AN OVERVIEW OF GEOTHERMAL DEVELOPMENT IN TIWI AND MAK-BAN, PHILIPPINES

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INTRODUCTION

Commercial-scale geothermal development in the Philippines began in 1972 with the completion of the discovery well in the southeastern portion of Luzon Island. A second geothermal anomaly was discovered in 1975 on the southern flank of Mt. Makiling, forty miles south of Manila. Both fields are being developed and operated by Philippine Geothermal, Inc. (PGI), a wholly-owned subsidiary of Union Oil Company of California. Currently the Philippines ranks second worldwide in installed geothermal-powered electrical generation capacity with 443 MW and PGI has developed 440 MW of the 443 MW country total. Additional generation capacity is planned or under construction in both fields. Over 1.9 billion kilowatt-hours of electrical power have been produced to date. This represents a savings of approximately three million barrels of imported fuel oil for power generation.

TIWI FIELD OVERVIEW

The Tiwi geothermal field, located 220 miles southeast of Manila was discovered in 1972 with the completion and testing of well Naglagbong No. 1. Development and exploratory well drilling has confirmed that at least 3225 acres are commercially productive. Figure 1 is a well location map showing the current scale of development. The eastern portion of the field has been well-defined by a series of dry and sub-commercial wells, but the limits of the resource on the western side of the field have not yet been determined. As of December 1, 1980, sixty-seven wells have been drilled and three are currently being drilled. Forty-three wells are commercially productive. The twenty-four remaining wells are non-commercial for different reasons: 1) nine wells have excessively high wellbore scaling rates, 2) six wells are too corrosive for the carbon steel production system, 3) five wells are dry holes and define the eastern limits of the field, 4) two wells were P and A due to mechanical problems during completion, and 5) two wells were drilled to monitor possible seawater encroachment from the Lagonoy Gulf. The average well depth for all wells drilled to date is 5040 feet. The shallowest commercial well is 1574 feet and the deepest is 9000 feet.

PRODUCTION SYSTEM

The Tiwi production system differs from most hot water geothermal production systems in its use of satellite stations, regional community separators that collect the production from three to six wells and separate the steam from the brine at 140 psia. This type of a production system eliminates the need for long distance two-phase pipelines. High pressure steam and high pressure brine flow from several satellite stations to the plant station located adjacent to each power plant. At the plant station the high pressure steam passes through a scrubber and then to the power plant. The high pressure water flows to a low pressure separator operating at 40 psia. The low pressure steam flows from the separator through a steam scrubber to the power plant. The brine from the low pressure separator flows to a large concrete diffuser where it is flashed to the atmosphere. The residual brine flows by canal to the sea. A simplified flow diagram is shown in Figure 2.

Electrical power generation is accomplished by two 55 MW dual-pressure, dual-flow Toshiba turbine-generators installed in each of two power plants. The total plant steam requirements are 1,840,000 lbs/hr of 115 psia steam. and 650,000 lbs/hr of 35 psia steam at saturated conditions. An additional power plant containing two 55 MW dual-flow turbines is currently under construction, and should be fully operational by the first quarter of 1982.

More than 134 billion pounds of fluid have been produced from the Tiwi reservoir as a result of reservoir testing and electrical generation. Over 1.1 billion net kilowatt-hours of electrical power have been produced in less than two years of commercial operation.

RESERVOIR DESCRIPTION

The Tiwi geothermal anomaly is primarily a liquid-dominated reservoir. Production is from a highly fractured andesite. The entire region is geologically very active. Numerous seismic events are recorded each month. The dominant feature in the western portion of the field is the Malinao volcano. The extremely rugged topography in this area has been a deterent to development. Exploratory drilling has begun this year in this area. The eastern portion of the field is very flat and covered by rice fields. It is in this area that most of the development has taken place.

The maximum static wellbore temperature varies from

510°F up to 575°F. The typical produced fluid composition is: 4500 ppm Cl^-, 2450 ppm Na^+, 471 ppm K^+, 440 ppm SiO_2^+, 58 ppm Ca^{++}, with an average pH of 6.0. All other chemical species are less than 50 ppm each.

Each well is flow tested for 5 to 20 days shortly after completion. Upon shut-in a pressure buildup is taken. Most wells behave as if they are vertically fractured in an infinite system, with wellbore storage. The permeability-thickness product (kh) for Tiwi wells ranges from 1000 md-ft to greater than 150,000 md-ft. The skin values are generally slightly negative but range from +40 to -10. In addition to the individual well tests, two long-term production tests have been conducted. Both tests have confirmed sufficient reserves for at least 330 megawatts for thirty years. In addition to the tests, the reservoir pressure response to production is continuously monitored. Five wells are outfitted with nitrogen-charged Sperry-Sun capillary tubes. Surface pressures are measured daily in these wells. Moreover, downhole pressure are monitored weekly in four wells with Kuster pressure bombs. In this manner, a constant surveillance is kept on the reservoir.

SUMMARY

The Tiwi anomaly is a high temperature low salinity resource. The extensive reservoir pressure response to production and the completion of 67 wells have defined a minimum of 3225 acres of productive reservoir. The installed electrical generating capacity is currently 220 megawatts with an additional 110 megawatts under construction and scheduled for commercial operation in early 1982. More than 1.1 million megawatt-hours of electrical power have been produced in less than two years of operation.

MAK-BAN FIELD OVERVIEW

A detailed review of the Mak-Ban field (at the time it was called Bulalo) was presented at the Fourth Annual Stanford Geothermal Workshop by P. H. Messer and P. F. de las Alas in 1978. This is an update of their presentation. Sixty-four wells have been drilled since the discovery well, Bulalo No. 1, was completed in 1975. Figure 3 is a well location map also showing the power plant sites. Four exploratory wells have been drilled at the Maibarara prospect located approximately three miles northwest of the Mak-Ban field. Additional drilling is currently in progress to evaluate the extent of the Maibarara prospect.

Of the sixty-four wells drilled at Mak-Ban, forty-two are commercially productive. Eight wells are non-commercial for the following reasons: four wells are dry holes, three wells have mechanical restrictions preventing production, one well is too corrosive to produce. An additional fourteen wells have been drilled as injection wells. Eight of these wells have been drilled on the field periphery and six wells are located adjacent to producing wells.

PRODUCTION SYSTEM

The Mak-Ban production system is similar to Tiwi in its use of satellite stations with one significant difference. After separation in Mak-Ban, the high pressure brine is injected back into the reservoir. The high pressure steam flows through steam scrubbers and on to the power plant. Electrical power generation is accomplished by four Mitsubishi 55-megawatt single-pressure, dual-flow turbine-generators. As of December 1, 1980, 77 billion pounds of geothermal fluid have been produced in Mak-Ban. Over 34 billion pounds of brine have been injected back into the reservoir with no observed negative effects. This leaves a net withdrawal from the Mak-Ban reservoir of 43 billion pounds. This net withdrawal includes not only the steam required for electrical power gneration but also the extensive well testing that was performed in the years prior to commercial startup. A total of 800 thousand megawatt-hours have been produced in Mak-Ban.

MAK-BAN SUMMARY

Exploratory and development drilling in Mak-Ban have defined the limits of this anomaly. It covers 2200 acres and contains sufficient reserves for at least 220 megawatts of electrical generation for thirty years. Additional drilling in the Maibrara area may confirm a resource sufficient for commercial power generation.

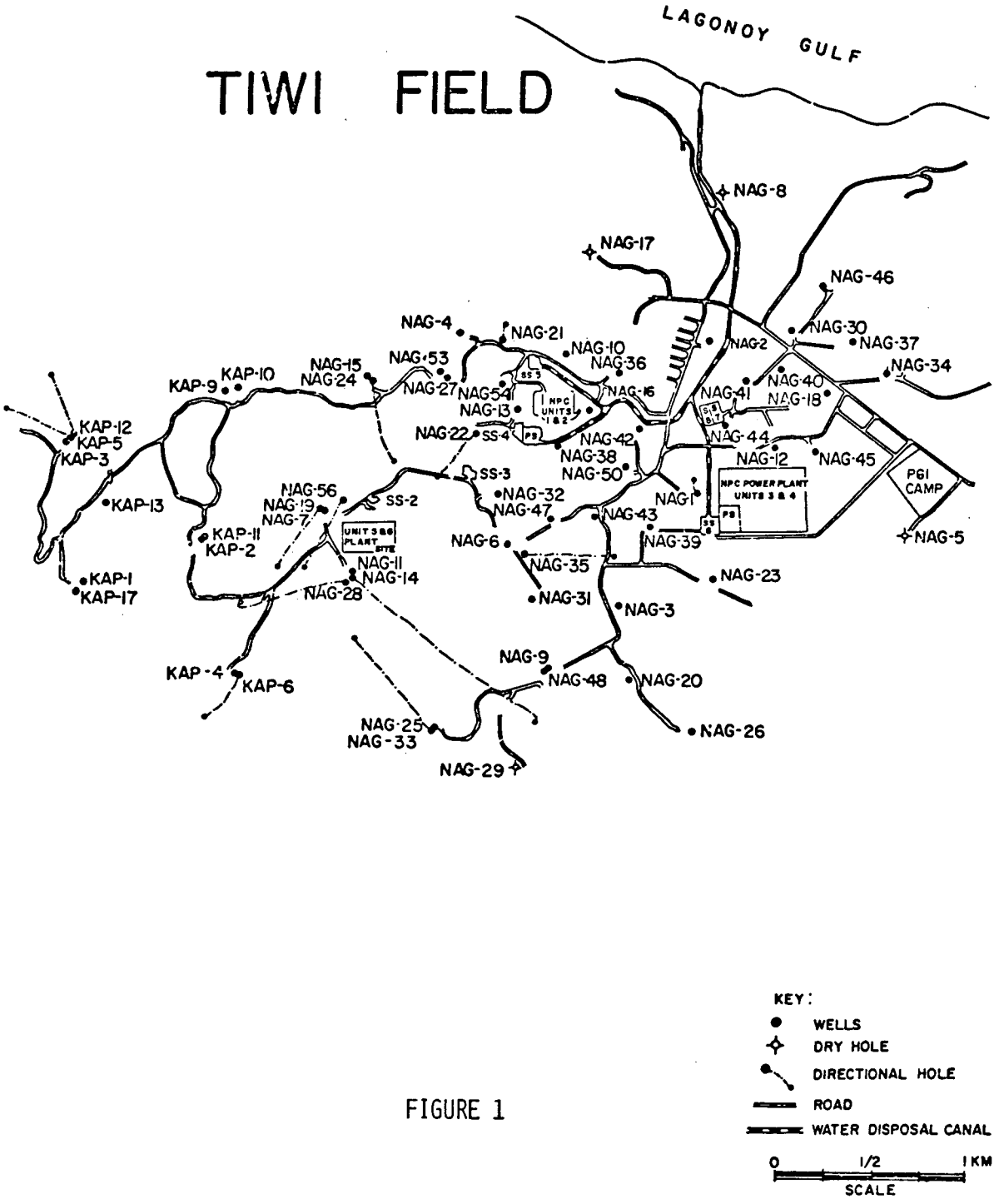
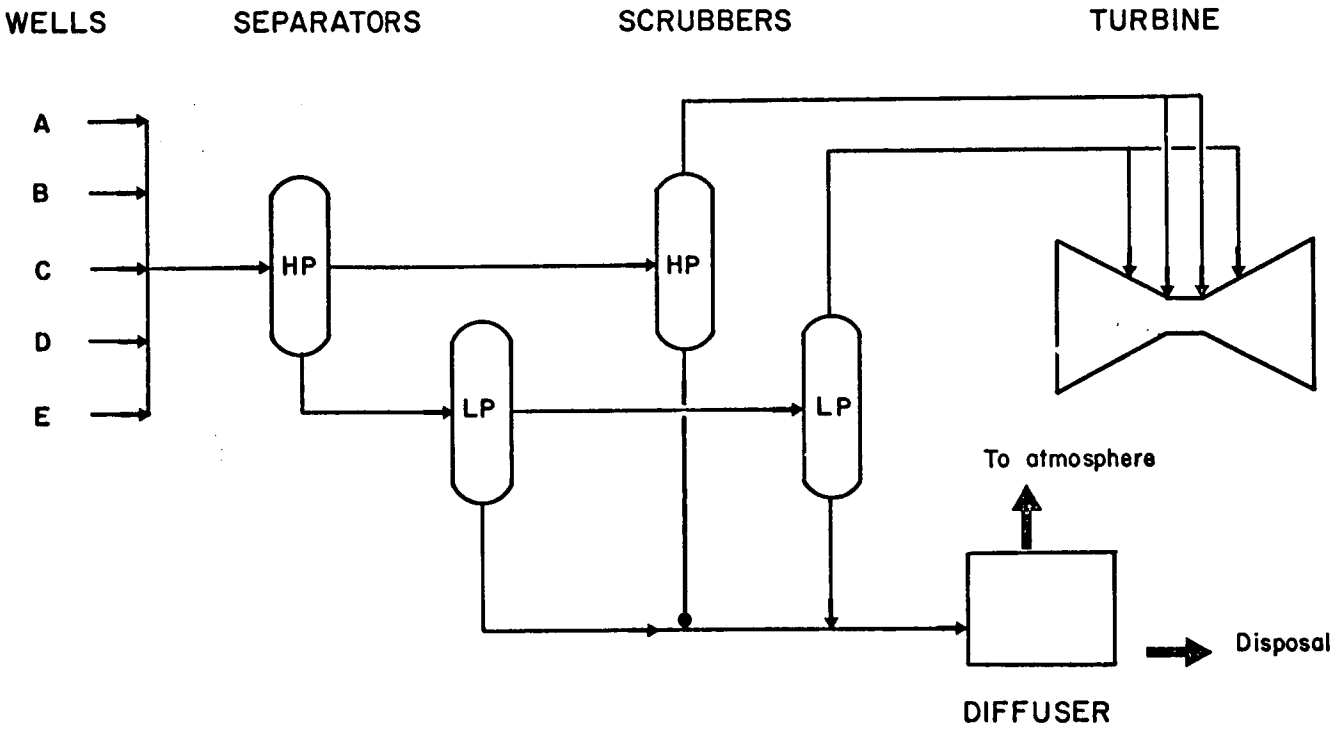

TIWI FIELD
LAGONOY GULF
NAG-8
NAG-17
NAG-46
NAG-4
NAG-21
NAG-10
NAG-36
NAG-2
NAG-30
NAG-37
NAG-34
NAG-15
NAG-24
NAG-53
NAG-27
NAG-54
NAG-13
NAG-16
NAG-41
NAG-40
NAG-18
KAP-9
KAP-10
KAP-12
KAP-5
KAP-3
NAG-22
SS-4
NAG-42
NAG-38
NAG-50
NAG-44
NAG-12
NAG-45
PGI CAMP
NPC POWER PLANT UNITS 3 & 4
SS-3
NAG-56
NAG-19
NAG-7
SS-2
NAG-32
NAG-47
NAG-1
NAG-43
NAG-39
NAG-5
KAP-13
KAP-11
KAP-2
UNIT 3 & 4 PLANT SITE
NAG-6
NAG-35
NAG-23
NAG-11
NAG-14
NAG-28
NAG-31
NAG-3
KAP-1
KAP-17
NAG-9
NAG-48
NAG-20
KAP-4
KAP-6
NAG-25
NAG-33
NAG-26
NAG-29
KEY:
WELLS
DRY HOLE
DIRECTIONAL HOLE
ROAD
WATER DISPOSAL CANAL
0
1/2
1 KM
SCALE

FIGURE 1

FIGURE 2



TIWI PRODUCTION FLOW DIAGRAM

MAK-BAN FIELD

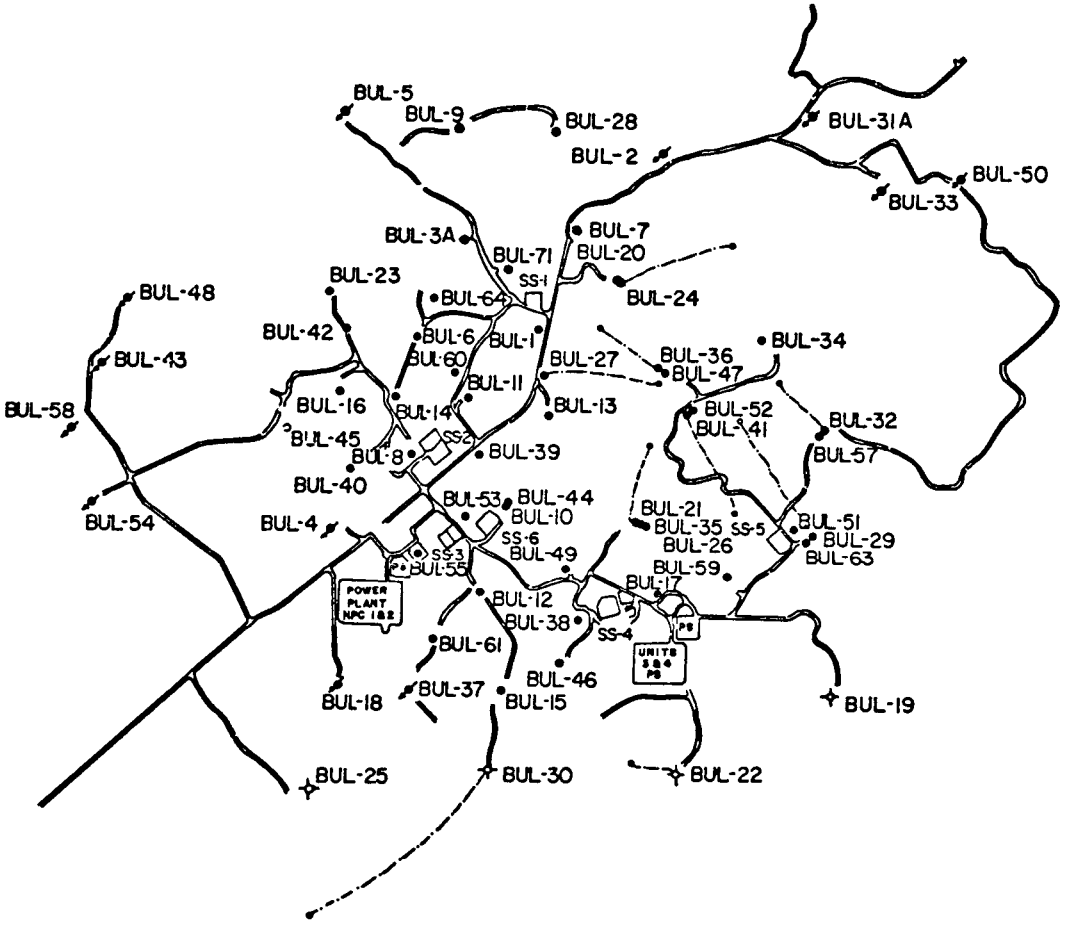


FIGURE 3

KEY :

- WELLS
- DRY HOLE
- DIRECTIONAL HOLE
- INJECTION WELLS
- ROAD

0 1/2 1 KM.
SCALE