarged. Accumulation of ash should be suppressed and the effect of soot blower should be improved.

ii) Optimum arrangement of soot blower

The relationship of fauling tendency, gas temperature and effective radius of sootblower are shown below. This figure shows that the effective radius of soot blower decreases as the fauling tendency becomes higher. Thus, the number of sootblowers should be determined taking into consideration ash-removal effect.

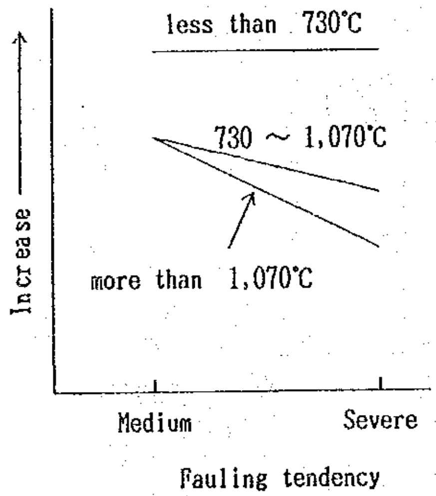



Fig. 6.10-2 Relationship between Fauling Tendency and Effective Radius of Soot Blower as a Parameter of Gas Temperature

The fauling index of design coal is at the boundary between the "Medium" and "High" and a sufficient number of soot-blowers for effectively removing ashes were arranged.

(3) Countermeasures against Abrasion due to Ash

Abrasion of convection tube due to ash is an important element that greatly affect the reliability and economy of a coal fired boiler and the convection tube was designed considering the following countermeasures:

i) Reducing of gas velocity at contact convection part (Ash loading)

Selection of gas velocity suited to ash loading per heating value is basic countermeasures against basic ash abrasion. The following figure shows the relationship between the ash loading per heating value and the designed gas velocity:

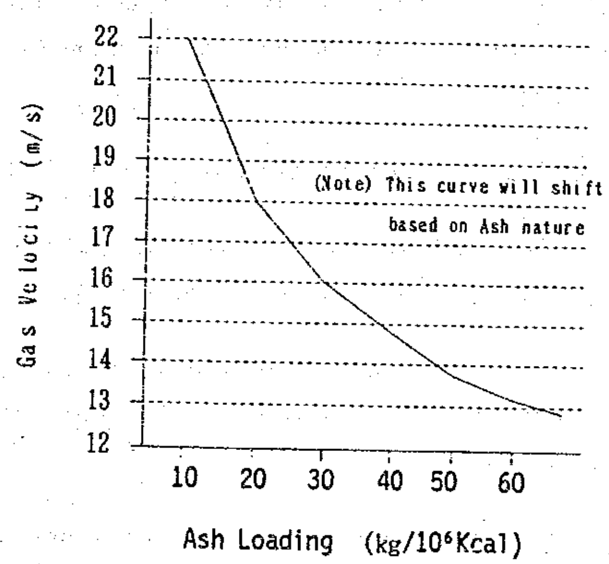



Fig. 6.10-3 Relationship between Ash per Heating Value and Designed Gas Velocity

The ash loading per heating value of design coal is 21.3 kg/$10^6$ Kcal and the target gas velocity is 17.5 m/s or less. However, we set the designed gas velocity to 16 m/s or less since the ash abrasion index shows "Severe".

ii) Prevention of local ash abrasion

Since gas flow rate locally increases drastically, if gas flow is extremely biased, biased gas flow should be prevented and a buffle plate and a protection plate should be installed at an area where there is much ash abrasion as shown below:

a. Area where gas velocity changes radically
b. Area where gas flow takes a short cut
c. Area closer to sootblower

(4) Gas Recirculation System as Steam Temperature Control

To adopt gas recirculation system to coal-fired boiler, two ways are considered to reduce ash abrasion of gas recirculation fan (GRF).

i) Use less ash loaded gas downstream of ESP.

ii) Use less ash loaded gas from the exit of the economiser by the mechanical dust collector (MC).

The first way i) is better to facilitate easy, however, this will increase the AH size because the recirculating gas passes through the AH.

On the other hand, since the design coal has a high moisture content, pulverizer inlet air temperature should be set at a high range and AH inlet gas temperature also should be set at a high range.

Furthermore, adoption of a gas recirculation system is not economical because this results in excess AH size and decreases the boiler efficiency due to rise of AH outlet gas temperature.

Therefore, GRF system is not adopted in this study.

(5) Application Range of Coal Blend Ratio

The design coal has been set as Semirara/Lemington = 50/50 weight percent. In actual operation, the blending ratio of Semirara coal might be increased by +15% due to the design margin.

However, it is extremely important, especially in case of coal-fired boiler, to accumulate operational know-how using various kinds of coal.

There is possibility to vary the blending ratio of Semirara coal depending on the characteristics of overseas coal, including Lemington coal, which are blended with Semirara coal.

For this reason, it is important to ascertain the range of coal blending ratio in the coal procurement plan and to accumulate combustion data of coal after the boiler is put into use.

(6) Study of Exclusive Use of Lemington Coal

In case of using Lemington coal exclusively for boiler which is designed for blending with indigenous coal, reduction of furnace outlet gas temperature and steam temperature might occur due to less contamination by ash in the furnace.

However, there is the possibility of 100% overseas coal combustion and to control steam temperature by examining the adoption of the following items.

i) Adoption of Gas Recirculation System

ii) High excess air operation by increasing the FDF capacity

### 6.10.2 Pulverized Coal Firing Equipment

(1) Pulverized Coal Firing System

This power plant is studied as a base load operation. Direct firing system and central bin system available for pulverized coal firing system. Direct coal firing system is generally preferred for reasons of performance and economy. This project also adopts the direct firing system.

i) Composition of Equipment by Direct Firing System

Coal bunker
Coal feeder
Pulverizer (Mill)
Coal burner

ii) Consideration of Standby Unit

According to the operation conditions of this project, the annual availability for this plant is planned for 300 days.

In accordance with existing operation data of 250 MW class coal-fired thermal power plant with 75% annual plant factor, inspection and maintenance of pulverizer are executed after 100,000 to 120,000 tons of coal is treated (equivalent to 240 days).

Based on this experience, 5-units of pulverized coal firing systems, including one stand by unit, will secure stable operation of the plant.

iii) Capacity/Capability of Each Equipment of the System

a) Capacity of coal bunker

According to the results of study given in Section 6.7, Coal Handling Facilities, the capacity of coal bunker is 5 each of 700 $m^3$ per unit (including one stand by).

b) Capability of Pulverizer

Capability of pulverizer is examined based on the MCR operation of the plant.

| | |
|---|---|
| Required coal supply at MCR | : 138 t/h |
| Utilization condition of pulverizer: | 5 units including one stand by |

$$\text{Capability of pulverizer} = \frac{138\ \text{t/h}}{4\ \text{unit}} \times 1.2$$

$$\fallingdotseq 41\ \text{t/h.unit}$$

(including 20% margin at MCR)

Therefore, pulverized coal firing system is 5 units of 41 t/h.

c) Type of pulverizer

The types of pulverizers available are vertical and horizontal. Both of the types have their advantages and disadvantages. Thus, it is necessary to select the type by performing economic evaluation with equipment cost, energy consumption and maintenance cost.

As a result of economic evaluation, a vertical type is more advantageous.

<u>Economic Comparison of Types of Pulverizers</u>

<u>Condition</u>

| | | |
|---|---|---|
| Annual utilization factor | : | 70% |
| Energy cost | : | ¥5.7/kWh |
| Accumulated net present value coefficient | : | 6.566 |
| Coal consumption | : | 138 t/h |

(Mil. Yen)

| | Items | Vertical Bowl Mill | Horizontal Tube Mill |
|---|---|---|---|
| | Equipment Cost | | |
| | Pulverizer including accessory | Base | 97 |
| | Foundation | Base | 72 |
| a | Sub total | Base | 170 |
| | Operation Cost (NPV) | | |
| | Energy charge | Base | 333 |
| | Parts | Base | 67 |
| | Labor cost | Base | - |
| b | Sub total | Base | 400 |
| | Total (a + b) | Base | 570 |

### 6.10.3 Oil Firing Systems

The oil firing systems are planned under the following conditions:

(1) Conditions

i) The heavy oil firing equipment should have a capacity which can withstand 50% load at MCR.

ii) The light oil firing equipment should have sufficient capacity to start up the boiler and ignitor for ignition of burner.

iii) The heating value of heavy and light oils should be approximately 10,000 kcal/kg.

(2) Heavy Oil Firing System

The heavy oil firing system consist of the following equipment:

Heavy oil pump
Heavy oil heater
Heavy oil burner

i) Capacity of heavy oil firing system

50% equivalent oil quantity Q of boiler at MCR load including 5% margin.

$$Q = \text{Coal consumption at MCR} \times \frac{\text{Heating value of coal}}{\text{Heating value of H.O.}} \times 50\% \times 1.05$$

$$= 138 \text{ ton/h} \times \frac{5,262}{10,000} \times 0.5 \times 1.05$$

$$= 38 \text{ ton/h}$$

ii) Heavy oil pump

The capacity of the heavy oil pump should be the same as the oil firing system of 38 t/h capacity. Two of them should be installed.

iii) Heavy oil heater capacity

The capacity of the heavy oil heater should be the same as the firing system of 38 t/h capacity. One unit should be installed.

iv) Heavy oil burner

In general, approximately 12 heavy oil burners are installed in a 300 MW class boiler. The burner capacity should be calculated by assuming that one burner is out for cleaning.

$$\text{Burner capacity} = \frac{38 \text{ t/h}}{11} = 3.5 \text{ t/h}$$

Burners are 12 x 3.5 t/h.

(3) Light Oil Firing System

The light oil firing system consists of the following equipment:

Light oil pump
Light oil burner

i) Light oil firing system

The required light oil capacity to ignite a boiler and to raise steam pressure is equivalent to 8 to 10% of coal consumption at MCR. The design value is 10% with 5% margin.

The required oil quantity at MCR (Q):

$$Q = \text{Coal consumption at MCR} \times \frac{\text{Heating value of coal}}{\text{Heating value of Light oil}} \times 0.1 \times 1.05$$

$$= 138 \text{ t/h} \times \frac{5,262}{10,000} \times 0.1 \times 1.05$$

$$\fallingdotseq 8 \text{ t/h}$$

ii) Light oil pump

Two of 8 t/h capacity light oil pumps shall be installed.

iii) Light oil burner

In general, the number of light oil burners in a 300 MW-class boiler is four (4). Therefore, light oil burner is calculated as 2.0 t/h.

### 6.10.4 House Service Boiler and Auxiliary Steam

(1) Basic Concept

It is necessary to install a house service boiler to secure the steam source needed for start up of the plant. The auxiliary steam line should be switched over to the main boiler steam line when the required steam can be obtained from the main boiler.

Thus, the capacity of house service boiler and the conditions of the auxiliary steam system should be examined.

(2) Quantity of Auxiliary Steam and House Service Boiler

The assumed time series until the power plant reaches continuous full-load operation from cold state and the points of supply of auxiliary steam, and the quantity of steam at each time are shown in Fig. 6.10-5.

As a result, the net capacity is approximately 2 t/h, but variation range shall be taken into account, thus,

| | | |
|---|---|---|
| House service boiler capacity | : | 5 t/h |
| Capacity of auxiliary steam facilities of main boiler | : | 30 t/h |

(3) Steam Conditions of Auxiliary Steam

Steam conditions of auxiliary steam are determined taking the most severe conditions of destination of supply of this steam.

Main turbine gland steam: 8 $kg/cm^2$ x 220°C to 240°C (at inlet of gland steam regulator).

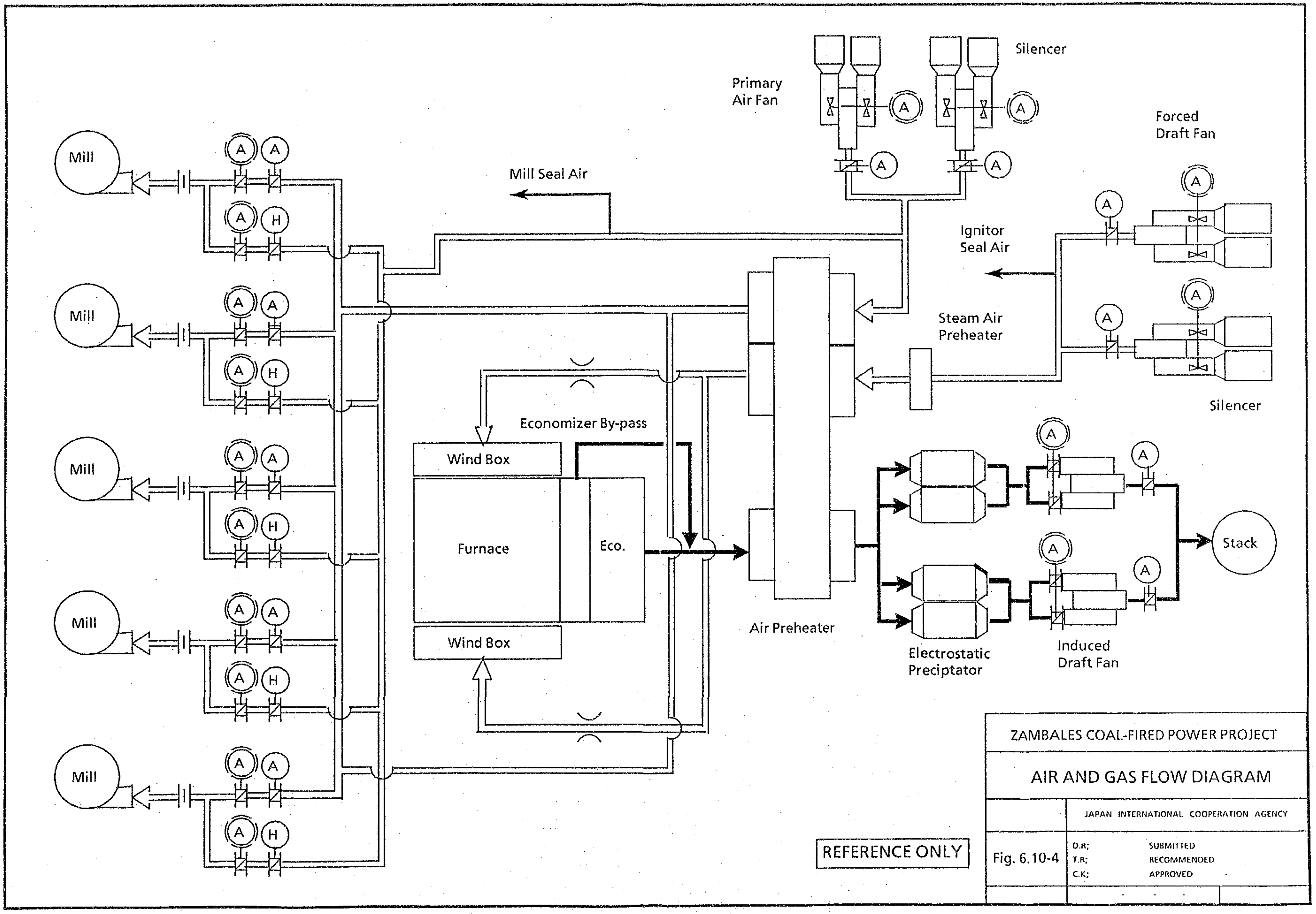

Silencer
Primary
Air Fan
Forced
Draft Fan
Mill
Mill
Mill
Mill
Mill
Mill Seal Air
Ignitor
Seal Air
Steam Air
Preheater
Silencer
Economizer By-pass
Wind Box
Furnace
Eco.
Wind Box
Air Preheater
Electrostatic
Preciptator
Induced
Draft Fan
Stack
A
H
REFERENCE ONLY
ZAMBALES COAL-FIRED POWER PROJECT
AIR AND GAS FLOW DIAGRAM
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 6.10-4
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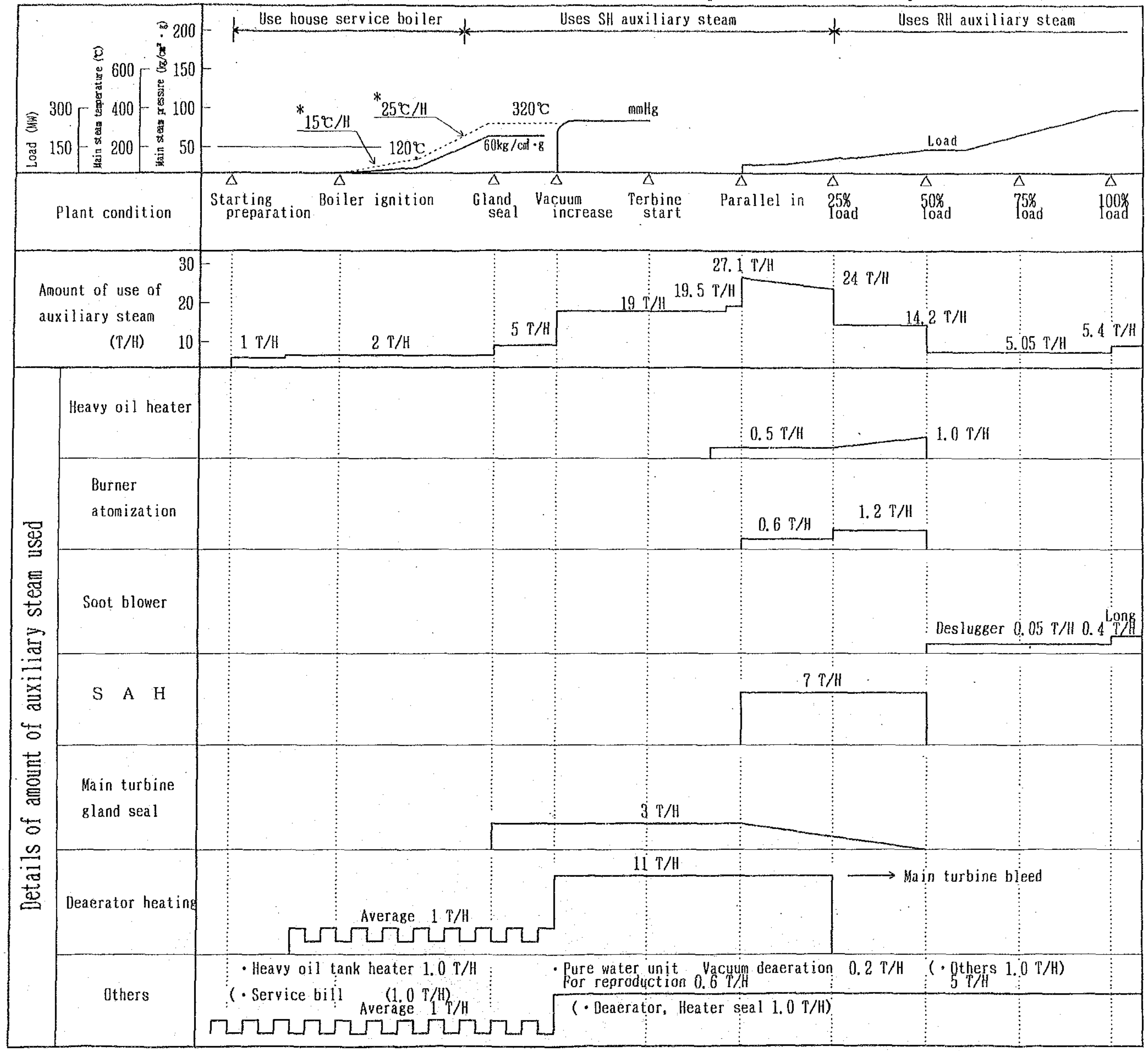
Fig 6.10-5 Examination on Quantity of Auxiliary Steam



## 6.11 Steam Turbine

### 6.11.1 Condenser

The condenser has the function to cool and condensate turbine exhaust steam and also to improve the thermal efficiency of steam turbine by reducing the exhaust steam pressure as low as possible.

The condensate facility is comprised of, besides a condenser, a cooling water pump, a condensate pump, an air ejector, and other accessories. Regarding the condenser type, a surface condenser is commonly used in a thermal power plant for power utilities.

(1) Selection of Optimum Vacuum Degree of Condenser

i) Fundamental conditions

a. Design temperature of sea water : 31°C
b. Allowable temperature of discharged sea water : 40°C or lower
c. A matter to be considered in design is the harmony between dimension of low pressure turbine and condenser

ii) Method of economic evaluation

The economic comparison is made on several cases, and the case taken is standard where the degree of vacuum in the condenser is 60 mmHg and the rise in temperature is 7°C.

a. Find the deviation in the turbine heat rate from the standard case, convert it into annual fuel cost, and further convert the equipment cost to present value.

b. Calculate the required sea water quantity from the vacuum degree in the condenser and the temperature difference between the inlet and outlet of sea water and convert the difference in annual power cost of pump required for the delivery of the seawater to the equipment cost (present value).

c. Difference in equipment cost of condenser, pump facilities, etc.

The optimum vacuum degree of the condenser is determined at the point where the above values of (a+b+c) becomes least, and also considering the harmony of dimensions of the condenser.

iii) Economic evaluation

a. Conditions to be used in economic evaluation

Fuel cost : ¥1.32/$10^3$ kcal

Electricity cost : ¥5.7/kWh

Cumulative present value conversion coefficient:

$$a_n = \frac{(1 + r)^n - 1}{r\ (1 + r)^n} = 6.566$$

where, $r = 15\%$

$n = 30$ years

Present value of operation cost:

$$P_V = a_n \times \text{(annual operation cost)}$$

Annual utilization factor: 70%

b. Calculation formula for economic evaluation

- Difference in annual operation cost due to the difference in turbine heat rate ($\Delta H_R$) : (A)

  A (¥/year) = $\Delta$HR kcal/kWh x 300,000 kW x 8,760 h/year x 0.7 x ¥1.32/$10^3$ kcal

  Present value of A: (A')

  A' = A x 6.566

- Difference in annual operation cost due to CWP power difference : (B)

B (¥/year) = $\Delta$ kW x 300 d/y
x 24 h/d x ¥5.7/kWh

Present value of B: (B')

B' = B x 6.566

- Difference in the cost of equipment such as a condenser and pump facilities: (C)

- Overall economic efficiency : (D)

D = C + A' + B'

iv) Results of evaluation of overall economy

The results of plotting, taking the overall economy in Table 6.11-1 on the axis of oridinates and the sea water temperature difference in the inlet and outlet on that of abscissas are shown in Fig. 6.11-1. From Fig. 6.11-1, it is indicated that the optimum vacuum degree in this project exists in the range of 65 to 70 mmHga when the sea water temperature difference at the inlet and outlet is 8 to 9°C.

Based on the results of the economic comparison, using the above method, the vacuum degree that should be adopted in this plant is about 65 to 70 mmHg at a temperature difference of 8 to 9°C at the inlet and outlet of cooling water. This value is almost equal to the vacuum degree in a thermal power plant in the Southeast Asian countries where sea water temperature is almost equal to that in this project.

(2) Sea Water Quantity for Condenser Cooling

i) Heat removed by the condenser

This is calculated from the plant heat balance explained in "(4) Thermal Efficiency of a Power Plant" in Section 6.2.4.

When the heat removed by the condenser is taken at Q,

$$Q = kW \times Q_{cond}$$

where, kW : Turbine output 300,000 kW

$Q_{cond}$: Heating value which are removed by condenser

= Turbine heat rate - Turbine mechanical loss - Generator loss - 860 (kcal/kWh)

Taking $\triangle t$ = 8°C and at 65 mmHg,

| | | |
|---|---|---|
| Turbine heat rate | : | 1,940 kcal/kWh |
| Turbine mechanical loss | : | -5 kcal/kWh |
| Generator loss | : | -10 kcal/kWh |
| Generator output | : | -860 kcal/kWh |
| | | 1,065 kcal/kWh |

$$Q = kW \times Q_{cond}$$
$$= 300{,}000 \text{ kW} \times 1{,}065 \text{ kcal/kWh}$$
$$= 320 \times 10^6 \text{ kcal/h}$$

ii) Calculation of cooling water quantity

$$G_W = \frac{Q}{(C_p \times \gamma) \times t_2 - t_1)}$$

where, $C_p$: Specific heat of sea water 0.94 kcal/kg°C

$\gamma$: Specific weight of sea water 1,024 kg/m$^3$

$t_2$: Sea water temperature at outlet 39°C

$t_1$: Sea water temperature at inlet 31°C

Q : Heat removed by condenser 320 x $10^6$ kcal/h

$$G_W = \frac{320 \times 10^6 \text{ kcal/h}}{(0.94 \text{ kcal/kg°C} \times 1{,}024 \text{ kg/m}^3) \times (39°C - 31°C)}$$
$$= \frac{320 \times 10^6}{963 \times 8} \text{ m}^3\text{/h}$$
$$= 41{,}500 \text{ m}^3\text{/h}$$

- Supplied quantity to bearing water cooler 2,000 $m^3/h$
- Others 1,500 $m^3/h$
- Total 45,000 $m^3/h$

### 6.11.2 Main Pumps

The main pumps in a large power plant are circulating water pump, condensate pump, and boiler feed water pump.

i) Circulating water pump

a) For convenience of operation, condenser in a large thermal power plant is of double chamber structure. Hence, 2 sets x 50% capacity circulating water pumps are provided.

b) Type of pump

The characteristics of circulating water pump are very large quantity of pumping water and rather low water head. To meet such characteristics, a vertical type mixed flow pump has been generally introduced.

c) Water head of circulating water pump

The water head of circulating water pump is determined by the following loss heads, the total of which is taken at 11 m.

Loss at water intake
Conduit loss
Condenser loss
Siphon loss
Discharge loss in the outlet pipe of the condenser

d) Shaft power of circulating water pump and motor output

- Shaft Power: $L_p$ (kW)

$$L_p = \frac{Lw}{\eta p}$$

where, Lw: Water power = 0.163 x Q x H

$\eta p$: Pump efficiency 0.85 to 0.87

$\gamma$ : Specific gravity of water 1.024 kg/1

Q : Discharge quantity 45,000 $m^3/h$

750 $m^3/min$

H : Total head 11 m

$$Lp = \frac{0.163 \times 1.024 \times 750 \times 11}{0.87} = 1{,}583 \text{ kW}$$

Per one pump = 790 kW

- Motor output: $L_m$ (kW)

$$Lm = \frac{L_p \times (1 + \alpha)}{\eta t}$$

$L_p$: Shaft power 790 kW

$\alpha$ : Allowance 0.15

$\eta t$: Transfer efficiency 1.0

$$L_m = \frac{790 \times (1 + 0.15)}{1.0} = 910 \text{ kW}$$

Motor output is calculated to be 910 kW.

ii) Condensate pump

The quantity of condensate water differs somewhat in each power plant. The reason is the differences among the main type of facilities and the differences in the external condition as well as the site condition. Hence, the capacity of the condensate pump is calculated taking existing plants into reference. This is shown below.

a) Steam quantity and condensate water quantity in existing plants

| | 250 MW | % | 350 MW | % |
|---|---|---|---|---|
| (at ECR) | | | | |
| Main steam quantity (t/h) | 767 | 100 | 1,080 | 100 |
| Reheated steam quantity (t/h) | 627 | 81 | 887 | 82 |
| Condensate quantity (t/h) | 465 | 74 | 670 | 76 |

b) Condensate quantity in this power plant

At ECR

| | |
|---|---|
| Main steam quantity | 930 t/h |
| Reheated steam quantity | 930 t/h x 82% = 763 t/h |
| Estimated condensate water quantity | 930 t/h x 75% = 698 t/h |

At MCR

| | |
|---|---|
| Main steam quantity | 990 t/h |
| Estimated condensate water quantity | 990 t/h x 75% = 740 to 750 t/h |

c) Capacity and number of condensate pump

Condensate water quantity is assumed at about 750 t/h, and the allowance is assumed as 5% for pump capacity. The number of pumps is 3 sets x 50% capacity, considering convenience in operation.

Condensate water quantity = 750 t/h x 1.05 = 788 t/h
Condensate pump capacity = 3 sets x 390 t/h

iii) Boiler feed water pump

The capacity of boiler feed water pump is taken to be equal to the feed water quantity at MCR of power plant. The number of pumps is normally 3 sets x 50% capacity. Pump capacity includes an allowance of 5%.

Feed water quantity at MCR = 990 x 1.05 = 1,045 t/h
Boiler feed water pump capacity = 3 sets x 520 t/h

As for feed water pump drive method, there are electric motor driven and steam turbine driven. In this project, an electric motor driven method is recommended for reasons of ease of operation and maintenance.

### 6.11.3 Feed Water Heater

In the study of feed water heater, it is necessary to determine the optimum number of extraction stages. The selection of number of stages depends on the influence on the turbine thermal efficiency and the difference in facility cost, etc.

For a plant of this size, the number of stages of heater is generally considered to be 7 or 8.

Case (a) 7-stage layout
High-pressure water heater (2 stages) + Deaerator + Low-pressure water heater (4 stages)

Case (b) 8-stage layout
High-pressure water heater (3 stages) + Deaerator + Low-pressure water heater (4 stages)

The difference in this extraction stages appears with the differences in boiler feed water temperature and turbine thermal efficiency.

The result of the economic comparison between the two cases is shown in the following table.

| Symbol | Items | No. of Extraction Stages | |
|---|---|---|---|
| | | 7 Stages | 8 Stages |
| a | Final feed water temperature(°C) | Approx. 245 | Approx. 275 |
| b | Turbine thermal efficiency difference (%)<br>(kcal/kWh) | Base<br>Base | -0.8<br>-16 |
| b' | Equivalent to boiler heat input (kcal/kWh) | Base | -18 |
| c | Annual fuel cost difference (1 million yen/year) | Base | -44 |
| d | Difference in present value of operation expenses (1 million yen/year) | Base | -290 |
| e | Difference in equipment cost (1 million yen) | Base | +200 |
| | d + e (1 million yen) | Base | -90 |

Conditions

Fuel price : ¥1.32/$10^3$ kcal
Accumulated present value conversion coefficient : $a_n = 6.566$
Operation expenses present value : $P_v = a_n$ x annual fuel expense

In this plant, the 7 to 8-stages produce a profit of 90 million yen in 30 years. Thus, the layout of water heater of this project is as follows:

High-pressure water heater (3 stages) + Deaerator + Low-pressure water heater (4 stages)

## Table 6. 11-1 Comparison for The Optimum Vacuum Degree

| Case | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inner Pressure (mmHg a) | 60 ($T_s$ =41.53) | | | 65 ($T_s$ =43.06) | | | 70 ($T_s$ =44.47) | | | | 75 ($T_s$ =45.84) | | | | |
| Temperature Rise ( ℃ ) | 7 | 7.75 | 7 | 8 | 9 | 9.28 | 8 | 9 | 10 | 10.69 | 8 | 9 | 10 | 11 | 12.06 |
| Cooling Area ( m² ) | 17,900 | 19,680 | 14,260 | 15,630 | 17,520 | 18,180 | 12,990 | 14,140 | 15,660 | 17,040 | 11,230 | 12,020 | 12,990 | 14,250 | 16,110 |
| Tube-Sheet-Separation ( mm ) Distance | 6,761 | 8,230 | × 5,370 | 6,727 | 8,482 | 9,074 | × 5,568 | 6,819 | 8,390 | 9,758 | × 4,787 | 5,765 | 6,922 | 8,352 | 10,350 |
| Number of Cooling Tubes | 33,180 | 29,968 | 33,280 | 29,120 | 25,888 | 25,108 | 29,240 | 25,988 | 23,392 | 21,884 | 29,404 | 26,132 | 23,520 | 21,384 | 19,508 |
| Pump Capacity(50%×2)( m³/h ) | 26,760 | 24,260 | 26,840 | 23,600 | 21,080 | 20,470 | 23,690 | 21,160 | 19,130 | 17,955 | 23,820 | 21,270 | 19,230 | 17,570 | 16,100 |
| Pump Head (50%×2)( m ) | 7.9 | 8.4 | 7.4 | 7.9 | 8.5 | 8.7 | 7.5 | 7.9 | 8.5 | 8.9 | 7.2 | 7.5 | 8.0 | 8.5 | 9.2 |
| Difference in Turbine (kcal/kwh) Heat Rate | Base | ← | 3.4 | ← | ← | ← | 7.9 | ← | ← | ← | 14.0 | ← | ← | ← | ← |
| Difference in Plant (kcal/kwh) Heat Rate | Base | ← | 3.8 | ← | ← | ← | 8.8 | ← | ← | ← | 15.6 | ← | ← | ← | ← |
| Difference in Annual Fuel Cost (Million yen/year) | Base | ← | 9.2 | ← | ← | ← | 21.4 | ← | ← | ← | 37.9 | ← | ← | ← | ← |
| Present Value of the Above (Million yen) | Base | ← | 60.4 | ← | ← | ← | 140.5 | ← | ← | ← | 248.9 | ← | ← | ← | ← |
| Difference in Pump Power ( Kw ) | Base | − 49 | − 82 | − 160 | − 207 | − 214 | − 217 | − 284 | − 314 | − 332 | − 256 | − 334 | − 370 | − 399 | − 407 |
| Difference in Annual Electric Power Cost (Million yen/year) | Base | − 2.0 | − 3.4 | − 6.6 | − 8.5 | − 8.8 | − 8.9 | −11.7 | −12.9 | −13.6 | −10.5 | −13.7 | −15.2 | − 16.4 | − 16.7 |
| Present Value of the Above (Million yen) | Base | − 13.1 | −22.3 | −43.3 | −55.8 | −57.8 | −58.4 | −76.8 | −74.7 | −89.3 | −68.9 | −90.0 | −99.8 | −107.7 | −109.7 |
| Difference in Equipment Costs (Million yen) | Base | 14 | − 78 | − 71 | − 51 | − 44 | − 126 | − 120 | − 103 | − 84 | − 163 | − 166 | − 160 | − 146 | − 119 |
| Overall Economy (Million yen) | Base | 1 | − 40 | − 54 | − 46 | − 41 | − 44 | − 56 | − 47 | − 33 | − 17 | − 7 | − 11 | − 5 | − 20 |

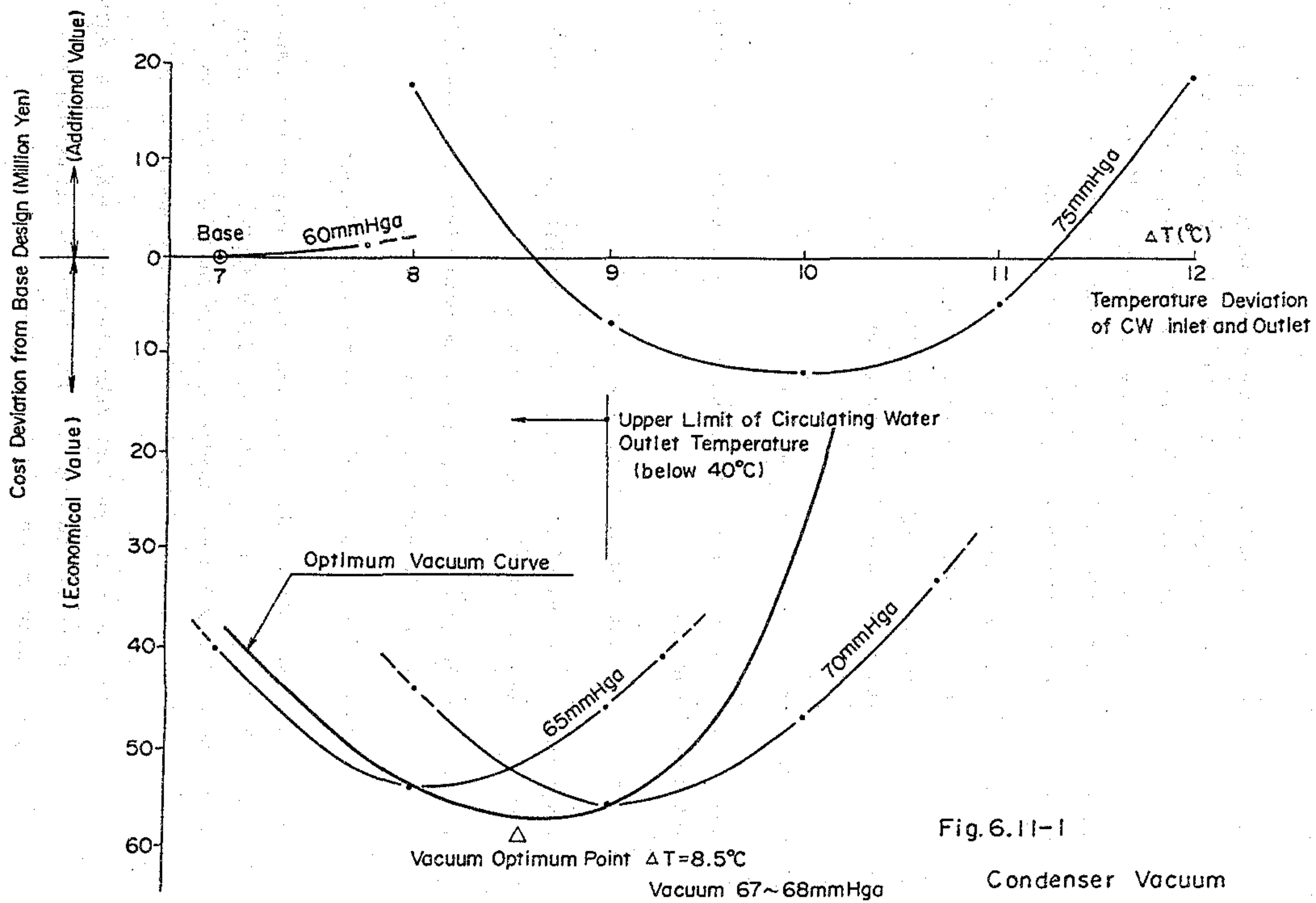



Fig.6.11-1

Condenser Vacuum Optimum Curve