Geothermal Resources Council, TRANSACTIONS Vol. 7, October 1983

STATUS SUMMARY OF THE HGP-A GENERATOR FACILITY: 1983

Donald M. Thomas

Hawaii Institute of Geophysics, 2525 Correa Rd., Honolulu, HI 96822

ABSTRACT

The HGP-A Generator Facility has been in nearly continuous operation for approximately 15 months. During this period well flow and power plant output have been maintained at 49,900 kg/hr and 2.9 MWe respectively. The quality and chemical composition of the steam from the well has been quite stable, whereas the salinity of the brines produced has increased steadily. The operational performance of the steam supply system has remained within specifications whereas maintenance difficulties with trip and control valve hydraulics have been experienced. The hydrogen sulfide abatement systems for normal and standby conditions have proven to be quite effective, however, the operating costs of both systems have been found to be extremely high. Silica deposition rates within the brine control and disposal system have gradually increased since beginning operations and are presently considered to be the major impediment to continued operation of the facility. A major overhaul of the HGP-A Generator Facility is currently planned to take place in the near future.

INTRODUCTION

Construction of the HGP-A Generator Facility, located in Puna, Hawaii was completed in June 1981. During initial start-up operations a number of difficulties were encountered with both equipment performance and process design but, after approximately six months of shake-down, redesign and repair, the power plant began supplying power to the utility grid on March 1, 1982. Despite some operational and maintenance problems, the availability factor for the generator facility during the last year of operation has averaged approximately 95%. The operating experience gained during this period has provided valuable insight into both the production characteristics of the reservoir tapped by HGP-A as well as the performance capabilities of the power plant equipment operating with Hawaii geothermal fluids.

RESERVOIR PRODUCTION CHARACTERISTICS

During initial testing of the HGP-A well, total fluid discharge rates of approximately 49,900 kg/hr (110,000 lbs/hr) to 54,430 kg/hr (120,000 bs/hr) were achieved; a steam quality of approximately 60% to 70% was also measured during these tests (Chen et al., 1978). More recently, during extended production from HGP-A, the total flow rate from the well has stabilized at about 49,900 kg/hr. The steam quality, however, has shown significant variations. Under power generation conditions (1241 kPaa (180 psi) wellhead pressure) the steam quality has remained stable at about 43% and increasing or decreasing the wellhead pressure yields a nearly isoenthalpic change in steam quality. Substantial variations in the steam quality and flow stabilization have, however, been observed in the course of start-up procedures. In the past at HGP-A, the steam quality stabilized over a period of several days to an equilibrium value at a set, stable, wellhead pressure. During the December 1981 start-up the steam quality remained lower than expected for three to four weeks. It is of note that this start-up occurred after approximately 98 days of shut-in that was preceded by an 84 day production period. We currently believe that this initial decrease observed in the steam quality was caused by heat loss from the reservoir rock around the wellbore during the earlier extended production. This suggests that a shut-down of HGP-A in the future will require a considerably longer period for thermal recovery of the reservoir around the well bore. This type of behavior may also have important implications on the potential for "on-off" cycling of the future geothermal wells in Hawaii.

Changes in the chemical composition of the fluids discharged by HGP-A have followed trends very similar to those observed during the wells' earlier production history (Kroopnick et al., 1978; Thomas, 1980; Thomas, 1982a). The concentration of the major dissolved ions (Cl, Na, K, Ca) in the brine have continued to increase (Table I) whereas the silica concentration and brine have remained quite stable. Although a portion of the increasing ion concentration in the brine may have been due to changing steam quality during the earlier production, it now seems more probable that the continuing increase is due to the rapid reequilibration of dissolved silica to the temperature of the wellbore under production conditions. The concentration of non-condensable gases in the steam phase have remained very stable: the CO_2 concentration at approximately 1200 ppm, H_2S at 950 ppm, N_2 at 125 ppm, and H_2 at 11 ppm.

Table 1. Chemical Analyses of HGP-A Brines (mg/kg)

	Cl	Na	K	Mg	Ca	SiO_2
6-12-81	1593	806	154	0.02	18.5	1200
9- 4-81	3700	2190	250	0.1	72	800
12-22-81	3261	1745	2.81	0.04	58.3	1100
5-19-82	5489	3066	508	0.06	124	802
7-12-82	6044	3300	536	0.073	157	-
10-25-82	6383	3419	579	0.10	186	802
1- 7-83	6902	3769	582	.131	218	-
5-28-83	7990	-	-	-	-	-

Power Plant Operations and Performance

The HGP-A Facility is presently generating a gross output of 2.9 MWe; 0.2 MWe is being consumed within the power plant and the remainder is being transmitted to the utility grid. Although there has been no apparent decline in the plant output or efficiency during the last year of generation, some operational and maintenance problems have developed.

The general design of the HGP-A Facility is presented in Figures 1,2, and 3. The subsystems of major concern to the present discussion are: the steam supply system consisting of the primary wellhead separator, the demistor vessel, and associated transmission piping; the turbine-generator package consisting of the trip and control valves and the steam turbine; the steam exhaust system consisting of the condenser and hydrogen sulfide abatement system; the "stand-by" steam exhaust system consisting of a pressure control valve, a chemical injection system, and a rock muffler; and the brine disposal system consisting of transmission piping, an atmospheric flash chamber, silica settling ponds and percolation ponds.

Steam Supply System

The primary separator vessel and the secondary demistor have operated at a high level of efficiency since well start-up in December, 1981. Brine carryover through the primary separator has remained below 0.5% and that through the secondary demistor vessel has not been observed above 0.01% during testing efforts.

During the early shake-down period for the plant, oxidative corrosion was observed in the steam transmission lines and in the demistor vessel. This corrosion is thought to have been the result of repeated cyclic exposure of the piping system to the hydrogen sulfide rich geothermal steam and then to air. No evidence has been found that significant steam line corrosion has occurred since continuous operations began in March 1982; inspection and wall thickness measurements will be made on these lines during the power plant overhaul operations currently being planned.

Turbine Package

In the course of shake-down operations in mid-1981, deposition of the above mentioned steam transmission line corrosion products onto the turbine blades degraded the turbine balance to the point that a catastrophic vibration incident damaged the turbine rotor (Thomas, 1982b). By contrast, the performance of the turbine during the nearly continuous operations since March, 1981 has been quite good. There has been little, if any, increase in the critical speed vibration during turbine start-up and no appreciable loss in turbine efficiency since beginning on-line operations. This is interpreted to indicate that solids deposition on the fixed and rotating turbine blades has been relatively minor during normal operations. However, a recent inspection of the hand-valve chambers in the steam-chest have found some silica and iron sulfide accumulation in a "dead-end" section of the number 2 hand-valve chamber. Inspection of the internal portions of the turbine is thus considered to be essential in the near future.

The subsystem in the turbine package that has experienced the greatest difficulty during recent operations has been the turbine trip and control valves. Initially, a number of problems were encountered with valve seat creep in the control valves; these problems have apparently been solved by the installation of stiffened seating rings on these valves. Another malfunction that has continued up to the present has been the repeated failure of the control valve actuators that apparently is the result of their continuous "searching" action. At the present time it is believed that the "searching" action may be due to the accumulation of water and particulate material in the hydraulic system. Modifications to the routine maintenance procedures have been introduced in an effort to alleviate this problem.

Steam Exhaust System

The hydrogen sulfide concentration in HGP-A steam is comparitively high (Thomas, 1982a) and, as a result, a surface condenser and an incenerator-scrubber hydrogen sulfide abatement system have been installed downstream of the turbine to deal with the non-condensable gases.

The performance of the surface condenser has been excellent throughout the operation of the generator facility. Neither ammonia nor boron have been detected in the HGP-A steam and, hence, partitioning of the non-condensable gases has been very favorable; less than 0.7% of the hydrogen sulfide in the steam phase remains with the condensate water which is recycled to the cooling tower.

The abatement efficiency of the incinerator-scrubber package has been found to be very high under optimal operating conditions; less than 0.1% of the hydrogen sulfide feed gas is emitted as sulfur dioxide. However, a number of problems have been encountered in its operation. Initially, inadequate air feed did not permit complete combustion of the hydrogen sulfide resulting in

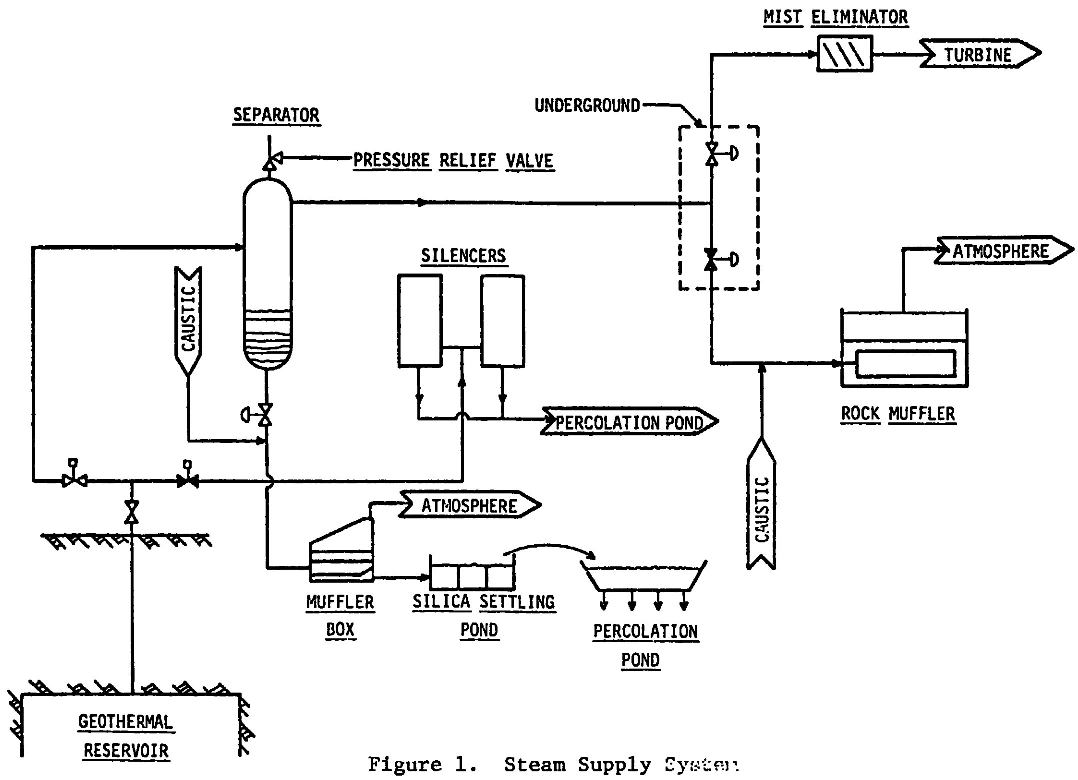

Figure 1. Steam Supply System

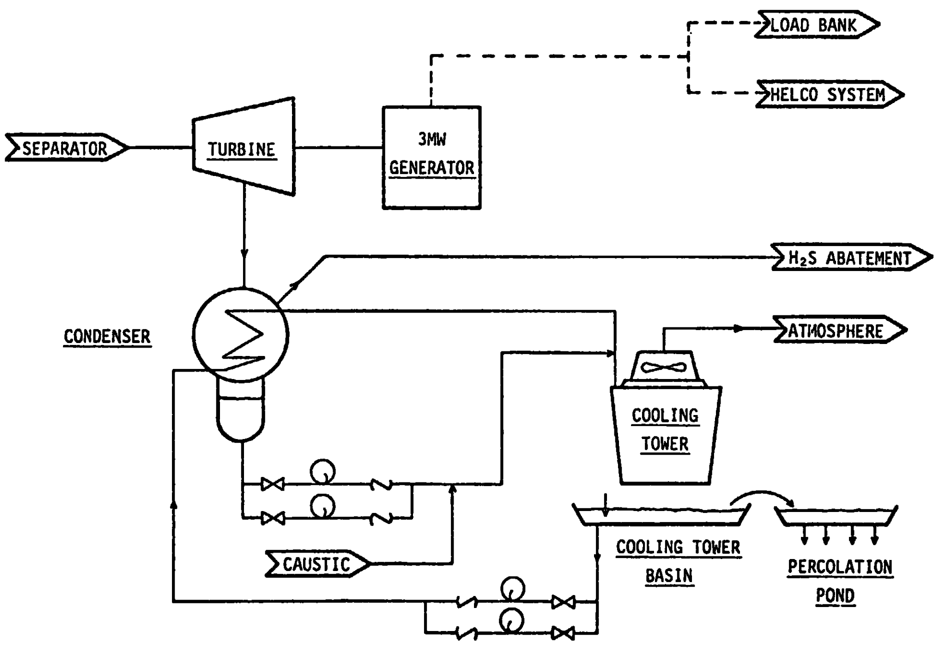

Figure 2. Turbine Generator System

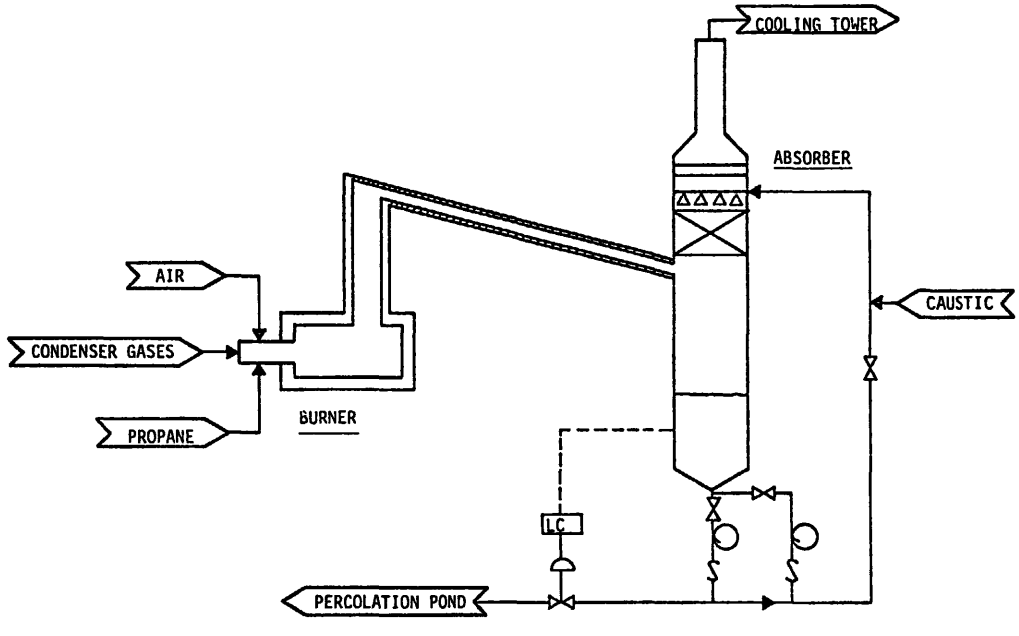

Figure 3. Incenerator-Scrubber System

elemental sulfur formation downstream of the incinerator. Sulfur deposition in the scrubber column packing resulted in rapid plugging and a high pressure drop across the column. Modification of the air feed system to increase the air supply rate, to twice the stoichiometric air requirement, alleviated this problem for routine operations. However, occassional recurrance of "flame out" conditions in the incinerator tank continue to generate a gradual build-up of sulfur in the column packing.

A second aspect of the incinerator scrubber abatement system that has caused considerable concern has been its operating costs. At the present timé the chemical costs for the caustic soda required for sulfur dioxide removal average more than $700/day. This cost is equivalent to about 30% of the gross revenues generated by the power plant from the sale of electricity. Attempts to reduce the chemical feed rate have resulted in substantially reduced abatement efficiencies and increased corrosion rates in the effluent disposal system. An evaluation of the utility of this abatement system in larger geothermal power plants in Hawaii also suggests that, presuming similar steam chemistry to HGP-A, the operating costs of this type of system will scale up on a 1:1 basis with plant size. Largely due to the costs of this systems, we are currently evaluating the feasibility of installing one of several alternative H_2S abatement systems that will provide equivalent abatement efficiencies at a somewhat reduced operating cost.

Standby Steam Exhaust System

This standby system is the primary steam disposal method used whenever the turbine cannot accept steam provided by the well. Its primary function is to abate both the noise and the hydrogen sulfide emissions that would be created by the direct release of the well flow to the atmosphere.

Noise abatement is accomplished by accoustic muffling of the pressure control valve and by a sparger and rock muffler at the steam discharge point. This design has been quite successful, reducing the ambient noise level from about 74 dbA at a distance of 30m under direct venting conditions to about 44 dbA at the same location under abated conditions.

Hydrogen sulfide is removed by the direct injection of caustic soda into the steam line downstream of the pressure reduction valve and upstream of a static mixer spool. During initial operations the maximum abatement efficiency obtained with this system was approximately 70% to 92%. More recently however, installation of spray nozzels on the caustic injection lines has improved the abatement levels to about 95%. The operating costs of this system are also quite high: approximately $1000/day.

Brine Disposal System

The major technical difficulty being faced in the continued operation of the HGP-A Facility is associated with the brine disposal systems. As currently designed, the pressurized brine discharge from the primary separator is passed through a level control valve to an atmospheric flash chamber. The flashing process reduces the brine temperature from approximately 190°C (375°F) to 100°C (212°F) and reduces the brine volume by about 16% through steam formation. The loss of dissolved CO_2 and H_2S from the brine to the steam phase increases the brine pH from about 7.0 to about 8.0.

As a result of the temperature and pH changes during the secondary flashing process, colloidal silica formation is induced in the low temperature brines. During initial operations the colloidal silica showed little tendency to precipitate of its own accord. (Early efforts to abate hydrogen sulfide emissions from the brine by caustic injection did, however, indicate that a significant increase of the brine pH (above 9.5) led to a very rapid flocculation of the colloidal silica into a wet gelatinous mass (Thomas, 1982b). Modifications to the abatement process eliminated this problem but, more recently, as the salinity of the fluids has increased, the precipitation of vitreous, sinter-like, silica scale within and downstream of the flash chamber has increased substantially. This has led to plugging problems downstream of the atmospheric flash chamber in the piping and the brine disposal ponds.

Although we have been unable to thoroughly inspect the brine discharge lines upstream of the flash chamber, there is some evidence that silica precipitation is occurring there as well; several small diameter "dead end" or intermittant flow ports attached to the brine line have shown a tendency to form short silica plugs immediately adjacent to the connection point. We have not however, observed a significant increase in the pressure drop through the brine line upstream of the level control valve and hence we believe that silica precipitation here is considerably slower than that occurring downstream of the level control valve.

Modifications to the brine disposal system are being planned for the near future that may alleviate some of the deposition problems, however, experimental investigations will have to be considered before anything more than a temporary solution will be possible.

Auxiliary Equipment

With a few exceptions the subsidary plant equipment (pumps, flow meters, level sensors, etc.) have operated within expectations. The most important exception is the steam and brine flow metering equipment. Despite frequent recalibrations the accuracy of the data provided by this equipment has proven to be marginal at best. The apparent source of the problems with this equipment is particulate build up adjacent to the venturi constrictions in the brine and steam transmission lines. We have not as yet devised a solution to this problem.

The major source of difficulties with other auxiliary equipment seems to be due to the fact that the design life for this demonstration project was set at two years. Refitting of pump internals and some piping with more durable materials may be able to extend the useful life of the HGP-A Facility to five or possibly ten years.

FUTURE OPERATIONS

The HGP-A Generator Facility has now been in nearly continuous operation for approximately 15 months. A thorough examination of the internal components of the steam supply system, the turbine generator package, and the brine disposal system is becoming increasingly necessary. Planning for a major overhaul is currently underway and numerous options are being considered, ranging from a complete shut down of the facility and overhaul of the entire system, to a subunit by subunit repair interspersed with normal operations. The former option would require a period of from 90 to 120 days for well recovery (with attendant lost revenue) whereas the latter could allow for continued revenue generation until shut-down of the turbine for overhaul is required. Availability of funding may dictate the course of action ultimately taken.

Planning is also underway to install one or more alternative hydrogen sulfide abatement systems on the facility to test their technical and economic feasibility. The abatement systems under consideration have not here-to-fore been used on geothermal power plants and may provide very valuable information for future design of full scale geothermal plants.

SUMMARY

The HGP-A Geothermal Facility, after more than a year of operation, has successfully demonstrated the technical feasibility of generating electrical power from Hawaii's geothermal resources. Some subsystems of the plant have proven more successful than anticipated whereas others have been less so. The experience gained at the HGP-A Facility since start-up will generate improvements in the design of future geothermal plants in Hawaii that should allow them to be both technically and economically successful.

REFERENCES

Chen, B.H., Kihara, D.H., Yuen, P.C. and Takahashi, P.K., 1978, Well Test Results From HGP-A, Transactions of the Geothermal Resources Council, Vol. 2, pp. 99-102.

Kroopnick, P.M., Lau, L.S., Buddemeier, R.W., and Thoams, D., 1978, Geochemistry of a Hawaii Geothermal Well: HGP-A, Transactions of the Geothermal Resources Council, Vol. 2, pp. 375-378.

Thomas, D.M., 1980, Water and Gas Chemistry From HGP-A Geothermal Well: January 1980 Flow Test, Transactions of the Geothermal Resources Council, Vol. 4, pp. 181-184.

Thomas, D.M., 1982a, A Geochemical Case History of the HGP-A Well, 1976-1982, Proceedings of the Pacific Geothermal Conference, 1982 and the 4th New Zealand Geothermal Workshop, pp. 273-278.

Thomas, D.M., 1982b, Process Chemistry Monitoring at the HGP-A Power Plant: Analytical Results, Process Problems and Modifications, Transactions of the Geothermal Resources Council, Vol. 6, pp. 401-404.