SUMMARY

GEOTHERMAL ENERGY IN HAWAII

HAWAII GEOTHERMAL PROJECT

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GEOTHERMAL ENERGY IN HAWAII

I. INTRODUCTION

Geothermal energy basically is energy from the earth's internal heat. Usually three elements must be available in a usable geothermal reservoir:

(1) a source of heat, which in Hawaii probably consists of underground magma at a temperature of 1200°C;

(2) a carrier which enables the heat energy to be brought to the surface; this is usually water and/or steam, the hotter the better;

(3) a rock formation which absorbs the heat from the source and transmits it to the water; the rocks must be sufficiently fractured to permit the water and/or steam to flow easily through it.

Drilling for geothermal energy in Hawaii started in the early 1960's on the Big Island. Four wells were drilled in the Puna region to depths of several hundred to a thousand feet; all were unsuccessful in locating geothermal steam. In 1973 a fifth hole was drilled near Halemaumau Crater to a depth of 4140 feet. The maximum temperature reached was only 279°F (137°C), but at bottomhole a high rate of temperature increase with depth suggested much higher temperatures at greater depths.

The sixth hole was completed in April of 1976. This well, HGP-A, which has the highest recorded temperature of any geothermal well, has raised hopes that in Hawaii geothermal energy might be a viable alternative to fossil fuel energy.

II. THE HAWAII GEOTHERMAL PROJECT (HGP)

The Hawaii Geothermal Project was organized by the University of Hawaii to locate and utilize geothermal energy resources in Hawaii. HGP came into being when the 1972 Hawaii State Legislature allocated $200,000 for geothermal research, contingent on the University's also obtaining federal funds, which it did. From the beginning this has been a cooperative project involving the Federal, State and County governments, the University, the electric utility and the private sector.

Research got underway in the early summer of 1973, with separate programs established for Geophysics, Engineering, and Environmental-Socioeconomics. Later an Experimental Drilling Program was added. The major emphasis initially was on geophysical surveys, but support activity was begun in the other programs as well. Since the Big Island, because of its active volcanoes, appeared to be the most promising island for locating geothermal resources, an initial reconnaissance was conducted there.

A. Geophysical and Drilling Summary

The geophysical program was designed to select a drill site with high potential for a geothermal resource and also to develop an understanding of the

thermal processes of a basaltic volcano and its associated rift zones. Various geophysical surveys were utilized: infra-red, surface manifestations, gravity, magnetic, electrical, well temperature, seismic, geochemical and hydrological. Data from a self-potential survey by the U.S. Geological Survey were also used.

The HGP Site Selection Committee considered all geophysical, geological, and geochemical evidence which had been collected and selected as the most likely location for finding a geothermal resource an area in the Puna District near the eastern rift of Kilauea Volcano. Permission was obtained from the Kapoho Land and Development Company to drill a well on a four-acre plot approximately three miles southeast of Pahoa. Figure 1 contains a map showing the location of the site, which is 600 feet above sea level.

Drilling of the experimental well commenced on December 10, 1975. The well was completed to a depth of 6450 feet on April 27, 1976, with casing from the surface to 2230 feet and a variable-slot liner from the end of the casing to bottomhole. To obtain data on the subsurface geology, wellbore cores of the rock were taken at approximately 700-foot intervals and samples of drill cuttings were obtained for every five to ten feet of drilling. The well was logged twice to measure resistivity, self-potential, natural gamma ray count, slow neutron count, and cement bond. The depth of logging was limited by surprisingly high downhole temperatures, which caused measurement equipment to burn out from the heat.

B. Well Testing Program Results

The well, HGP-A, was first flashed briefly to produce a steam output on July 2, 1976. The rate of discharge of steam was impressively high but noisy -- resulting in DBA readings of 120, roughly equivalent to that of a 747 jet aircraft at takeoff. On July 22 steam was discharged continuously for four hours, verifying that natural fluid flow into the wellbore was taking place. The quality of the fluid from HGP-A was very good -- surprisingly low in chloride content, but with an expectedly high amount of silica since a bottomhole temperature of 676°F (358°C) had been measured, making HGP-A the hottest geothermal well in the world.

In order to proceed with a testing program a silencer/separator was installed to muffle the noise and also to separate the steam from the water, so that the amount of each component could be measured. In late December and early January muffling and stiffening were added to the silencer to reduce the noise further, after which a series of throttled flow tests was conducted to provide a better assessment of the well's possible output and to obtain preliminary design data for an electrical generator which could be connected to the well to produce electricity. Table 1 summarizes the test results and shows that a relatively wide range of operating pressures is available with relatively small change in steam output. Approximately 3.5 Mw of electrical power is available from this well.

Temperature and pressure profiles throughout the full 6450-foot well depth have been obtained. Figure 2 contains typical temperature profiles during quiescent and discharge periods. It is of especial interest that each succeeding test has resulted in increased steam output. Table 2 indicates this improvement and shows that the steam flow rate increased from 60.0 to 75.2 Klb/Hr, a 25% increase, between the November and March tests.

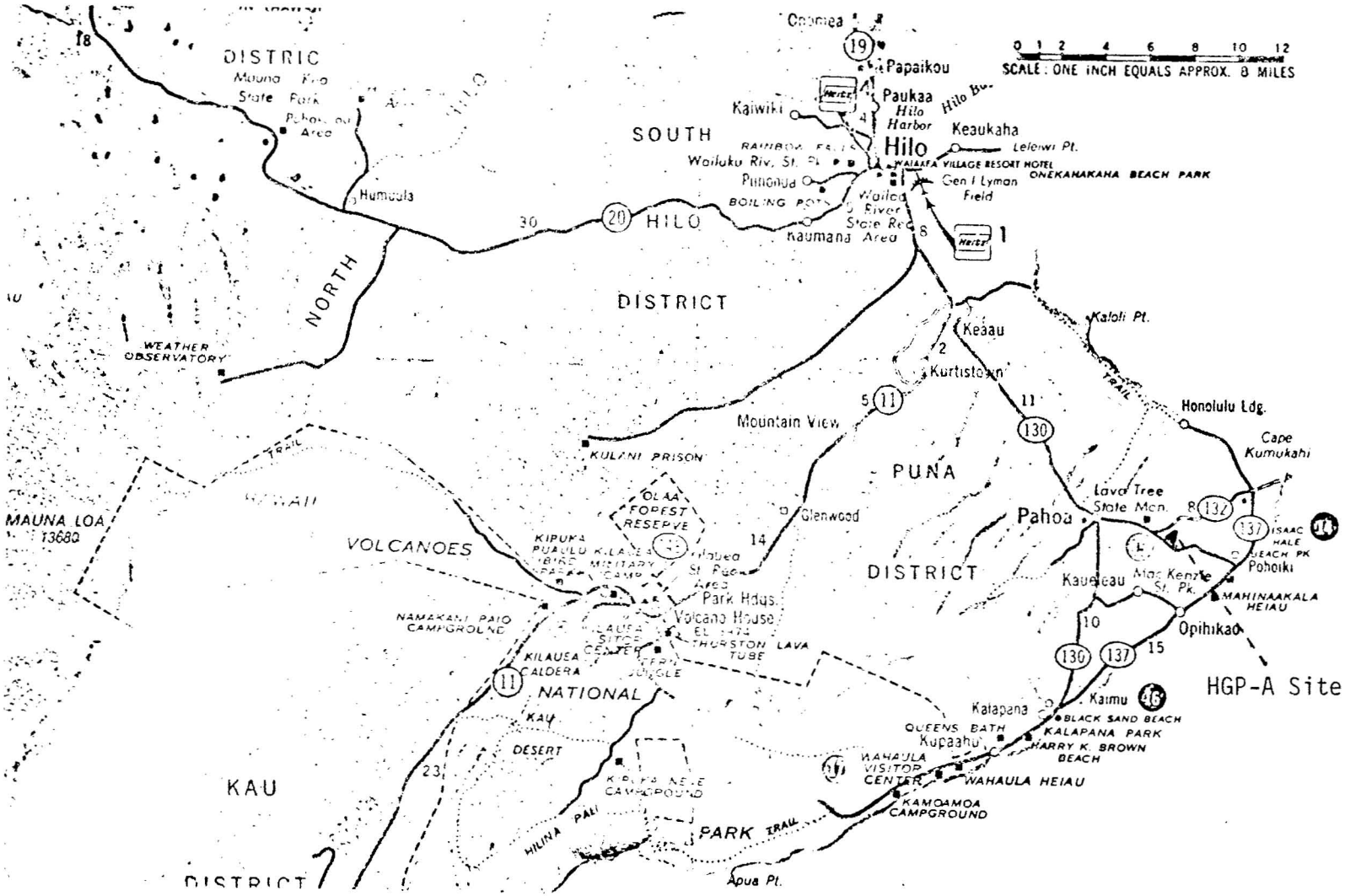
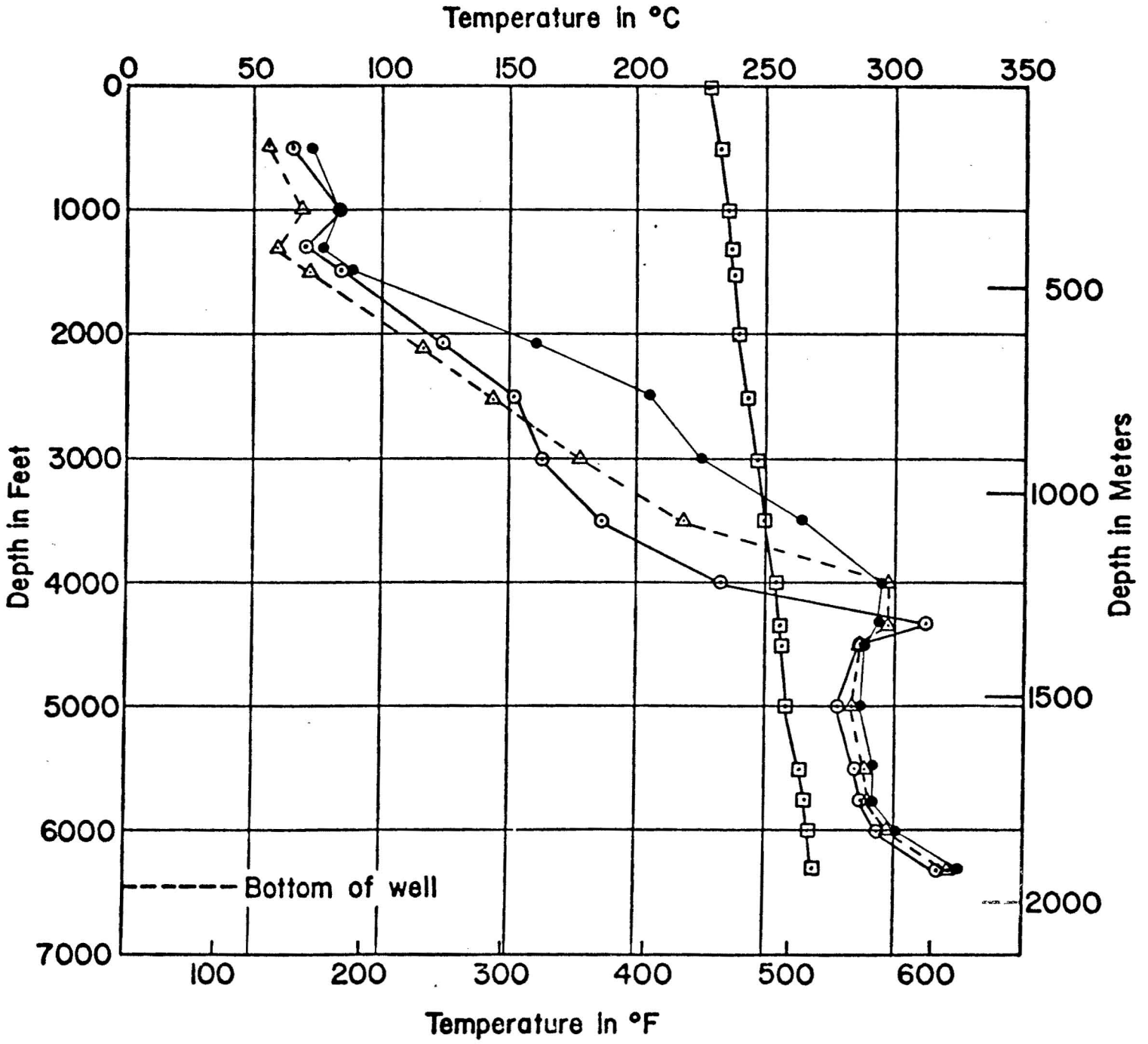


Figure 1. Location of HGP-A Site

Table 1

THROTTLED FLOW DATA

ORIFICE SIZE (INCHES)	TOTAL MASS FLOW RATE (KLB/HR)	STEAM FLOW RATE (KLB/HR)	STEAM QUALITY (%)	WELLHEAD PRESSURE (PSIG)	WELLHEAD TEMP. (°F)	POSSIBLE ELECTRICAL POWER OUTPUT (MWE)
8	101	64	64	51	295	3.3
6	99	65	66	54	300	3.4
4	93	57	64	100	338	3.5
3	89	54	60	165	372	3.5
2-1/2	84	48	57	237	401	3.3
2	81	43	53	293	419	3.1
1-3/4	76	39	52	375	439	3.0



2/10/77 Well Discharging with 1 3/4" Orifice Plate

2/19/77 8 Days after Shut-in

2/25/77 14 Days after Shut-in

3/8/77 25 Days after Shut-in

Figure 2. Temperature Recovery After January Flow Test

Table 2

COMPARISON OF DISCHARGE TESTS AT 25 HOURS AFTER INITIATION OF FLOW

	November	December	January	March
Steam Flow Rate (Klb/hr)	60.0	63.9	71.8	75.2
Wellhead Pressure (psig)	47	53	59	59
Wellhead Temperature (°C)	146	150	151	153
Electrical Power (Mwe)	3.4	3.8	4.3	4.5
Liquid Flow Rate (Klb/hr)	27.9	39.5	42.5	45.2
Mass Flow Rate (Klb/hr)	87.9	103.4	114.3	120.4
Steam Quality (%)	68	62	63	62
Enthalpy (BTU/lb)	888	833	845	842
Thermal Power (Mw)	22.9	25.2	28.3	29.7

The results of these preliminary tests were sufficiently encouraging that a ninety-day flow test was begun in late March, 1977. However, the nuisance effects of very small hydrogen sulfide emissions combined with the fact that the wellhead pressure had begun to stabilize led to the termination of the test on May 9 after six weeks of flow.

C. Present Status

Figure 3 is a sketch of the present wellhead and silencer assemblies, including instrumentation installed to obtain important data about the performance of the well. Table 3 summarizes the characteristics of the well and the Kapoho Geothermal Reservoir as deduced from the tests and measurements made to date. Of importance are: the water/steam mixture is very clean, the bottomhole temperature is about the highest recorded in the world, a very large geothermal reservoir may exist in Puna, and about 3.5 Mw of electrical power can be obtained long-term from this well.

Figure 4 contains a possible model for the underground system in the vicinity of the well and also shows how an electrical generating system could be connected to the well. As shown, the heated water/steam mixture enters the wellbore near bottomhole and flows quickly to the surface where it is sent to a separator, which discards the water and sends the steam to drive a turbine generator which produces electricity. It should be noted that once the wellhead turbogenerating system is installed with the proper hydrogen sulfide scrubbers, any noise and odor problems present will be remedied.

The early installation of a wellhead generator, both to provide power for the Big Island electric-grid network and to obtain additional information on the characteristics and the extent of the geothermal resource, is the next logical step for developing the Kapoho Geothermal Reservoir. To this end a consortium, the HGP-A Development Group, has been formed with the responsibility for constructing and operating an electrical generating plant using the steam from HGP-A. The consortium consists of the State of Hawaii through the Department of Planning and Economic Development, the County of Hawaii, and the University of Hawaii through the Hawaii Geothermal Project. The lead agent for the consortium is DPED. Although not legal members of the HGP-A/DG Consortium, the Hawaii Electric Light Company and the Hawaiian Electric Company are active participants in the program.

III. THE FUTURE OF GEOTHERMAL ENERGY IN HAWAII

The Hawaii Geothermal Project will continue into a Phase IV effort, concentrating on an assessment of the Kapoho Geothermal Reservoir. The thrust of the program is a better determination of the characteristics of the reservoir and its boundaries. Included will be an evaluation of the hazard of siting a power plant in the vicinity of an active volcano and/or rift zone and the methods by which this hazard can be minimized or eliminated.

Negotiations are currently in progress by the HGP-A/DG Consortium with the U.S. Department of Energy for funding of the wellhead generator. Current plans call for completion of the electrical power plant in two years. In addition to generating electricity, the facility will include a visitor information center

Figure 3

HAWAII GEOTHERMAL PROJECT
FLOW TEST EQUIPMENT AND INSTRUMENTATION

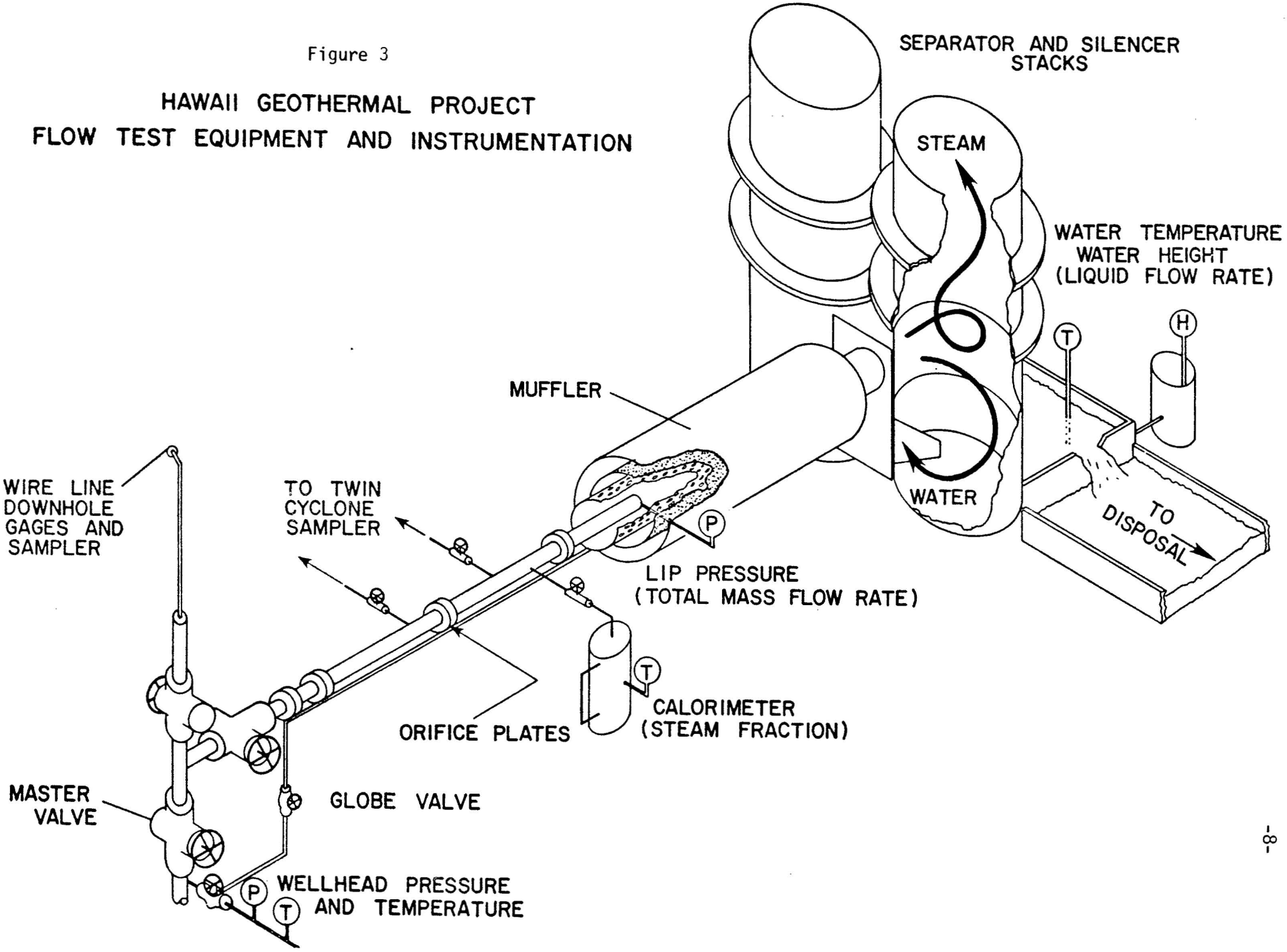


Table 3

Summary of Preliminary Test Results and Analyses

Kapoho Geothermal Reservoir

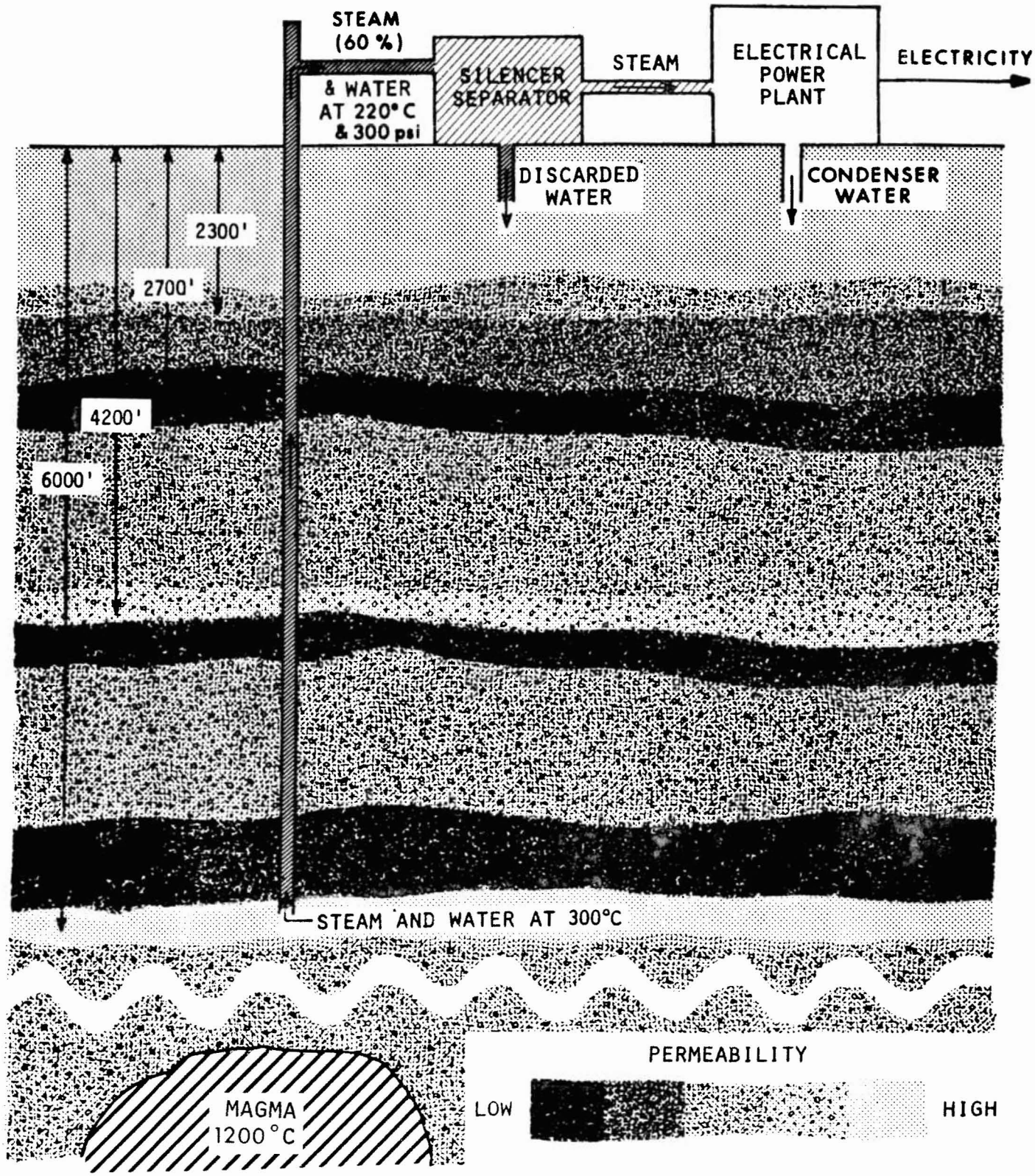
1. Liquid-dominated
2. Tight Formation: Permeability Thickness ~1000 md-ft
3. Very High Temperatures ~350°C
4. High Formation Pressure ~2000 psi
5. Slightly Brackish Water
6. Potentially Large Reservoir
7. High Silica Content

HGP-A Geothermal Well

1. During Flash Borehole Contains Steam and Water at Saturation
2. Flashing Occurs in Formation
3. High Wellhead Pressures ~160 psi at 60 klb/hr Steam
4. Producing Regions Probably at Bottomhole and 4300 feet
5. Probably Has Severe Skin Damage
6. Potential Power Output ~3.5 MWe
7. Flows Have Increased With Each Test

Figure 4

POSSIBLE MODEL OF HGP-A UNDERGROUND SYSTEM



and means for connecting to the well to perform experiments on the well or to use the well's output to test new geothermal devices.

With the installation of a 3.5 Mwe wellhead generator at HGP-A, the electrical needs of 3,500 people can be met. It is expected that relatively high-quality fluid can be expected from HGP-A for well over the 30-year life expectancy of the generating plant. Geoscientists have estimated that the Kapoho Geothermal Reservoir may have a capacity of 500 Mwe, or greater, for 100 years. If one theory which suggests that the entire rift zone is an immense reservoir proves to be true, 5,000 Mwe for 100 years might easily be possible for this rift zone alone. To exploit this vast potential, additional wells must be drilled and additional power plants constructed.

In addition to Puna, there are other potential geothermal areas on the Big Island such as the east rift of Kilauea and regions near South Point and Mt. Hualalai. Geothermal reservoirs are believed to be able to retain heat for hundreds of thousands, and even millions, of years. Since Haleakala on Maui erupted late in the 18th century, Maui, too, has potential. Furthermore, hot water sources have been found on Molokai, and in Lualualei and Waimanalo on Oahu. As the population center of the State is located on Oahu, discovery of geothermal energy in the City and County of Honolulu would be welcomed.

But how would geothermal energy be used? What does geothermal energy mean to the average citizen? What impact will this alternative have on the environment, economics and society in general?

Geothermal energy has been shown to be among the most economical of all fuels for producing electricity, and one of the cleanest. Pure steam wells are about the most competitive, while fluid containing only 20% steam, although presently exceeding fossil fuel power plants in cost, is still below nuclear power plant costs. The fluid from HGP-A is of 64% steam quality so its economics seem attractive at this time. However, the utilization of geothermal energy will not cause electrical rates to come plummeting down. As economies of scale improve, however, what should be possible is that rates will not rise as rapidly as those of energy derived from fossil fuels.

As the Big Island presently consumes only an average of 70 Mw of electricity, power in excess of this amount could be diverted to other uses. One possibility is to connect the major islands in the Hawaiian chain by means of a submarine power cable. This is technically feasible but the costs appear too great for implementation now. Another possibility is to use the geothermal energy for the processing of deep sea mining ores. Several hundred to a thousand megawatts can be used, depending on the size of the processing operations. It has been speculated that perhaps half a billion dollars in annual revenue can be approached at full production ... about the present annual value of petroleum used in Hawaii. Other minerals from land ores, such as aluminum and copper, have also been discussed as having potential. However, the possible negative impacts on the environment will have to be addressed.

Another thought is to produce hydrogen by the hydrolysis of water. Hydrogen is a good long-term possibility as a synthetic fuel. As Hawaii attempts to gain energy self-sufficiency, hydrogen could be a vital key, as hydrogen, in addition to residential and transportation use, can also be exported, allowing Hawaii to become an energy supplier.

Additional uses of geothermal energy could be for tourism -- health spas, resorts; agri-business -- aquaculture, sugar processing, papaya processing; and other non-electric applications. It is estimated that 90% of present worldwide uses for geothermal energy is non-electric.

In summary, then, geothermal energy can be relatively inexpensive. If proven to be in abundance, it could improve the State's economic picture, and definitely would reverse the bleak balance of trade situation on energy. At this time geothermal energy shows exciting promise as a feasible alternative to fossil fuels and nuclear energy. The next few years will be important ones in proving the extent of the resource and sensibly developing its potential.