AN EXAMPLE OF RAPID UTILIZATION OF GEOTHERMAL ENERGY

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ABSTRACT

The first commercial geothermal electric power plant in the Republic of the Philippines was commissioned in July 1977 on the island of byte.

Steam for the power plant is supplied by the first deep exploration well drilled into the Mahiao Reservoir of the Tongonan geothermal field. Drilling of well 401 commenced in October 1976 and was completed in January 1977. The installation of the power plant commenced in Hay 1977 and was inaugurated by Imelda Marcos the First Lady of the Republic of the Philippines on 21 July 1977.

INTRODUCTION

The first commercial geothermal electric power plant in the Philippines was commissioned in July 1917 and is sited on the Tongonan geothermal field.

The turbine-generator is installed in a power Rouse designed and constructed by the National Power Corporation (NPC). Twenty kilometers of transmission line constructed by the NPC supply power to the electrical supply franchise holder of the nearby city of Ormoc. A branch transmission line provides electricity for the project camp.

Steam is conveyed to the power house stop valve by a pipeline and wellhead system constructed by the Philippine National Oil Company - Energy Development Corporation (EDC). The initial pipeline and wellhead system was connected to well 401* and commissioned in July 1977. A standby steam supply in the form of a wellhead system and a pipeline between wall 404** and the power house was constructed and subsequently commissioned in July 1978.

The pipeline and wellhead systems were designed by KRTA and constructed by the EDC.

DRILLING OF WELL 401

Drilling of well 401 commenced on 21 October 1976. A 18" OD surface casing was run on 26 October landed at 129 m and cemented back to surface. The 13 3/8" OD anchor casing, landed at 306 m was similarly cemented on 4 November. Following completion of the 12¼" hole, the 9 5/8" OD production casing was run to 475 m and cemented back to surface. The 8½" hole was drilled to a total depth of 1942 m by 7 January 1977. The rig was released on 12 January 1977 after the liner had been run and the completion tests carried oat.

* Previously named Mahiao 1
** Previously named Mahiao 4

INXTIAL DISCHARGE TEST ON WELL 401

During the heat up period after well completion, the well was vertically discharged for 1 hour. On the basis of results from this discharge, an electrical power potential of 6 MW was estimated, At this time (4 February) a maximum downhole temperature of 290°C was recorded.

The results suggested that the well would be a good producer and to make use of the steam it was decided to install a 3 MW demonstration power plant nearby.

In order to obtain well output information for the ongoing exploration programme and to provide design data, a single stack silencer was installed and horizontal discharge tests were carried out. The results of these tests indicated that' at a wellhead pressure of 3.1 MPa* the well produced a total mass flow rate of 23 kg/s at an enthalpy of 1200 kJ/kg. A further vertical discharge followed the horizontal discharge and indicated, for an assumed enthalpy of 1200 kJ/kg and a wellhead pressure of 1.1 MPa a total mass flow rate of 56 kg/s.

This output data provided the basis for the pipeline and wellhead system design'.

PORTABLE 3 MW TURBINE-GENERATOR

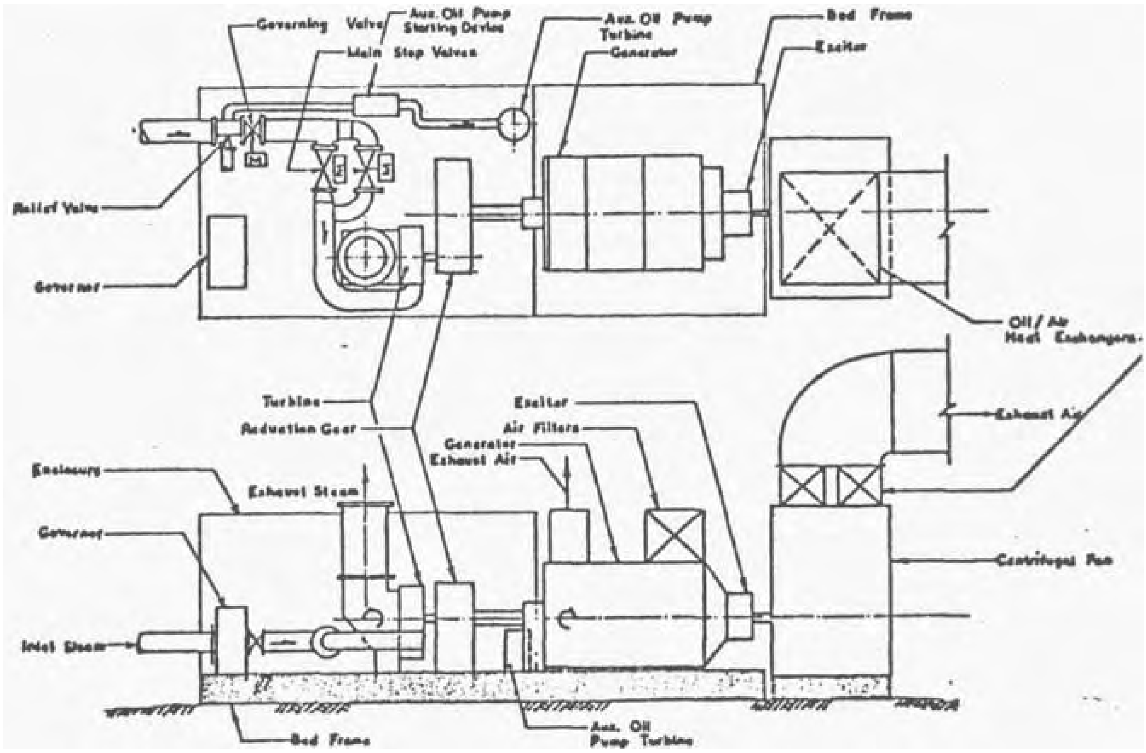
The turbine-generator is a portable unit supplied by Mitsubishi Heavy Industries Ltd to NPC. The unit was originally supplied for use at the Tiwi Geothermal Project on the island of Luzon.

then recombine and enter the steam chest.

The turbine consists of a two-row Curtis stage and the disc is overhung from the pinion of the reduction gear.

The steam, expanded in the turbine is exhausted vertically and piped to a vertical silencer mounted externally at the rear of the power house.

* All pressures in this paper are relative to atmospheric pressure



PORTABLE 3MW TURBINE GENERATOR

Figure 1

The turbine torque is transmitted to the generator and the oil cooling fan through the single helical reduction gear. Gear couplings are used between the gear wheel and the generator, and between the exciter and the cooling fan. The reduction gear is arranged so that the axial thrust balances the turbine blade thrust.

The oil cooling fan is of the double inlet centrifugal type and the exhaust air from the oil/air heat exchangers is discharged to atmosphere above the front entrance of the power house.

The generator is of the open, self ventilated air cooled type, drawing air through filters mounted at the exciter end of the generator.

Table 1: Turbine-Generator Data

Turbine	Impulse, single flow, back pressure, geared turbine
Maximum output (at generator terminal)	3.MW
Rated turbine speed	7,554 rpm
Rated steam pressure at governing valve	0.69 MPa
Backpreesure at exhaust flange	0.13 MPa
Gas content, wight	5%
Steam consumption	4.9 MW/kg/s
Number of stages	One
Type	Curtis
Reduction gear	single helical
Rated generator speed	1,800 rpm
Rated voltaga	4,000 volt
Frequency	60 Hz

PIPELINE SYSTEM

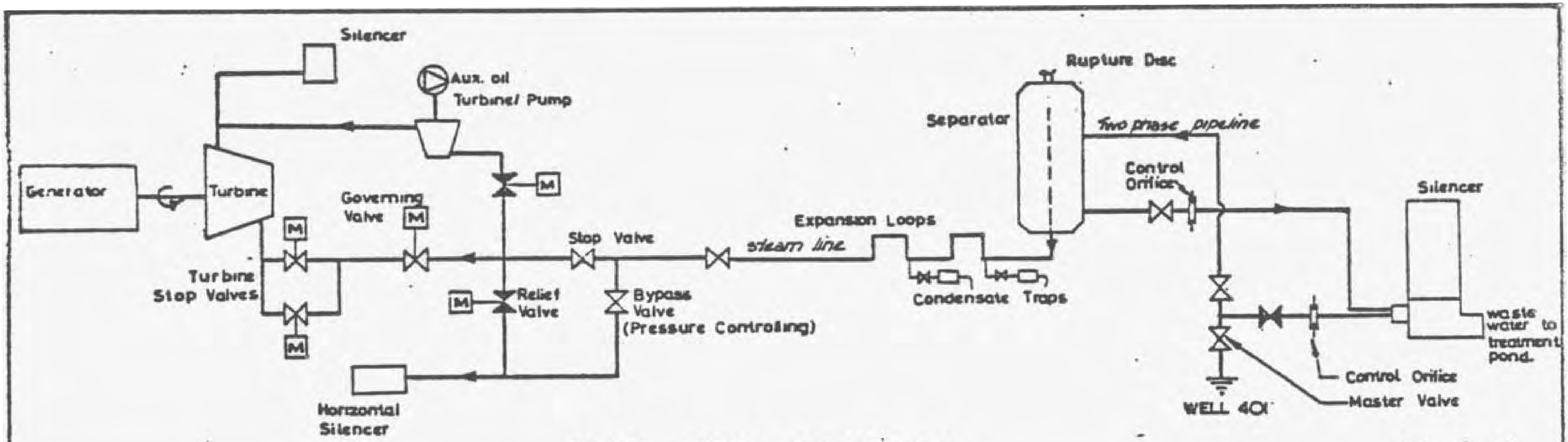
The target date of 2 July 1977 for the commissioninq of the power plant left little time for the system a8 designed to be constructed. The need for rapid development resulted in the installation of a system which operated leas than satisfactorily. The system as initially installed to meet the target date is shown in Figure 2.

Earth works for the power house and the pipeline from 401 were begun in May 1977.

Although drawings for an integral drum separator were produced by early March, there was insufficient time to manufacture a separator to meet the target date for installation. A second hand 1000 mm 'W.K.M. Brewster' separator was therefore obtained from another Philippine geothemal project. The separator was installed adjacent to well 401 and connected to it by a two-phase pipe loop sired to allow for the thermal expansion of the wellhead and casing.

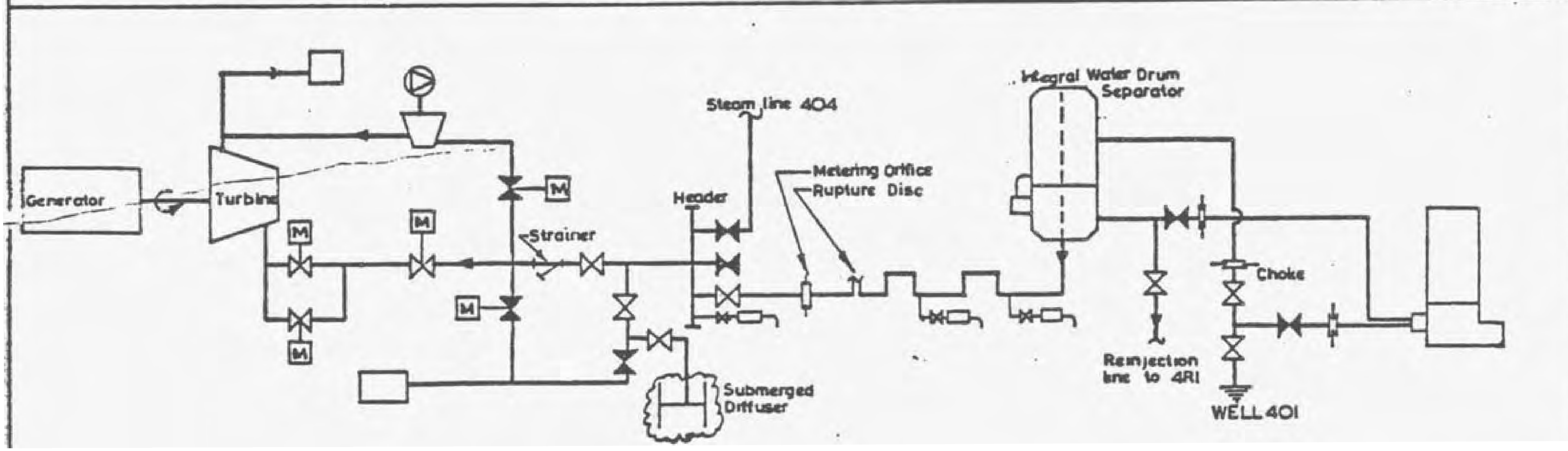
The permanent concrete silencer at the well was of necossity built before tho position of the wellhead system was fixed and its position was a constraint to the design. The elevated inlot of the silencer necessitated raised bypass and water line..

It was planned to operata the turbine at a constant preasure of 0.7 MPa and to exhaust the excess steam to atmosphere. A manually operated pressure controlling bypass valva and line mra installed immediately upstream of the power house stop valva. The bypass line discharged to a horizontal 'silencer'.



INITIAL 3 MW$_e$ INSTALLATION

Figure 2



FINAL 3MW$_e$ INSTALLATION AT TONGONAN GEOTHERMAL FIELD

Figure 3

Table 2: Pipeline data

Two-phase line	$300 nun NB ANSI sch 40. Loop 14 x 5 m. Counterweight support from two towers.
Steam line	ø300 nun NB ANSI sch 40. Pipeline anchored in 5 sections, with horizontal or vertical expansion loops. Pipe guided on rollers.
Bypass line	$200 mm NB API line pipe.
Separator water line	ø250 mm NB ANSI sch 40.

SYSTEM MODIFICATIONS

Operational problems necessitated a number of modifications to the system. The final system, as presently installed is shown in Figure 3.

During commissioning, the two-phase pipeline loop oscillated in a horizontal plane with an amplitude estimated as 25 mm. This vibrational problem was corrected by installing wire strops between the center of the loop and the support towers. The strops were arranged so as not to be affected by the thermal expansion of the pipe and well, and were fitted with turnbuckles to enable the wire tension to be adjusted until the system frequency was , sufficiently different from the forcing frequency to minimise vibration.

The 'Brewster' separator was initially operated such that some steam exited with the separated water. Even under these conditions, the separation efficiency of the system (92%) was less than satisfactory.

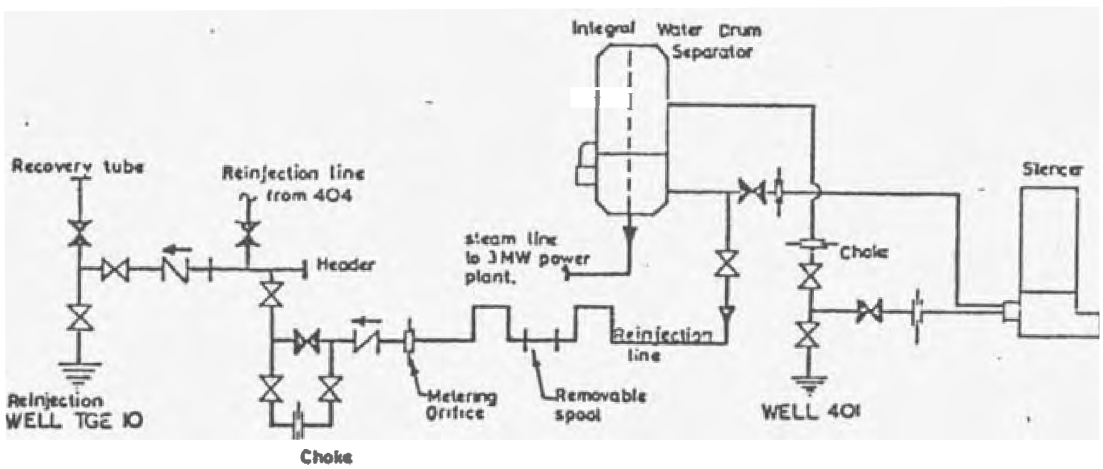
The inefficient separation resulted in the occurrence of severe mineral deposition within the turbine. Thick, dense, blue-black, banded deposits of halite (NaCl) and sylvite (KCl) were evident on the nozzles of the steam chest, and deposits of amorphous silica were present on the blades of the rotor and stator. The turbine operated until the force exerted on the turbine thrust bearings activated the over thrust device and shut down the turbine.

In an attempt to ease the scaling problem a 125 mm choke was installed in the two-phase pipeline above the wellhead. With the choke installed the production pressure rose from 0.8 MPa to 1.2 MPa and the separation efficiency measured near the power house increased to 97%.

An integral water drum separator manufactured in Manila was used to replace the 'Brewster' separator during mid March 1978. The 125 mm choke was replaced with a smaller 100 mm choke which resulted in an increase in the production pressure to 1.8 MPa. Other modifications carried out at this time included the installation of a strainer immediately upstream of the turbine, a header for future pipeline connections, a steam flow rate metering orifice and deepening of the condensate pots to prevent re-entry of the condensate into the steam flow. Dryness tests conducted at various operating conditions Indicated that the separation efficiency of the system had increased to 99.972.

Prior to February 1978 the separated wastewater exhausted from the silencer was cascaded down cooling channels and into a pond where it was cooled before flowing into the Mahiao river. Because of the potentially toxic nature of the effluent and the need to discharge the effluent from other nearby wells into the waterways, it was decided to reinject the wastewater from 401 into a nearby shallow well. The shallow well TGE-10* chosen is located near the power house and indicated a favourable injectivity based on cold water pumping tests conducted during November 1977. Well TGE-10 completed in April 1976 to a depth of 590 m encountered a steam heated meteoric water zone overlying the hot chloride waters of the Mahiao Reservoir. A maximum downhole temperature of 254°C was recorded at 590 m (KRTA 2nd Stage Report).

A reinjection system as shown in Figure 4 was constructed and reinjection of waste fluid began in February 1978.



TGE 10 REINJECTION SYSTEM **Figure 4**

The wastewater is separated at about 1.0 MPa and is cooled approximately 3 °C while flowing through the reinjection line. The water flow rate from the 401 separator was estimated at 10 l/s.

Results from reinjection into TGE-10 indicated that there are no apparent problems with reinjecting 177°C fluid Into this hot section of the field.

The horizontal 'silencer' located to the rear of the power house and used to exhaust the bypassed steam was extremely noisy. The drop in pressure across the bypass valve caused the steam to become superheated and when exhausted through the horizontal 'silencer' gave rise to sound power levels estimated to be in excess of 100 dB.

A pipe torous constructed from 300 mm diameter pipe perforated on its upper hemisphere and submerged in a pool of water served as a submerged diffuser and reduced the sound to an almost negligible level.

* Also known as 4RI

ADDITION OF WELL 404

As mentioned elsewhere, the 3 MW power plant was installed as a demonstration unit and reliable operation was therefore of considerable importance. To provide for an alternative steam supply it was decided to connect well 404 to the system. This wall was completed on 23 May 1977 to a depth of 1668 m and tested for output between October and December 1977.

Design of a wellhead and pipeline system commenced in October 1977 and construction during February 1978. The steam line and also the reinjection line from the separator of wall 404 were constructed concurrently.

The pipeline between well 404 and the power station was commissioned in July 1978 and is presently supplying steam to the power plant while well 401 is being monitored for pressure and temperature recovery following recent output tests.

FUTURE

It is planned to operate tho 3 MU power plant until a 112 MW power plant to be built at Tongonan, is commissioned.

Contiruous operation of the 3 MW power plant will provide long term production and reinjection data which will assist further field development.

Since ita completion, well 401 has been discharged for a total of 23 months and over this period ita output characteristics have changed. Prior to the well having been used to supply steam to the power plant, a total mass flow rate and enthalpy of 42 kg/s and 1500 kJ/kg respectively were determined for a wellhead pressure of 1.8 MPa. A recent output test indicated a total mass flow rate of 23 kg/s and an enthalpy of 2300 kJ/kg at a production pressure of 1.8 MPa.

Over the full discharge period, despite a decrease in the total mass flow rate, the steam flow rate at a separator pressure of 1.0 MPa has increased from 15 to 16 kg/s.

CONCLUSIONS

The 3 MU electric power plant installed at Tongonan is an example of successful rapid utilization of geothermal energy.

Transmission of 0.6 MW of power from Tongonan to the nearby city of Ormoc has replaced electricity otherwise produced by diesel driven generatora.

Valuable experience in geothermal engineering and power plant operation have been gained by NPC and EDC staff.

Reinjection of waste fluids has provided considerable data on the feasibility of reinjecting fluid from the high pressure (0.51 MPa) separators to be used for the first stage of the 112 MW development designed for the Tongonan field.

Tho installation of further small demonstration electric generating units is being planned by NPC and EDC for a geothermal field on tho nearby island of Negros.

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MHI Portable 3 MW Turbine Generator, Plana and Specifications, Mitsubishi Heavy Industries Ltd, Nagasaki Shipyard and Engine Works.