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PROCEEDINGS, Eleventh Workshop on Geothermal Reservoir Engineering
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NOI'I O PUNA: GEOTHERMAL RESEARCH IN HAWAII

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ABSTRACT

Noi'i O Puna - The Puna Research Center (PRC), located on the grounds of the HGP-A power plant site in Puna, Hawaii, was dedicated on August 24, 1985. Research projects, supported by the U.S. Department of Energy (USDOE), State, County, utility, and the private sector have been initiated in the areas of geothermal reservoir engineering, silica utilization, and corrosion of materials.

An international geothermal applications workshop was held in Hilo, Hawaii the day before the dedication to discuss common problems and methods of solution by cooperative research. The three main categories addressed were process chemistry design, reservoir engineering, and agriculture/aquaculture applications. The workshop identified how PRC might be used for these research purposes.

The advantages provided by PRC include the availability of non-proprietary information, an operational power plant with adjacent laboratory, proximity of private wells, the Fellows in Renewable Energy Engineering program, and strong support from the State, County, and utility. A second workshop is in the planning stages to follow through on the recommendations and will be held in the Orient next year.

The Community Geothermal Technology Program, featuring projects conducted by individuals and companies in the local community, has been funded and will actively initiate projects this month. This program received matching funds from the USDOE, County of Hawaii and the private sector.

INTRODUCTION

The research test facility, Noi'i O Puna - the Puna Research Center (PRC), was dedicated in August 1985. The facility is located on the grounds of the HGP-A power plant on the Big Island of Hawaii (see Figures 1, 2, 3, and 4). PRC will provide heat and high pressure brine (186°C, 11.25 kg/cm^2) for research on direct use applications and by-product recovery. A number of research projects and a special community program of direct heat use have been initiated through support from the U.S. Department of Energy (DOE), State and County governments, utility, and industry.

RESEARCH EFFORTS

Research projects being conducted at PRC largely relate to reservoir engineering, silica recovery, and corrosion. An international series of geothermal applications workshops, and the Community Geothermal Technology Program are also affiliated with PRC.

Reservoir Engineering

The reservoir engineering project is re-examining all engineering data collected in light of recent findings from the HGP-A well. The original results were calculated utilizing the theory developed for oil and gas fields. However, caution is needed in using these methods for several reasons, including the fact that the theory is basically for single-phase flow, and HGP-A produces two-phase flow.

These early pressure drawdown and buildup tests revealed the following results [1, 2]:

1. The HGP-A reservoir is tight (low permeability of perhaps less than 1 milli darcy), and the well suffers from significant skin damage, resulting in a discharge rate of only 38-60 percent of the full potential;
2. There appears to be at least two production layers with permeability-thickness (kh) values. While the theory does not permit a calculation of the two kh values, there is indication that the effective kh ranges between 1000-1500 milli darcy-feet. Evidence of the two-production-zone theory is also reflected in the temperature/pressure profiles measured downhole in HGP-A well (see Figures 5 and 6), where three distinct slopes are seen in the pressure plots.

Recent geochemistry data have provided more evidence to the theory that two production layers do exist - one layer producing mostly

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steam and the other mostly water. Thus, with this new information calculations will be completed to verify this two-production-zone model [3, 4].

Silica Recovery [3, 5]
The objectives of this research program are to determine whether: a marketable form of silica can be recovered from the geothermal fluids at HGP-A; the silica precipitation process can be controlled using chemical additives; and markers or tracers exist in the cuttings from the geothermal wells already drilled that will differentiate between steam and water production aquifers.

The first of these entail an analysis of the charcteristics of silica precipitated under a variety of pH, temperature, and chemical conditions. Recovery rate and particle size determinations will be made for each condition in order to check whether marketable particle sizes (> 100 m^2/gm) can be obtained. Currently, a method has been identified on a laboratory scale that removes silica quite effectively and at a particle size having market potential. If optimal particle sizes can be obtained on a batch scale, a continuous recovery pilot process will be developed to determine whether product quality can be maintained.

The recovered material will be analyzed for purity, including trace metal concentrations. Specialty products of high purity such as special doped silica products might be fabricated from this material.

By using a variety of additives to the geothermal brine, chemical reactions which could inhibit or polymerize the silica will be examined. An accelerated reaction in a settling chamber before it reaches the valves and heat exchangers is desired. Initial experiments will be conducted at boiling and atmospheric pressure and, if a control agent is found, a pressurized reaction vessel will be used.

An additional study will search for chemical or physical markers in the cuttings and drilling logs to help differentiate between liquid producing aquifers with silica and dry steam producing aquifers without silica. The identification of such markers would permit a drilling engineer to exclude the silica producing aquifers and thereby reduce the scaling problems associated with water production, or conversely, tap only the shallower silica saturated fluid for commercial purposes.

Corrosion of Materials
Investigations on the corrosive properties of the geothermal fluid on various materials have been on-going at the HGP-A site. The goal is to develop criteria for selection of materials to be used in equipment (pipes, valves, heat exchangers, etc) that will transport and extract heat from the fluid.

Exposure tests of the relevant metallic and polymeric materials are being performed to classify the corrosiveness of the fluid on a global reference scale, which would allow comparison with data developed elsewhere [6].

The tests at HGP-A have shown that relative to geothermal sites world-wide, the Hawaiian geothermal fluid is moderately aggressive. Of the three environments tested, the aerated flashed steam caused the most corrosion, followed by the liquid after flashing. The non-aerated flashed steam was the least aggressive. Aluminum alloys suffered severe pitting in all three environments, while the high alloy stainless steels were fully resistant. Carbon steel and copper alloys suffered severe general corrosion in the aerated steam, moderate damage in the non-aerated steam, and considerable general or crevice corrosion damage in the liquid. Nickel, zinc, and Monel 400 were severely pitted, especially in the aerated steam and in the liquid [7].

Preliminary tests in the silica settling pond on several types of plastics indicated that most plastics which survived the temperature were relatively resistant to chemical attack. At the present time testing in the hot end of the silica settling pond is being carried out to select plastics for engineering applications. While the evaluation is not complete, results indicate that a number of common plastics were embrittled in the fluid during the two-month exposure period [6].

International Workshop [8, 9]
An invitational workshop on geothermal technology for the Pacific Basin was held in August 1985 at the University of Hawaii Hilo Campus to bring together researchers, scientists, and technologists from Pacific countries to discuss common problems and means of resolution. The three specific areas of interest were process chemistry design, reservoir engineering, and aquaculture/agriculture applications.

The most critical problem identified by the process chemistry group was scaling. Two separate approaches were discussed: a field-oriented research program to investigate the various methods of inhibiting or accelerating scale formation; and a theoretical modeling of the geothermal fluid chemistry to determine the critical parameters associated with scale formation and solid species saturation in the fluid. The chief recommendation for future research was to pursue both avenues interactively using the laboratory and field results to guide the theoretical models of fluid saturation and to use the theoretical results to suggest potentially fruitful laboratory or field methods. Another problem discussed that required research was mineral recovery.

The reservoir testing session considered an inventory of benefits offered by the Puna Research Center for cooperative research. The advantages included: an existing steam field containing a single well feeding a 3 MW power plant; two-phase reservoir fluid of extremely high temperature (186°C at the wellhead, and 358°C at bottomhole); direct communication with the University of Hawaii; an interested and supportive utility in Hawaiian Electric Company; adjacent commercial geothermal development; a geographic location in relatively close proximity to the ocean; and possible recharge by seawater. Experiments can be conducted involving either the power plant or the HGP-A well. An adjacent well drilled by Thermal Power may offer possibilities for inter-well experiments. As the reservoir is in an existing fractured rift zone typical of other circum-Pacific systems, this situation appears especially appropriate for cooperative research.

The following recommendations were made by the group: drill a second well in the Puna geothermal field; conduct multi-well interference testing; develop and test new downhole instruments; and identify the source and nature of the fluids at HGP-A. In order to permit multi-well testing, and to provide backup steam production capability, the group labeled drilling and completion of a new well as the highest priority. Multi-well testing between the Thermal Power, HGP-A, and the experimental well would then more accurately enable estimation of the size of the reservoir. Interference testing between the Thermal Power and HGP-A wells was also suggested.

The agri-aquaculture group felt that non-electrical use of geothermal energy is already state-of-the-art, and therefore, small scale demonstrations should be initiated to prove commercial feasibility in Hawaii. Recommended were the following applications which show promise in the Puna district: food processing (human food, animal feed); food technology; refrigeration (ice-making and cold storage); greenhouse operations; dehydration; aquaculture; and balneology.

The second international workshop will be held late in 1986 or early 1987 in the Orient. A steering committee has been formed and is tentatively planning to hold the meeting in Japan with re-convened sessions in Taiwan, Philippines, China, and/or Indonesia.

Community Geothermal Technology Program (CGTP)
The CGTP is similar to an earlier U.S. Department of Energy appropriate technology program and provides the opportunity for small businesses and individuals to use the discarded geothermal fluids for non-electric purposes. The topics that show promise for funding include soil heating and greenhouse use; green papaya drying; refrigeration; glass making; lumber drying; and cloth dyeing [8].

OTHER DEVELOPMENTS

The College of Engineering and the Hawaii Natural Energy Institute at the University of Hawaii are completing a search for a geothermal researcher for the Fellows in Renewable Energy Engineering (FREE) program. This program involves corporate and foundation endowment of teaching and research positions to advance the development of renewable energy technologies. The Hawaiian Electric Industries has provided $250,000 specifically to support a FREE researcher in geothermal energy. A selection will be announced soon.

The entire geothermal facility, which includes the visitor center, Puna Research Center, and HGP-A power plant, has been transferred to State ownership and placed under the authority of the Natural Energy Laboratory of Hawaii Board. This board is composed of officials from the State, County, and University of Hawaii and currently oversees the work at the Seacoast Test Facility located at the western tip of the Big Island, where ocean energy and related aquaculture research have been on-going since 1981 [10].

Private developers have drilled several geothermal wells in the vicinity of the HGP-A site. Recently, the consortium of Thermal Power, AMFAC, and Hawaiian Dredging completed its third well, Kapoho State 1A (see Figure 1). Preliminary flow tests have indicated good steam production. A proposal has been submitted to the State to provide steam and brine for the HGP-A power plant and PRC [11].

CONCLUSION

Since 1976 six wells have been completed and tested in Hawaii. A 3 MW powerplant has provided reliable electricity for four years. The activities at PRC should further increase interest and stimulate geothermal development in Hawaii.

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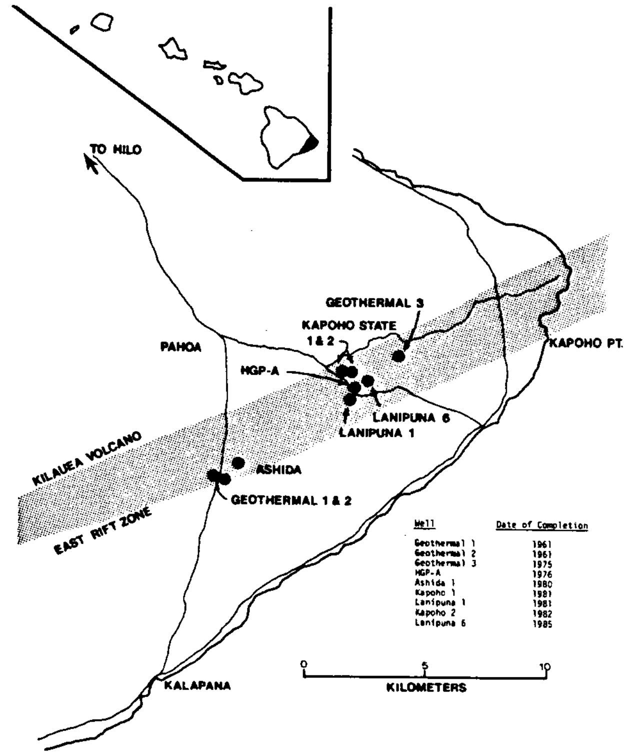

Figure 1. Map of Geothermal Wells in Hawaii

Figure 2. Noi'i O Puna - Puna Research Center

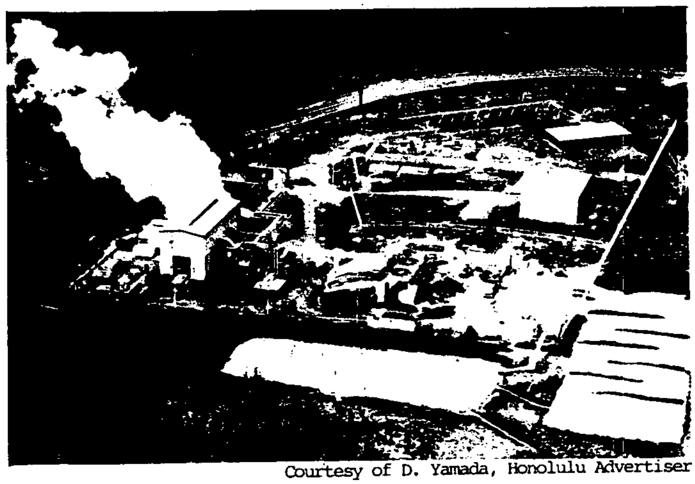

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Figure 3. HGP-A Site

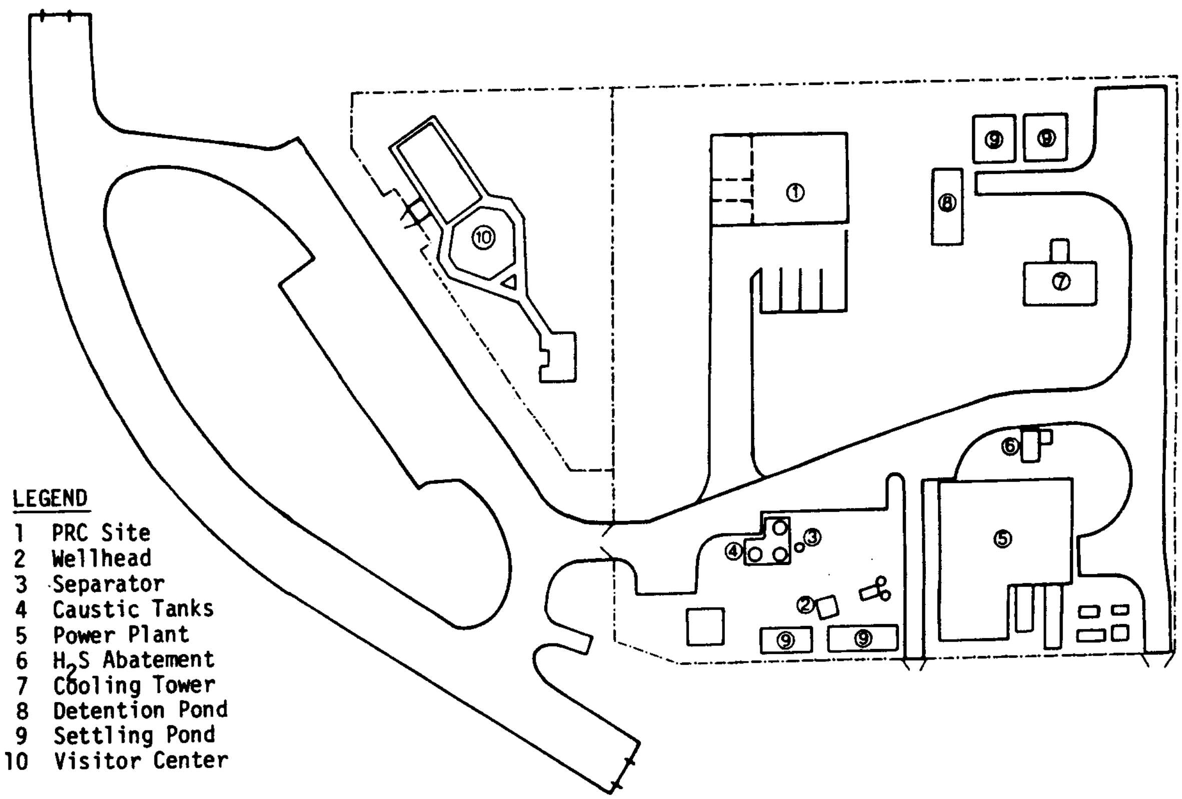

Figure 4. Schematic of HGP-A Site

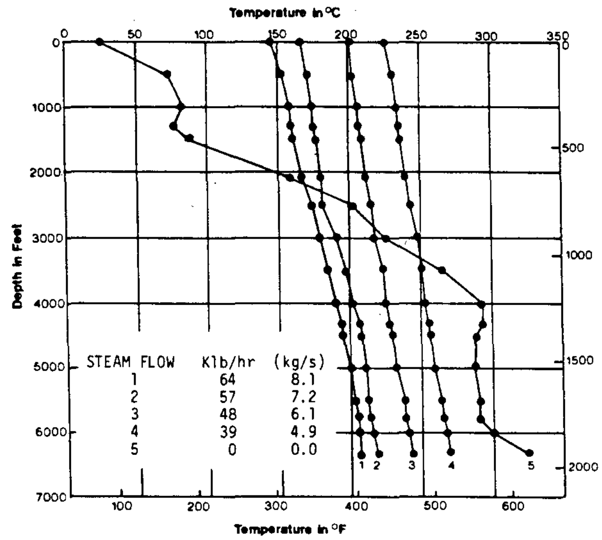

Figure 5. Temperature Profiles in HGP-A [1,2]

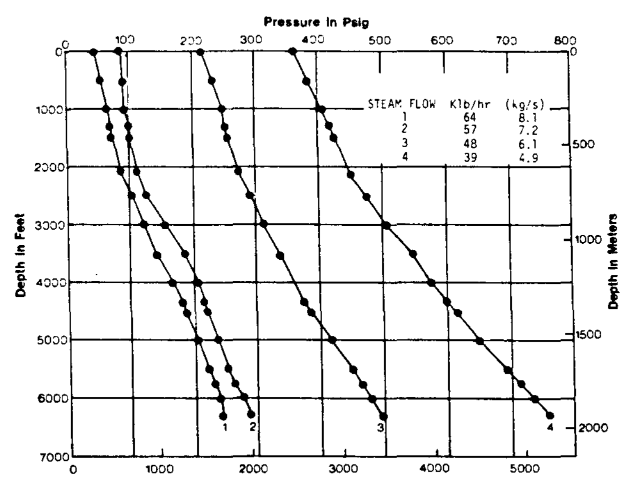

Figure 6. Pressure Profiles in HGP-A [1,2]