Geothermal Resources Council, TRANSACTIONS Vol. 4, September 1980

PROGRESS REPORT ON HGP-A WELLHEAD GENERATOR FEASIBILITY PROJECT

Bill H. Chen and Louis P. Lopez

The Research Corporation of the University of Hawaii

James T. Kuwada and Ray J. Farrington

Rogers Engineering Co., Inc.
San Francisco, California

ABSTRACT

The HGP-A Well underwent a substantial workover last fall. A new tie-back 7" casing was installed from surface to 3000 ft. A two-week test was conducted in January, 1980, with full hydrogen sulfide and noise abatement. Preliminary test results showed a slight increase in total mass flow. Both noise and odor abatement were shown to be very effective. As a result of the two week test, some changes have been made to the final design, and the projected plant on-line date has been extended to 3/31/80.

WELL WORKOVER

The HGP-A Well on the Big Island of Hawaii was drilled by the University of Hawaii's Hawaii Geothermal Project in 1976 (Ref. 1). After setting the 20" conductor and 17-3/8" surface casing, the 9-5/8" production casing was set from the surface to ~ 2200 ft. below surface, and a slotted liner was set off bottom from total depth at 6400 ft. to ~ 2100 ft. below surface. Prior to the well workover the wellhead pressure during shut-in periods was approximately 140 psig, and the temperature profile inside the casing (See Fig. 1) was low until it reaches the 9-5/8" casing shoe.

However, after the well flow test in November, 1978, the static wellhead pressure began to increase gradually to over 500 psig by January, 1979, and the temperature profile in the casing showed a dramatic rise, especially in the section from ~ 1400 ft. to the bottom of the 9-5/8" casing shoe. Furthermore, a gas cap formed in the wellbore during static condition, which was not observed prior to November, 1978. These phenomena led us to speculate that there was either a break in the casing which permitted hot fluids to circulate inside of the wellbore, or that the cement anchoring of the casing to the formation had deteriorated, allowing well fluids to migrate upward on the outside of the casing.

A casing caliper log and a cement bond log were run in May, 1979 to determine whether there was a break in the casing and/or that the cement had deteriorated. No apparent break in the casing was detected. However, substantial deterioration of the cement bond was confirmed and the fact that high temperature cement had not been used in the original cementing program prompted the project to contact a drilling contractor to perform a casing perforation and cement squeeze job as part of the well workover.

Water Resources International, a local drilling contractor, was selected to perform the day work. Mr. Sheldon Hopkins of Global Geothermal served as the drilling supervisor and Mr. James Kuwada of Rogers Engineering was the drilling consultant. The workover started on September 15, 1979 and was completed on October 18, 1979 with a short four-hour flow test to confirm the success of the well workover. During the workover, the 9-5/8" casing was perforated at several intervals and high temperature cement was squeezed particularly around the 9-5/8" production casing shoe and around the 13-3/8" anchor casing shoe. A portion of the 7" slotted liner from approximately 2100 to 3000 ft. was cut and removed. This zone which was a production zone of lower temperature water was cemented off after a new 7" tie-back casing string was run in and attached to the slotted liner and run back to surface. A cement bond log was taken after the cementing of the 7" casing and over 80% bond was shown on the entire string.

WELL TEST

After the well workover, a wellhead steam separator and flow test system was installed so a two week test could be performed to verify the following: quantity of steam flow, the quantity of non-condensible gases and percentage of H_2S present, to check out the steam collection system which will be used in the final power plant operating system, to prove out the effectiveness of the caustic/peroxide H_2S abatement system, and the noise abatement system specifically designed for the test.

The steam collecting system and its associated test equipment included the wellhead christmas tree, steam-water separator, control valves and flow venturis, H_2S abatement system, and noise abatement system.

After the steam is separated from the hot water in the separator, the steam flow is metered prior to discharge through the pressure control valve. Ten percent caustic solution and fifty percent hydrogen peroxide solution are sequentially sprayed into the steam line which contains sections of static mixer following each spray. The static mixer consists of a series of doughnut shaped rings placed inside the pipe to force the sprayed liquid to thoroughly mix with the steam and react with the H_2S to form hydro-sulfide. The treated steam is allowed to flow to a rock pit where the steam flows through a perforated diffuser pipe and then through a five-foot layer of 1" to 1-1/2" crushed rock.

The results of the flow test are summarized in Table I. Table II is an abbreviated version of the well flow data performed in 1977, duplicated here for comparison purpose (Ref. 2). The noncondensible gases and the water chemistry will be reported separately by Dr. Donald Thomas of the Hawaii Institute of Geophysics.

The rock muffler was very effective. In general a 30 dbA noise reduction was experienced at almost all stations around the wellhead as compared to the old twin stack cyclone separator arrangement.

The stoichoimetric mole ratio of sodium hydroxide to hydrogen sulfide is two and that of hydrogen peroxide is four. The caustic actually determines the H_2S abatement because it reacts with H_2S and removes it from the steam as a hydro sulfide in liquid phase. The hydrogen peroxide merely serves to oxidize the hydrosulfide to a sulfate so it cannot revert back to H_2S as it would if the hydrosulfide steam became acidified.

This caustic/peroxide abatement system was first tried successfully at the Geysers during air drilling operation and FMC furnished us with data developed at Geyser (Ref. 4). This data showed that in order to achieve approximately 92% abatement, the system had to deliver 7 moles of caustic per mole of H_2S and 4.5 moles of hydrogen peroxide per mole of H_2S. Our system was designed to provide that capacity.

During the two week test, analysis showed approximately 16 ppm of H_2S in the untreated brine from the bottom of the separator and approximately 774 ppm of H_2S present in the steam phase. Table III summarizes our preliminary results with caustic injection only. The analysis of the H_2S in the steam discharged from the rock muffler was determined with Draeger tube.

The extreme effectiveness of the caustic treatment was attributed to the static inline mixers that were installed. The rock muffler also contributed to the effectiveness because the rock surfaces provided an extremely large amount of wetted interfacial area of contact for the H_2S and caustic.

When hydrogen peroxide was injected at the equivalent rate of 4.1 moles/mole H_2S, we observed a remarkable change of color of liquor from the rock muffler drain. The color changed from the black sulfide to water white soluble sulfate. However, since the liquor from the rock muffler drain immediately percolates into the ground through lava tubes and there is little opportunity for the liquor to become acidified and to release H_2S, the peroxide system is probably not necessary in the treatment.

The effectiveness of this caustic treatment system will be verified and retested in February, 1981 prior to the starting-up of the power plant. More precise instrumentation and measurements will be employed to determine the effects of the inline static mixers, residence time and the rock muffler.

POWER PLANT

Due to the extreme effective performance of the H_2S abatement system during the two week test, the caustic/peroxide abatement system and the rock muffler will be retained for the final power plant design as the emergency abatement system when the turbine trips out. Table IV summarizes the major equipment procurement and their suppliers (See Ref. 3 for design considerations). The projected plant-on-line date is March 31, 1981.

TABLE I
THROTTLED FLOW DATA 1/3/80 - 1/18/80

Separator Pressure (PSIG)	Total Mass Flow Rate (Klb/hr)	Steam Flow Rate (Klb/hr)	Water Flow Rate (Klb/hr)	Steam Quality (%)
56	111.5	70.9	40.6	63.6
110	110.3	64.7	45.6	58.7
132	108.0	61.0	47.0	56.5
161	105.9	56.6	49.3	53.4

TABLE II
THROTTLED FLOW DATA 1/26/77 - 2/10/77

Wellhead Pressure (PSIG)	Total Mass Flow Rate (Klb/hr)	Steam Flow Rate (Klb/hr)	Water Flow Rate (Klb/hr)	Steam Quality (%)
54	99	65	34	66
100	93	57	36	64
165	89	54	35	60

TABLE III
H_2S ABATEMENT DATA 1/3/80 - 1/18/80
(CAUSTIC ONLY)

Caustic/H_2S Mole Ratio	H_2S in Discharged Steam	% Abatement in Steam Phase	% Abatement in Total Flow	pH
1.5	91	88	86	7
2	20	97	95	11
3.2	6	99	97	> 11
8	1	99	98	> 11

TABLE IV
MAJOR EQUIPMENT FOR HGP-A WELLHEAD GENERATOR
FEASIBILITY PROJECT

Equipment	Supplier	Major Feature
Turbine/Generator	Elliott	6 stage turbine, inlet pressure = 160 psig., exhaust pressure = 4" Hg., output = 3MW
Condensors	Graham	Surface type units, inter and after condensers are integrally stacked.
Cooling Tower	Marley	All redwood construction, twin towers, common basin.
H_2S Abatement	John Zink	Incinerator and scrubber
Separator	Peerless	Capable of producing 99.95% dry saturated steam at 160 psig.

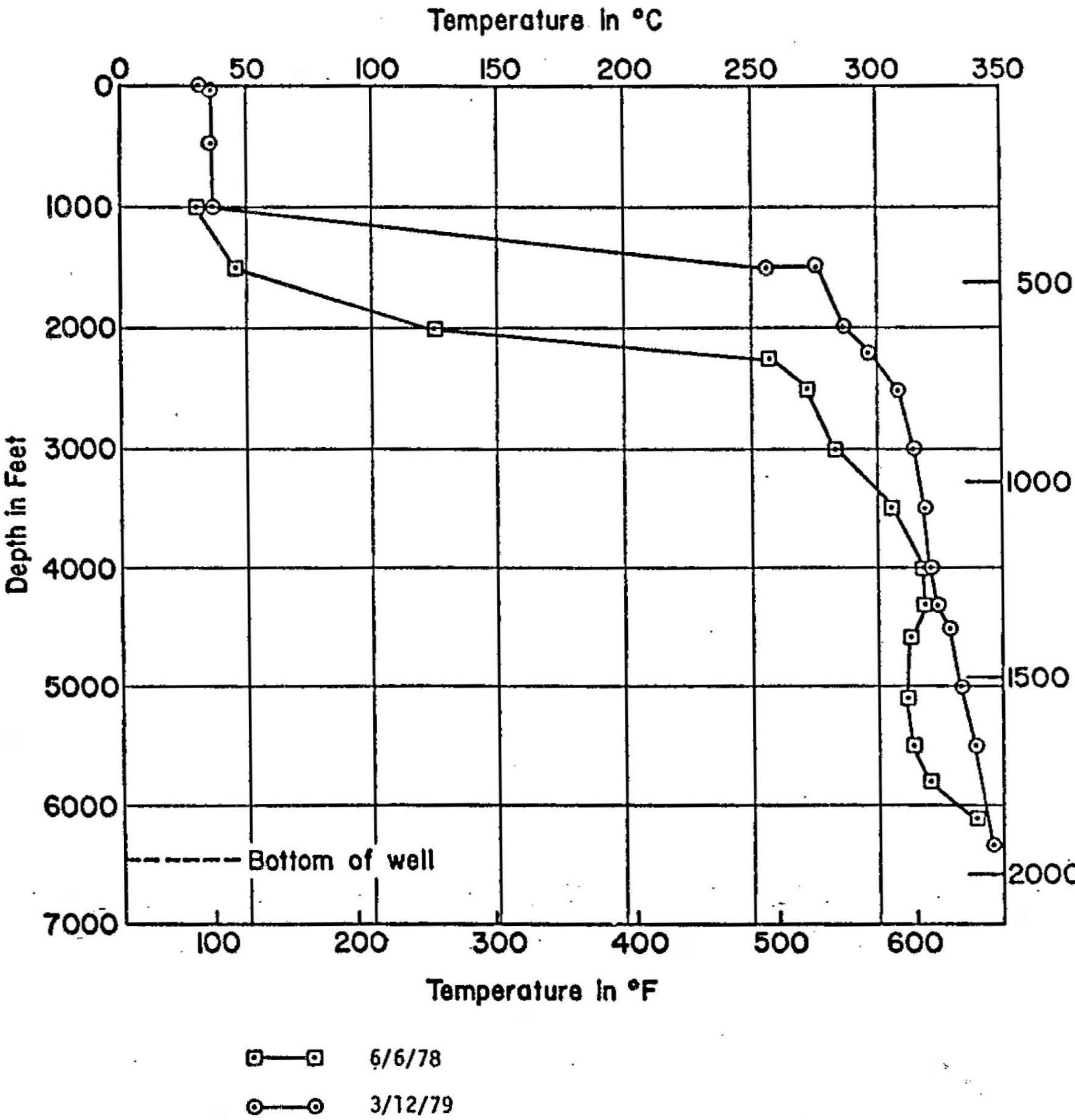

Figure 1 Temperature Profiles of HGP-A Well.

ACKNOWLEDGMENTS

This work is performed under the Department of Energy Contract DE-AC03-78ET28420, and fundings from the State and County of Hawaii and Hawaii Electric Light Company.

The authors would also like to thank the University of Hawaii's Hawaii Geothermal Project for their assistance in conducting the two-week well test. In particular, Drs. Paul Yuen, Deane Kihara, Mr. Art Seki and Ms. Ellen Kitamura.

REFERENCES

1. Kingston, Reynolds, Thom & Allardice Limited, Hawaii Geothermal Project Well Completion Report, HGP-A.
2. 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, p. 99-102.
3. Chen, B.H., Lopez, L.P., Farrington, R.J., Kuwada, J.T. and Uemura, R.T., 1979, HGP-A Wellhead Generator Project, Transactions of the Geothermal Resources Council, Vol. 3, p. 103-106.
4. Castrantas, Harry, FMC, private communication.