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GEOTHERMAL BINARY POWER GENERATION SYSTEM

Keio Ura and Shojirou Saitou
Mitsubishi Heavy Industries, LTD
Nagasaki Shipyard Machinery Works
1-1 Akunoura-machi , Nagasaki , Japan

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1.Introduction

In utilization of geothermal resources in Japan, high temperature geothermal resources have been used for power generation but intermediate and low temperature geothermal resources which are widely distributed in Japan are mostly left unused, only a part of which is directly used for some purposes such as bath and heating.

In consideration of such a situation, New Energy and Industrial Technology Development Organization in Japan (NEDO) started a project to generate electric power by utilizing the low level geothermal resources with a binary power generating system and the function of Mitsubishi Heavy Industries was to engineer, manufacture, and supply all major equipment for power generation.

The results of the project were verified with a 500 kw class pilot plant which was built in Takigami in Oita Prefecture in February 1997 and operated for one year.

In Takigami area, there is one 25 MW geothermal power plant , which is owned operated by Kyusyu Electric Power Corporation.

And there are many production and injection wells for the 25MW power generation.

The binary power plant utilized the hot water from the separater which had been injected.

This paper introduces the system, specification of main equipment and operating results of the pilot plant.

2. System Outline

2.1 System Specification

1) Operating medium	: FREON HCFC-123
2) Hot water inlet flow	: 200 t/h
3) Hot water inlet temp.	: 130 °C
4) Hot water outlet temp.	: 106 °C
5) Generator end output	: 490 kw
6) Auxiliary power	: 90 kw
7) Net output	: 400 kw
8) Transmission voltage	: 3,300 v
9) Cooling water temp.	: 22 °C
10) Cooling water flow	: 230 t/h

2.2 System

The system is shown in Fig-1.

Hot water of 200 t/h x 130°C is led into the pre-heater & evaporator. In those heat exchangers, freon receives the heat energy from hot water and 47 °C of freon liquid changes into freon steam (104 °C x 860 kpa abs.). Freon steam is led into the turbine, rotates the generator and generates power. Freon steam discharged from the turbine is led into the condenser, where it is cooled and returns to freon liquid of 47°C.

2.3 Selection of working fluid

Selection of a working fluid is an important task in designing a system. So freon HCFC-123 was selected from many candidate medium after studying the following conditions.

1) The thermal characteristics required for a binary system are satisfied.
2) Adverse effects on environments are less.
3) Adverse effects on human body are less.
4) Handling is easy (non-inflammable and non-explosive).
5) Properties are stable.

2.4 General Arrangement of System

General arrangement is shown in Fig-2 and Photo-1,-2.

Each equipment of the system is arranged compact for space saving.

There are electrical panels and data loggers in the control room.

3. Specification of Main Equipment

3.1 Turbine

Outline drawing and sectional drawing of the turbine are shown in Fig-3,-4, respectively and related photographs are shown in Photo-3,-4.

Freon steam of 860 kps abs. x 104°C leaving the evaporator is led into the turbine and exhausted into the condenser after it work in the turbine.

The turbine is of a radial flow type which is high in efficiency though small in heat drop and capacity and the reduction gear is provided between the turbine and the generator.

The turbine impeller is of a single stage with 395 mm diameter and rotates at 6,790 rpm. The impeller is attached to an end of the pinion and pinion and wheel are supported by sleeve bearings.

Lubricating oil is supplied to the bearings and the reduction gear by an AC motor driven pump.

Turbine, reduction gear and generator are mounted compact on a common bed with an oil tank built in.

A mechanical seal is provided at turbine gland to prevent the medium from leaking out.

An induction generator was applied to the pilot plant.

The turbine speed shall be manually controlled because of induction generator and no speed governor , and so simplification of the speed control system contribute to the economy (cost reduction) of the plant.

Overspeed protection device is provided to stop the turbine safety when turbine speed reaches more than 10% of the rated speed. When this device operates, the control valve and main stop valve which are provided at turbine inlet close quickly and stop the turbine.

At a failure of AC motor driven oil pump or at power failure, lubricating oil is supplied to each bearing of the turbine from the head tank provided on the top of the control room to prevent damage to the equipment.

3.2 Generator

An induction generator was used to the pilot plant.

As compared with a synchronous generator, an induction generator is less expensive because it does not require DC excitor system interconnection protective relay, and automatic cycle detecting equipment.

An induction generator cannot be operated independently when separated from the system and the type of generator shall be selected based on the electrical system condition.

The generator is rotated at 1800 rpm by the turbine via reduction gear and generates 490 kW and generator terminal voltage is 440v.

The electric power generated is transmitted to 3,300 V system via a transformer.

3.3 Pre-heater and Evaporator

The pre-heater and evaporator is of horizontal shell and tube type and these are contained in one shell to achieve a compact design.

Hot water passes through the tubes inside and considerations given to facilitate removal of scales.

Low fin tubes are used to improve heat conductivity.

Floating tube plate type is used so that the tubes can expand and contract freely. Tubes made of stainless steel (SUS304L) are used to prevent corrosion and the shell is made of carbon steel.

Construction and appearance of the pre-heater and evaporator are shown in Fig-5.

3.4 Condenser

The condenser is also of a horizontal shell and tube type as the pre-heater and evaporator is.

Circulating water cooled in the cooling tower is used for cooling and passes through the tubes inside.

The tubes are made of Al-Cu alloy and the shell is made of carbon steel.

Construction and appearance of the condenser are shown in Fig-6.

3.5 Cooling Tower

The cooling tower is of 3-cell cross-flow type.

Cooling capacity is 19,259,000 kj/h x 230 m^3/h and river water is used as make-up water. Construction and appearance of the cooling tower are shown in Fig-7.

3.6 Freon Feed Pump

The freon feed pump is of non-seal type which permits no leakage to outside.

Bearings are of self-lubricating type by freon liquid and made of carbon graphite.

4. Operating Results of Pilot Plant

The pilot plant was operated for one year from March 1, 1997 to February 28, 1998, during which time verification was made on plant performance, turbine and heat exchanger performance and reliability of each equipment.

4.1 Plant and Turbine Performance

Plant and turbine performance test was conducted at the end of each month.

Each performance showed a good result exceeding the design value as follows.

		Design	Result
1) Generator output	kw	490	490
2)Aux. power	kw	90	90
3)Hot water flow	t/h	200	200.51
4)Hot water inlet temp.	°C	130	129.7
5)Hot water outlet temp.	°C	106	107.0
6)Plant efficiency (Gross Output Base)	%	8.78	9.26
7)Plant efficiency (Net Output Base)	%	7.17	7.56

Monthly changes in performance are shown Fig-8.

Gross output basis plant efficiency was in a range from 9.13 to 9.44% in the first 8 months after start of operation but fell slightly to 8.88 to 9.11% in the following 4 months. The probable cause is a decrease in heat transmission co-efficient of the condenser.

As the result of overhaul carried out after the operation, a considerable amount of slime in cooling water was found deposited on the condenser cooling tube inside and the probable cause was substantiated.

4.2 Plant Availability

During the one-year operation, the pilot plant achieved 98.3 % availability while showing a good performance exceeding the design value as mentioned above and demonstrated a high reliability.

4.3 Results of Overhaul Inspection

An overhaul inspection of each equipment was conducted after the one-year operation and salient points of the results are as follows.

1) Mechanical Seal at Turbine Gland

As the result of the overhaul, O-ring used for the mechanical seal was found deteriorated. It was considered that 104°C freon steam was too severe for the O-ring made of chloroprene rubber.

So it was decided to change the material to PFA resin or an equivalent material.

2) Freon Feed Pump

Non-seal type freon feed pump was adopted to prevent freon from leaking out of the system. Bearings made of carbon graphite which were used for the pump were found worn out after the one year operation.

So it was decided to change the pump to a high reliability centrifugal pump with mechanical seal.

3) Pre-heater and Evaporator

Slight scales due to impurities in hot water were found on the heating tubes inside but no other unusual conditions were found. The scales were removed by jet water washing.

4) Condenser

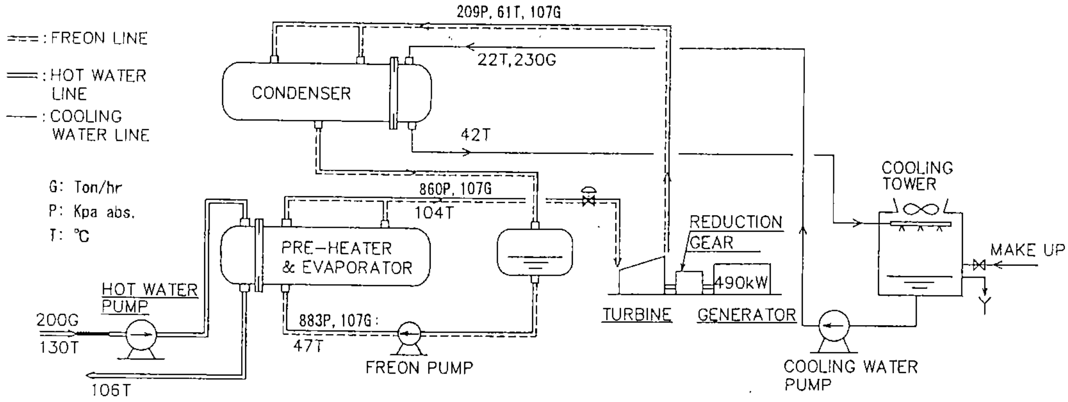
A considerable amount of slime in the cooling water was found deposited on cooling tube inside. The slime was removed jet water washing. No other unusual conditions were found.

5. Conclusion

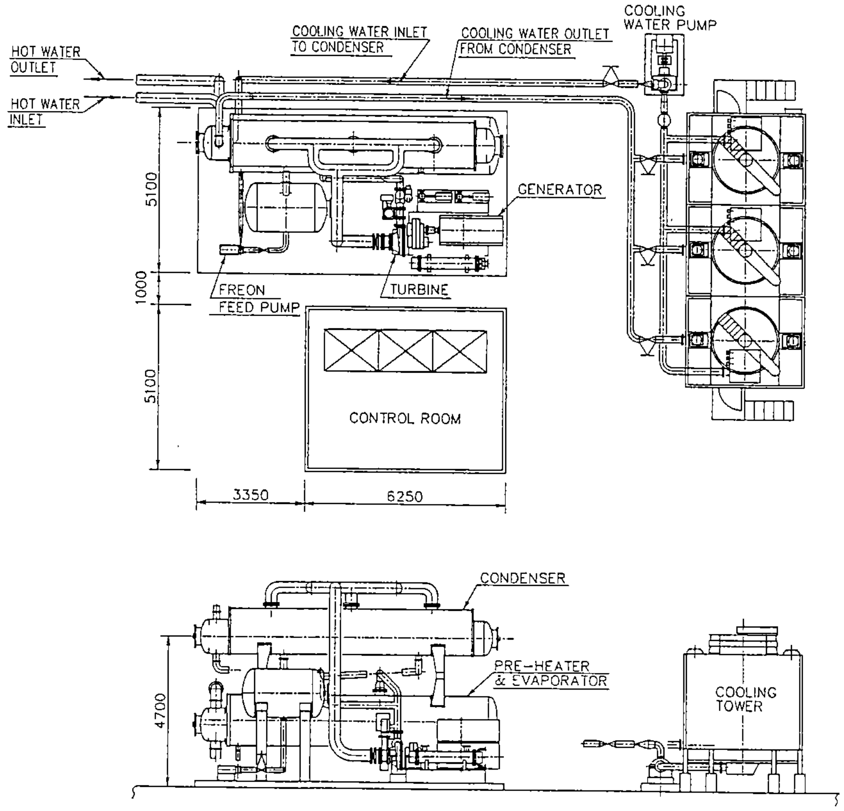
Although minor problem were experienced, the one year operation of the pilot plant demonstrated high availability (98.3% availability factor) and reliability of the binary power generation system.

Causes of the troubles have been investigated and fully reliable remedial measures have been worked out, so there is no problem in manufacturing production plants and we believe that this system can fully meet the needs of the users.

This system can be used not only for recovering geothermal energy but also for power generation by recovery of industrial waste heat and is expected to make a great contribution to prevent global warming and energy saving as a power generating system which does not emit CO_2 at all.



FIG–1 FLOW DIAGRAM



FIG–2 GENERAL ARRANGEMENT

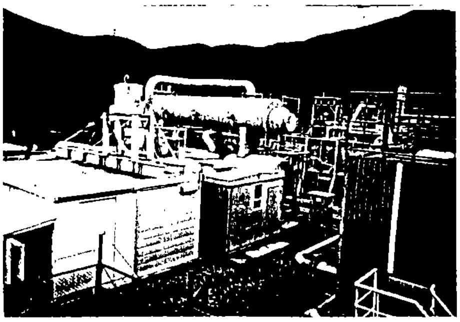


Photo – 1 SYSTEM OUTWARD

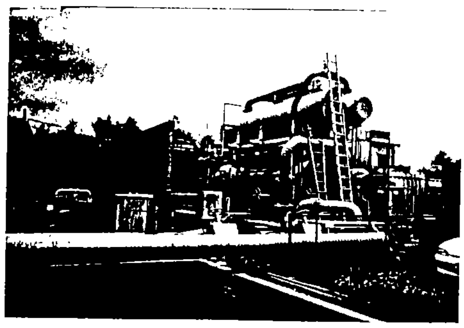


Photo – 2 SYSTEM OUTWARD

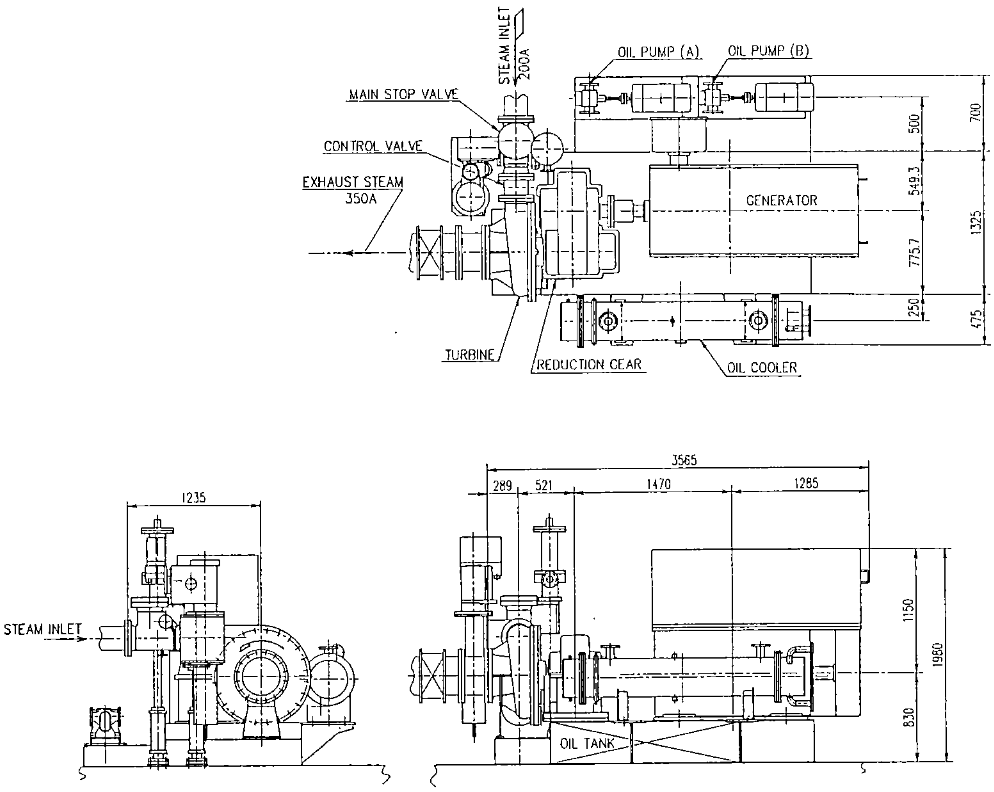
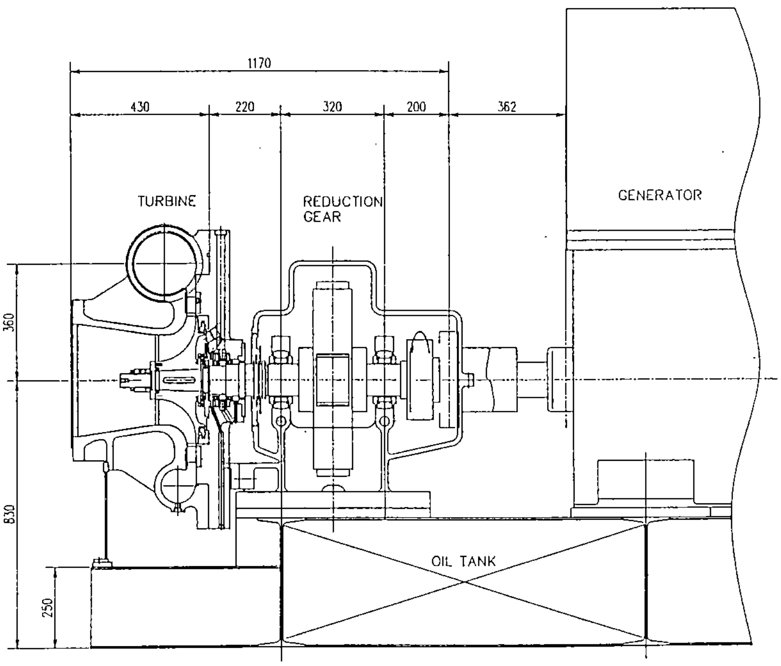


FIG-3 TURBINE OUTLINE



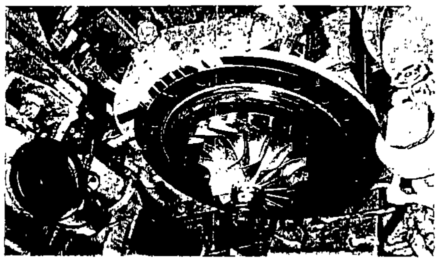


Photo - 3 TURBINE INSIDE

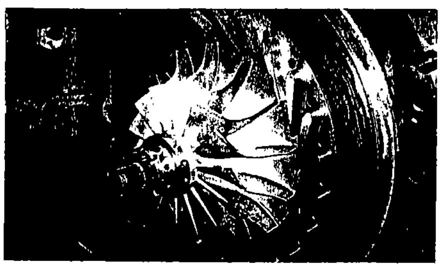


Photo - 4 TURBINE IMPELLER & NOZZLE

FIG-4 TURBINE SECTIONAL ASSEMBLY

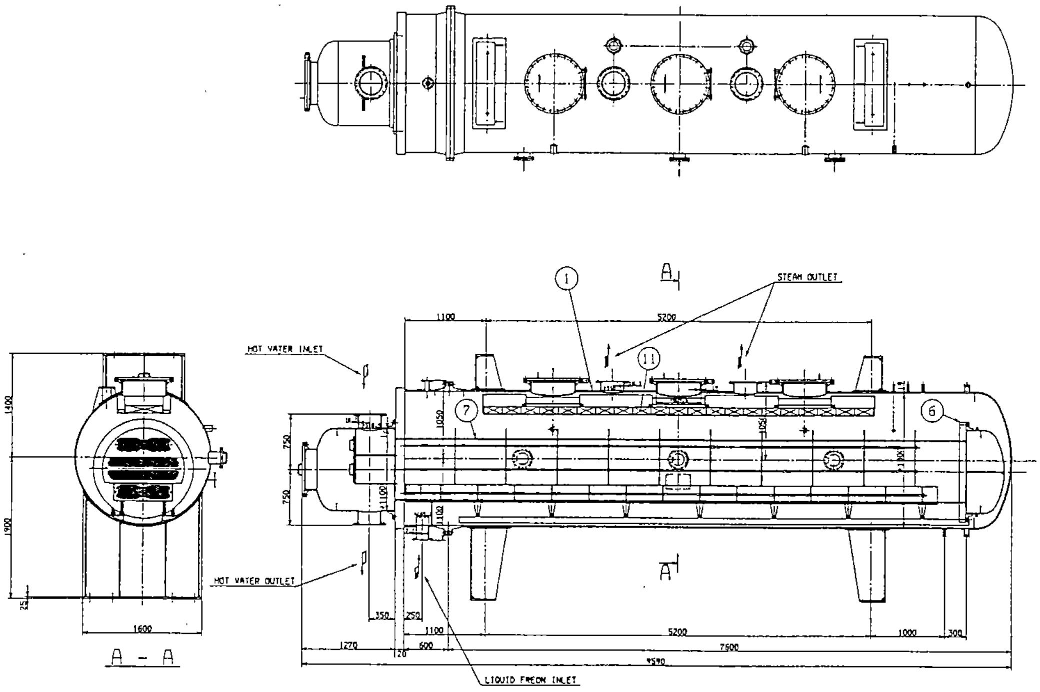


FIG - 5 PRE-HEATER & EVAPORATOR

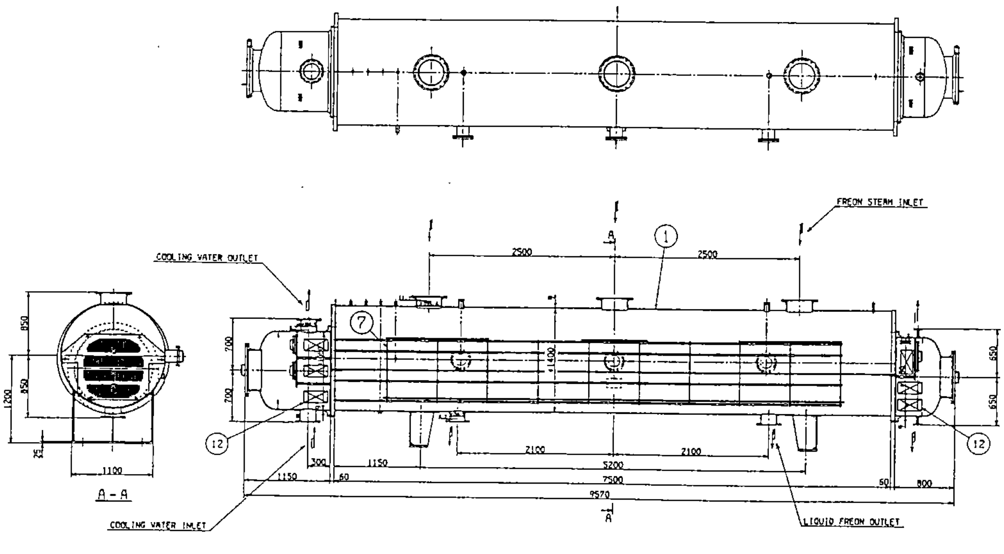


FIG - 6 CONDENSER

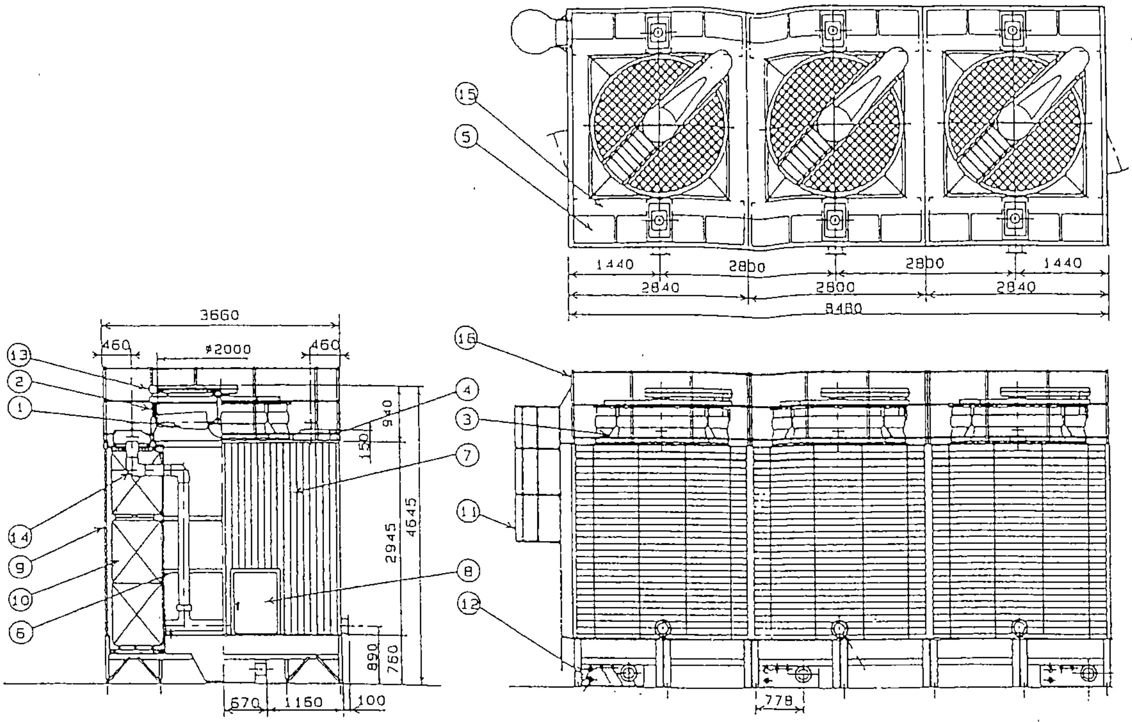


FIG - 7 COOLING TOWER

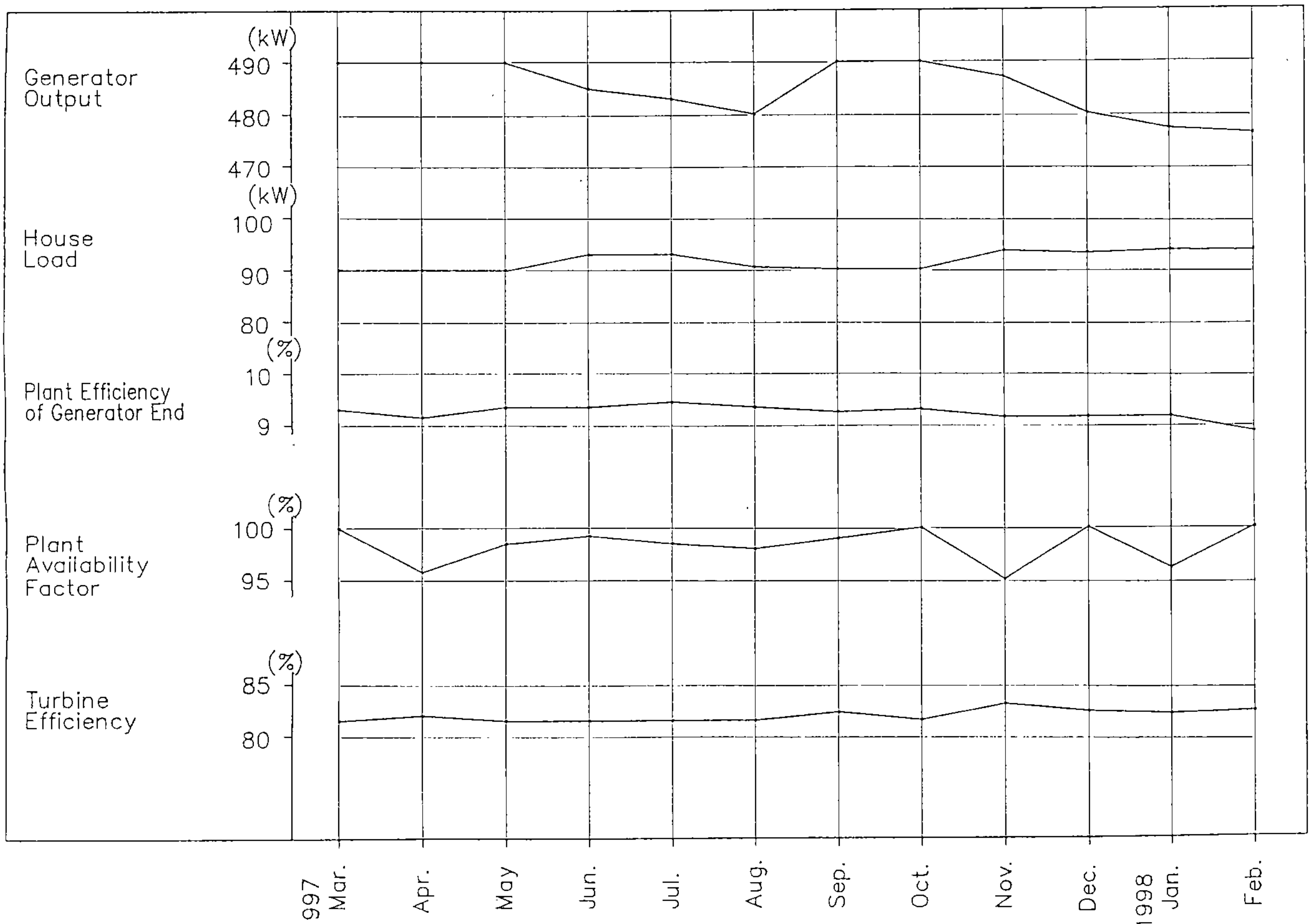


FIG-8 Operation Result