Malitbog Geothermal Power Plant, Leyte, Philippines

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1. Introduction

In the Philippines, the development of geothermal electric power has been strongly promoted to enforce the effective utilization of "pure domestic" energy after the oil shock of the 1980s. The 3 × 37.5MW geothermal power plant, delivered by Fuji Electric in 1983 to the Palimpinon Geothermal Power Plant, National Power Cooperation of Philippines (NPC), has operated smoothly.

In the latter half of the 1980s, the development of electric power stagnated due to various domestic situations. However, it has been promoted again according to the domestic policies of the 1990s. Fuji Electric received an order for 4 × 20MW geothermal power plants from NPC to expand the Palimpinon Geothermal Power Plant. These plants, which were put into commercial operation as of December 1993, have helped solve the shortage of electric power in the Philippines.

In addition, Fuji Electric received an order in March 1993 for a geothermal power plant with a total output of 232.5 MW (3 × 77.5MW at the generator terminals), from the Visayas Geothermal Power Company (VGPC) for the Leyte Island facility in the Philippines. At present, we have completed the production of unit No.1 and are assembling it on site.

This paper will present a summary of this power plant.

2. Summary of the Project

This plant is delivered for the Malitbog Geothermal Power Plant which is about 25 km north from Ormoc city, of Leyte Island. Leyte Island is located approximately 530 km southeast from Manila.

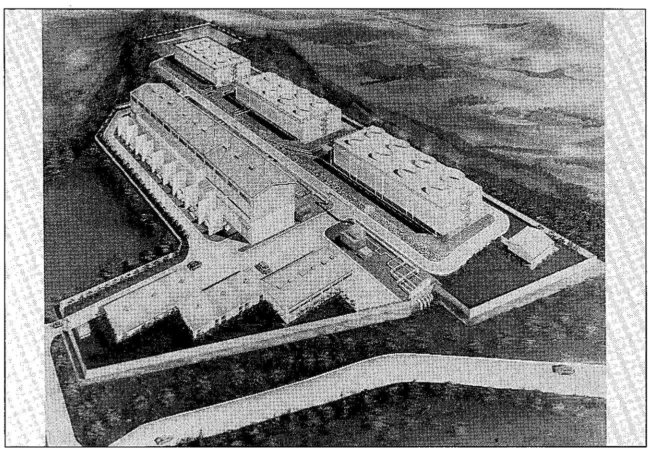
On Leyte Island, in addition to this Malitbog Geothermal Power Plant, the Upper Mahiao Geothermal Power Plant (total output 130 MW), Mahanagudong Geothermal Power Plant (total output 180 MW) and Altopeak Geothermal Power Plant (output approx. 70 MW) are currently under construction. Power plants having a total output of approximately 610 MW are planned to be completed between 1996 and 1977.

The contract for the Malitbog Geothermal Power Plant is a BOT (Build, Operate and Transfer) contract. VGPC will construct the power plant, operate it for 10 years, and then transfer it to the Philippine National Oil-Energy Development Corporation (PNOC). Fuji Electric, with Sumitomo Corporation as a main contractor, has received an order for the entire plant with a full turnkey contract that includes civil engineering and construction.

The main power equipment consists of 3 × 77.5MW geothermal steam turbines, the largest class of single-cylinder type turbines in the world. Low pressure blades of 658 mm (29.9 inches), the largest class in the world, are used in the last stage. Direct contact low level condensers of the jet-spray type, for which Fuji Electric is most experienced, are utilized. These facilitate a compact equipment layout. Barrel type vertical centrifugal pumps of 1,800 mm/1,050 mm caliber, the largest class in the world, are used as hotwell pumps to extract the turbine condensate that is mixed with cooling water.

Air-cooled 3-phase synchronous generators are used. Generated electric power from the generators are supplied through 13.8/230 kV main transformers to a 230 kV substation constructed by PNOC. Further, this electric power is transmitted along with power generated by other geothermal power plants through sub-

Fig.1 Prospective view of Maltibog Geotharmal Power Plant



marine cables to Luzon Island and Cebu Island, the main regions of electric power consumption in the Philippines.

A distributed control system (DCS) is used in the control and monitoring equipment. Main monitoring items are transmitted to a marshaling station in Leyte Island. This Malitbog Geothermal Power Plant will begin commercial operation of unit No.1 in June 1996, and units No.2 and 3 in June 1997.

A prospective view of the Malitbog Geothermal Power Plant is shown in Fig. 1.

3. Power Plant Plan

3.1 Heat cycle

Based upon an analysis of hot water characteristics and economic and maintenance considerations, single flush system is utilized in geothermal wells of liquid dominated type. The geothermal fluid emitted from the geothermal wells is separated in to steam and hot water by a separator. Only the steam is sent to a turbine. The remaining hot water is re-injected underground with re-injecting pumps.

3.2 Main piping diagram

Figure 2 shows the main piping diagram. Features of this system are that three hot well pumps and ejectors of 50% capacity are provided, and that the cooling tower has a spare cell. These features are utilized to avoid plant shut downs as much as possible since the customer has a BOT contract. Dual seal valves, steam scrubbers, etc. are also provided in the main steam piping for the same consideration.

3.3 Layout

Figure 3 shows the overall layout and Fig. 4 shows the layout of the turbine-generator building. From the west side of the site in this power station, the cooling towers, outdoor auxiliary equipment, turbine-generator building and transformers are located, an H_2S abate-

Fig.2 Main piping diagram

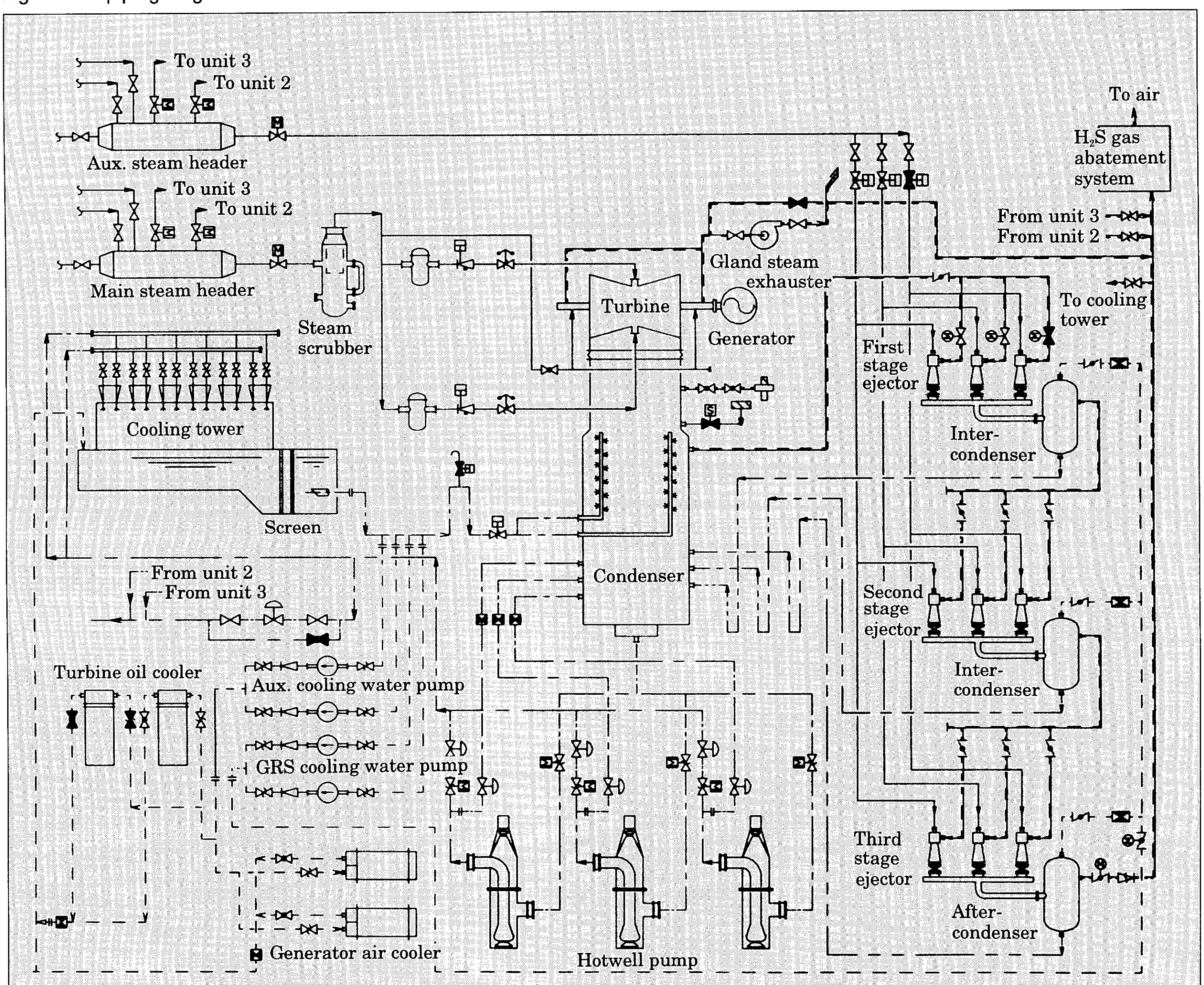
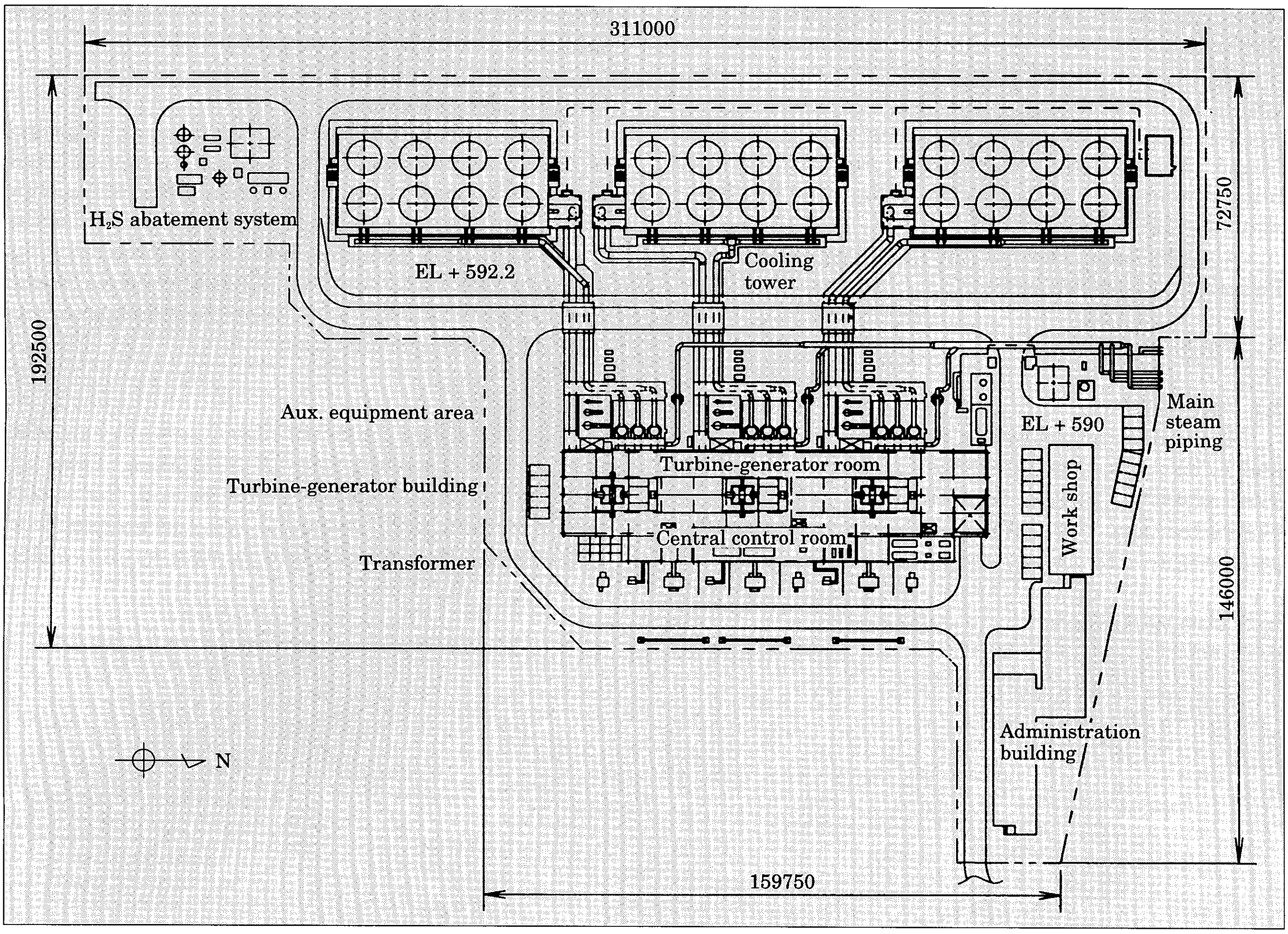


Fig.3 Overall layout



ment system is provided on the south side of the cooling towers, and a workshop and administration building are located north of the turbine-generator building. The total area of the site is about 40,000 m^2. A substation , not supplied by Fuji Electric, is located on the neighboring east side site.

The turbines, generators and a control room are located on the operating floor (the third floor), an electrical room and oil console are on the mezzanine floor, and the condensers, an electrical room and emergency diesel generators are located on the first floor.

4. Turbine and Auxiliary Equipment

4.1 Features

Fifteen years have passed since Fuji Electric delivered a steam turbine-generator to a geothermal power plant in El Salvador. Since that time, we have delivered many geothermal turbine-generators to the USA, the Philippines, etc. All of these have operated satisfactorily. In this plant, single-cylinder, double-flow, condensing turbines with low pressure blades 658 mm (25.9 inches) in diameter have been utilized. These are Fuji Electric's largest capacity geothermal turbines.

In addition to a drum type rotor, reaction type blading, high pressure blades with an integral shroud and free-standing low pressure blades, all atandard features in Fuji Electric's geothermal turbines, a skid type oil console mounted main oil tank, oil pumps, lubricating filters and blowers are utilized. For details of this turbine, refer to "Progress of Geothermal Steam Turbine Technology".

4.2 Specifications of the turbine

The main specifications of this turbine are as follows. Figure 5 shows the exterior view of this turbine.

Type: Single-cylinder, double-flow, condensing turbine

Output: (Rating) 77,500 kW

Steam conditions Pressure: 10.5 kg/cm^2 abs {10.29 bar}

Temperature: 182.6℃

Exhaust pressure: 0.12 kg/cm^2 abs (0.1176 bar)

Gas contents: 2% (max.)

Rotating speed: 3,600 r/min

No. of stages: 2 × 8 stages

Fig.4 Layout of turbine-generator building

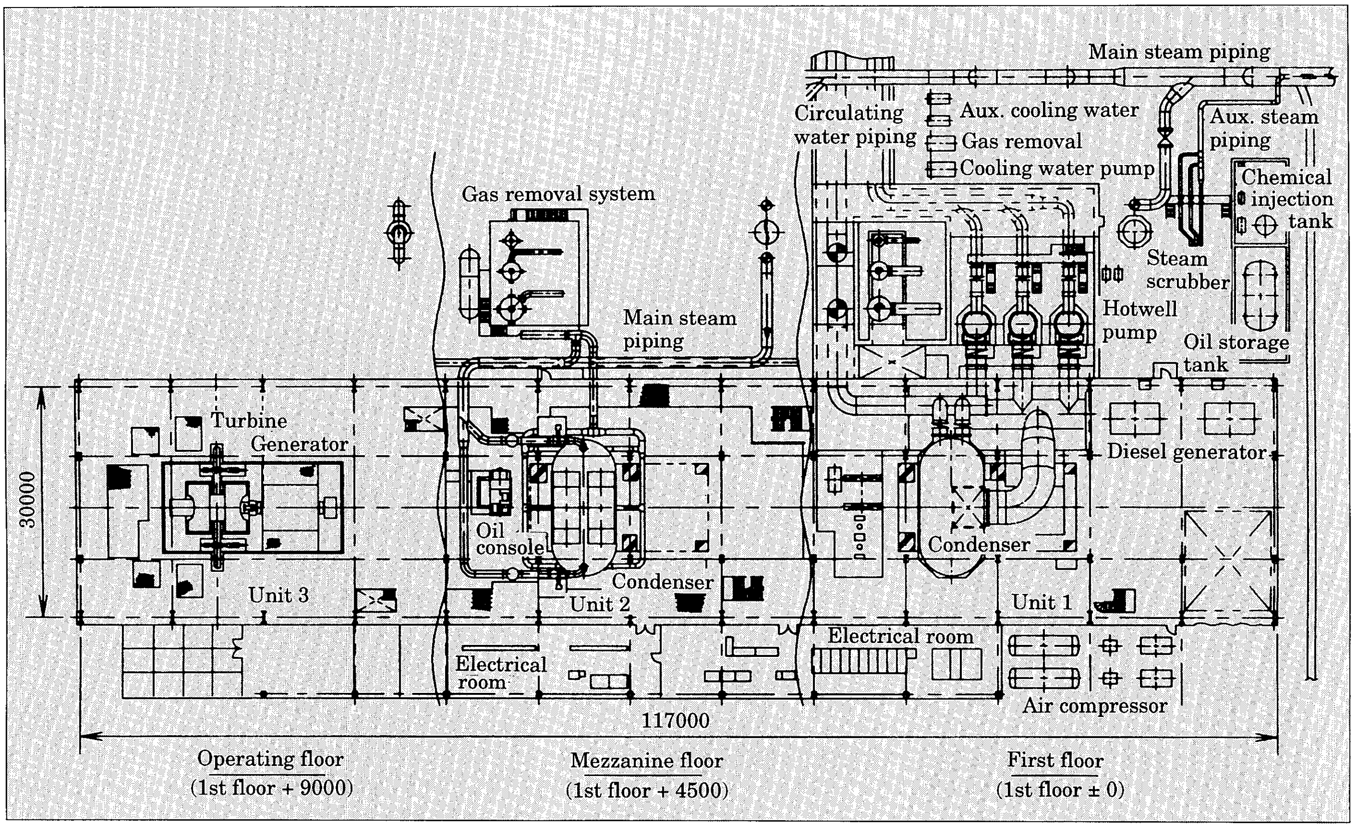


Fig.5 Exterior view of turbine

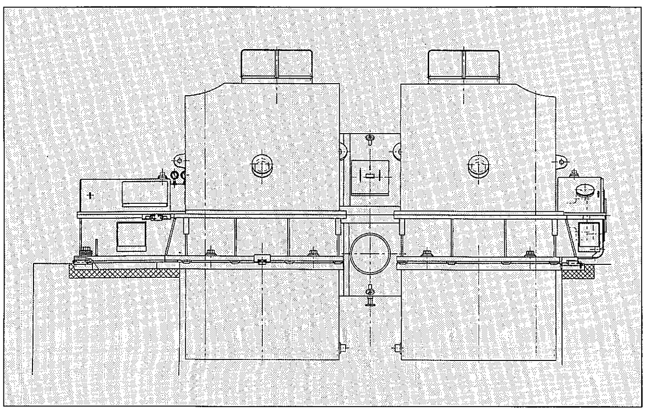
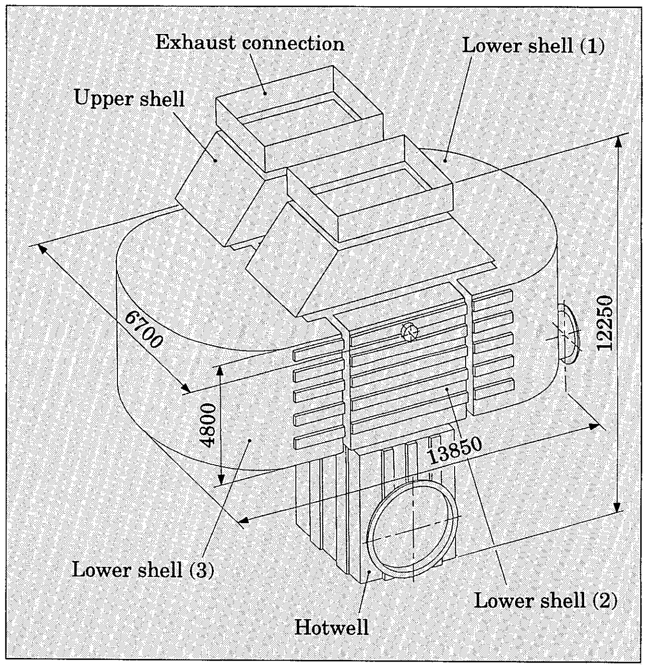


Fig.6 Separated section of condenser



5. Condenser and Gas Removal System

5.1 Condenser

Direct contact low level type condensers were utilized due to their history of success. The external dimensions of the condenser are 14.0 m (L) × 7.0 m (W) × 12.5 (H). After pre-assembly at the factory, this condenser was transported to the job site in 8 pieces as shown in Fig. 6. The condenser consists of shell plates of stainless clad steel and internal parts of stainless steel, to prevent corrosion. Since the condenser body is in an oval shape that combines cylindrical and plain sheets to withstand the vacuum force, only a few reinforcements are necessary for it to become firm. The main specifications of the condenser are as follows.

Outlet steam: 502.1 t/h

Internal pressure: 0.12 kg/cm^2 abs {0.1176 bar}

Cooling water flow: 20,600 m^3/h

Cooling water inlet temperature: 32.5℃

5.2 Gas removal system

Steam jet ejectors are utilized in the gas removal system because of their handling ease and trouble free operation resulting from a simple structure with no moving parts. The composition of ejector system is in three-stages of 50% × 3 train to efficiently operate even with variations in the gas flow.

The ejectors, inter-condensers, after-condenser and their interconnecting piping are adopted with stainless steel (SUS316L) to have corrosion resistance. To simplify the piping, the three condensers are not arranged in 3 trains, but in one of 150% capacity for the ejector configuration of 50% × 3 trains.

The main specifications of the gas removal system are as follows.

Type: Steam jet ejector with direct contact type condenser
Extraction gas flow: 9,127 kg/h
Driving steam flow: 9,321 kg/h
Cooling water flow: 1,409 m^3/h

6. Mechanical Equipment

In this project, various mechanical equipment is utilized. However, only that equipment which we are using for the first time or which has special features will be described.

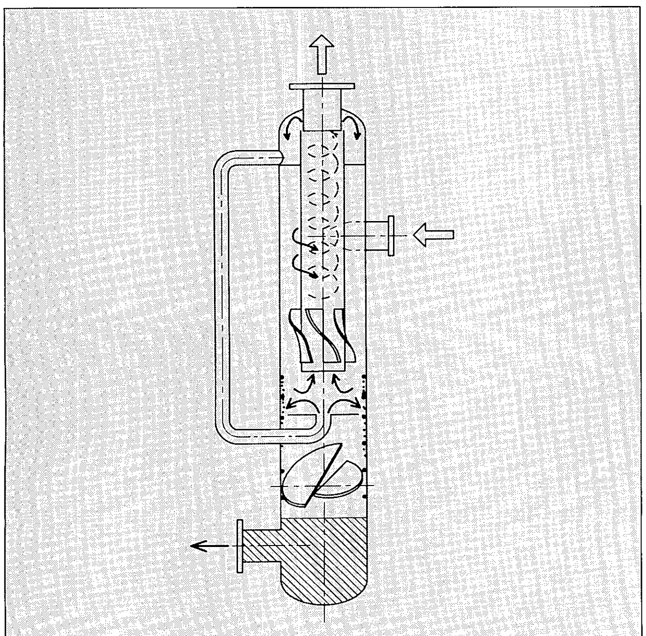
6.1 Steam scrubber

Vane type demisters have been utilized in prior geothermal power stations to remove the moisture up to 2-3% in steam. However, recycling type scrubbers are utilized in this project. These scrubbers can eliminate 99.9% or more moisture, even when the moisture content in steam is approximately 25%. If many foreign particles are included in the steam, these scrubbers can scrub the foreign particles by injecting water on the inlet side. The main specifications of the scrubber are as follows.

Capacity: 508 t/h
Allowable moisture contents (inlet): 25% or less
(outlet): 0.1% or less
Allowable pressure drop : 0.1 kg/cm^2 {0.098 bar} or less
Dimensions: ϕ 2,300 mm × 12,000 mm (H)

Figure 7 shows the exterior view of steam scrubber.

Fig.7 Exterior view of steam scrubber



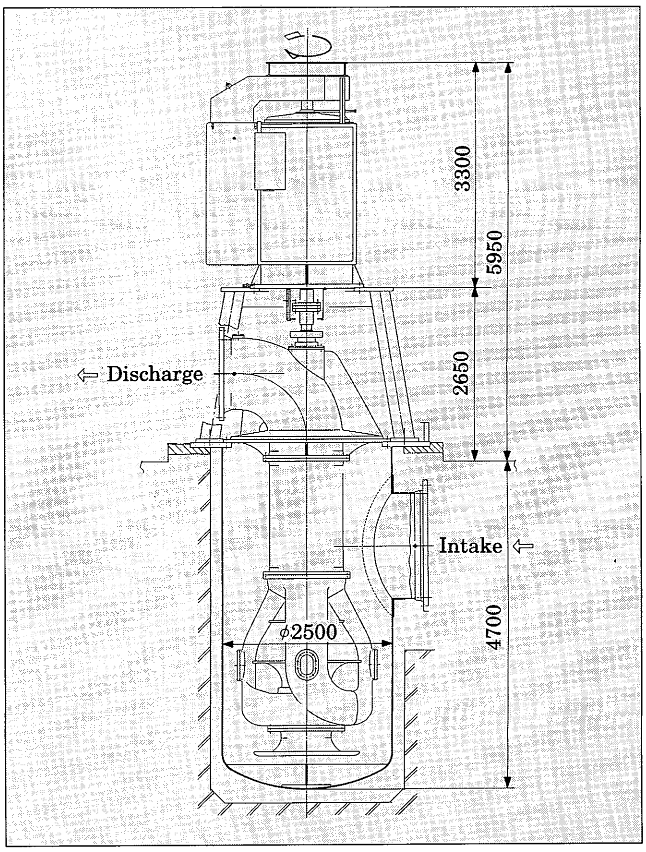
6.2 Hotwell pump

The steam cooled in the condenser is mixed with cooling water and becomes condensate-water. It is then introduced into a cooling tower by hotwell pumps.

A single pump at 100% capacity or two pumps at 50% capacity have been used in prior geothermal plants. However, since this is a BOT project, the full operational term of the plant should be as long as possible and the invested funds should be recovered early on. Therefore, three pumps of 50% capacity are provided. This increases the number of operation modes such as start up, stop and changeover. The operation of each made can be verified in advance by simulation. The main specifications of the hotwell pump are as follows.

Type: Double suction vertical centrifugal pump

Fig.8 Cross section of hotwell pump



with barrel

Capacity: 11,300 m^3/h

Total head: 26 m

Motor rated output: 1,000 kW

A cross section of a hotwell pump is shown in Fig. 8.

6.3 Cooling tower

The cooling tower in the geothermal field have been using cross flow type with splash fill to prevent lowering the efficiency due to clogging of foreign particles. However, in this project, a counter flow type with film fill is utilized to reduce the parasitic load. This caused a new problem of clogging, which was resolved by using a new type film which is clog resistant, installing a film weight monitor and providing a spare cell. The main specifications of the cooling tower are as follows.

Type: Induced draft counter flow type

Water flow: 22,500 m^3/h

Wet bulb temperature: 25.5℃

Cooling water temperature (inlet) : 44.6℃

(outlet): 31.5℃

No. of cells: 8 (including 1 spare cell)

6.4 H_2S abatement system

Steam spouted from the ground at a geothermal power plant generally includes a few hydrogen sulfides. Until now, in geothermal plants delivered to the Philippine, gases including hydrogen sulfide, were extracted from the condenser by a gas removal system, and directly discharged into the air. However, the Philippines a regulation related to air pollution was revised in September 1994, to restrict the amount of hydrogen sulfide discharge. Therefore an H_2S abatement system has been provided in this project.

The principle of this system is to decompose hydrogen sulfide using on oxidation reaction (absorption) and a deoxidization reaction (regeneration) of ferric ions and ferrous ions, and to separate the sulfur. These reactions are described as below.

Absorption reaction:

$$H_2S\,(gas) + 2Fe^{+++} \rightarrow 2H^{+} + S^{0} + 2Fe^{++}$$

Regeneration reaction:

$$\frac{1}{2}O_2\,(gas) + H_2O + 2Fe^{++} \rightarrow 2OH^{-} + 2Fe^{+++}$$

The main specifications of the H_2S abatement system are as follows.

Total gas flow : 19,541 kg/h

Fig.9 Single line connection diagram

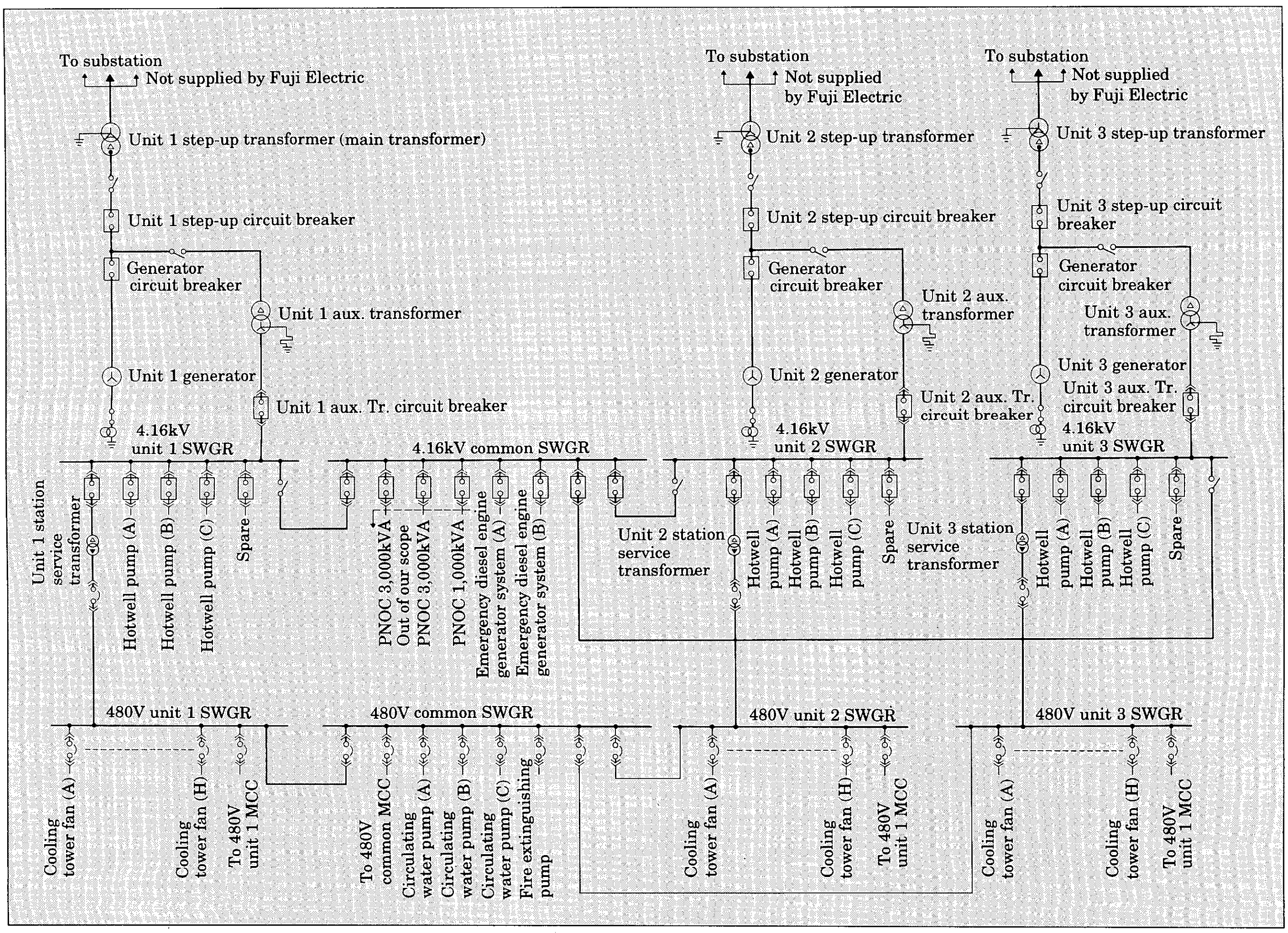
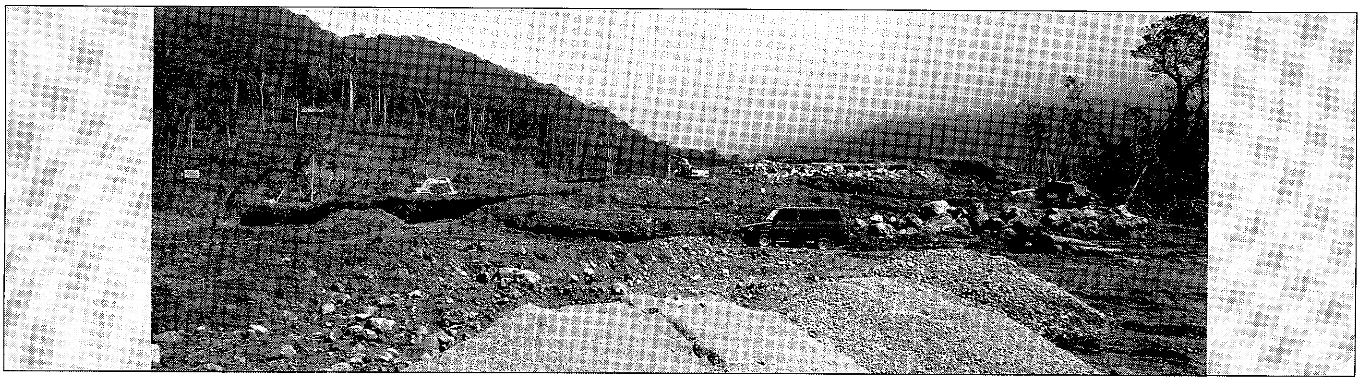


Fig.10 Grading of plant site



H_2S flow : 185.61 kg/h
Efficiency : 82%
Product sulfur: 3.4 t/d (Theoretical value)

7. Electrical, Instrumentation and Control systems

7.1 Electrical system

The electrical system of this plant is shown in Fig. 9. The generated electric power is boosted to 230 kV with the main transformers and sent to an outside system. The power is also supplied to unit circuits after being reduced down to 4.16 kV (originally, 13.8 kV) with unit transformers.

The specifications of main electrical equipment are shown as follows.

(1) Generators
Type : Horizontal, cylindrical, totally enclosed, air-cooled type
Capacity : 94,100 kVA
Voltage : 13.8 kV
Power factor: 0.824
Frequency : 60 Hz

(2) Transformers
(a) Main transformers
Capacity: 92 MVA
Voltage : 13.8 kV/230 kV
(b) Unit transformers
Capacity: 11.2 MVA
Voltage : 13.8 kV/4.16 kV
(c) Low voltage power transformers
Capacity: 3 MVA
Voltage : 4.16 kV/480 V
(3) Emergency diesel power-generating equipment
Rated capacity: 3,400 kW
Rated voltage : 4.16 kV

7.2 Instrumentation and control systems

This plant utilizes DCS to monitor and execute all operations through 3 CRTs. In this system, equipment such as control devices, man-machine interfaces (MMI) and transmission devices are duplicated, and made highly reliable. Moreover, even if both systems duplicated by DCS breakdown, it is possible to operate each piece of equipment from a panel installed in the main control room or from site panels.

Table 1 Construction work

Item	Turbine-generator building	Administration building and work shop
Building structure	Structural steel	Structural steel
Building area (m^2)	3,278	1,440
Total floor area (m^2)	7,200	1,440
Building volume (m^3)	71,539	8,640
Floors	3	1
Roof height (m)	GL + 23.5	GL + 6.0
Foundation	Turbine-generator building Self-standing footing + Under ground beam Foundation thickness: 1.2m Turbine-generator foundation Mat foundation Foundation thickness: 4.0m	Self-standing footin + Underground beam Foundation thickness: 0.3m

8. Civil Engineering, Construction Work and Ancillary Equipment

8.1 Civil engineering and construction work

Since there is a full turnkey contract for this project, the civil engineering work has a wide scope, from soil boring at the planned location of the power plant to grading and excavation. The altitude of the power station is selected to be 590 m above sea level based on the drilling survey. In this case, approximately 47,000m^3 of soil was removed. Figure 10 shows the grading of the plant site.

Construction work consists of a turbine-generator building, an administration building and a work shop. The main specifications are shown in Table 1.

8.2 Ancillary equipment

Only main equipment will be described.

8.2.1 Air conditioning system

Air conditioning system is divided into the following 3 systems.

(1) Air conditioning system for the central control room
(2) Air conditioning system for the electrical room
(3) Air conditioning system for the administration building

All the air sent into the central control room and electrical room is cleaned with charcoal filters to protect electrical and control devices in those rooms. However, in the administration building, normal package type air conditioners are used since this building is separated from the power plant and does not contain electrical devices.

8.2.2 Fire protection system

The fire protection system consists of following items.

(1) Water spray fire protection system
   Protects: Main oil tank, diesel generators, main transformers, oil storage tank and cooling towers
(2) Water hydrants
(3) CO_2 gas fire protection
   Protects: Main oil tank, oil storage tank, electrical room, bartery room, central control room and computer room
(4) Fire alarm system
(5) Fire pump system
   (a) Fire pump (motor driven) 1 set
      Total head: 5.3 kg/cm^2 {5.19 bar}
      Capacity : 500 m^3/h
   (b) Fire pump (diesel driven) 1 set
      Total head: 7.73 kg/cm^2 {7.575 bar}
      Capacity : 568 m^3/h
   (a) Jockey pump (motor driven) 1 set
      Total head: 8.44 kg/cm^2 {8.271 bar}
      Capacity : 4.89 m^3/h

8.2.3 Overhead travelling crane

An overhead travelling crane uses a pendant style mechanism in order to move on the operating floor in the turbine-generator room. There are two different lifting and travelling speeds to facilitate installation and disassembly.

The main specifications of the crane are as follows.

Type : Overhead cabtyre supply type travelling crane
Capacity: 40/8 t
Span : 21.5 m

The other ancillary equipment consists of the following.

(1) Sanitation system
(2) Outdoor lighting system
(3) Lighting system
(4) Service water system

9. Miscellaneous Equipment

Miscellaneous equipment consists of the following.

(1) Auxiliary cooling water pump
   Total head: 18.9 m
   Capacity : 450 m^3/h
(2) Gas removal system cooling water pump
   Total head: 7.5 m
   Capacity : 15,500 m^3/h
(3) Air compressor system
(4) Potable water system
(5) Lube oil storage system
(6) Chemical injection system
(7) Chemical laboratory
(8) Machine shop equipment

10. Conclusion

A summery of the power generating plant delivered to the Malitobog Geothermal Power Station of the Visayas Geothermal Power Company was presented. Because of the support from the companies and engineers concerned with this project, we are able to report that, at present, construction of this power plant is progressing according to schedule. We thank all concerned parties for their effort.