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DISCLAIMER

INSTRUMENTATION AND TEST RESULTS FOR HAWAII GEOTHERMAL PROJECT'S HGP-A WELL

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With the completion of the drilling of HGP-A and indications of extremely high bottom hole temperatures, the next major phase in the Hawaii Geothermal Project is a test and analysis program designed to determine the properties of the well, the fluid, and the reservoir. The program described below was formulated as a first step to obtain this information.

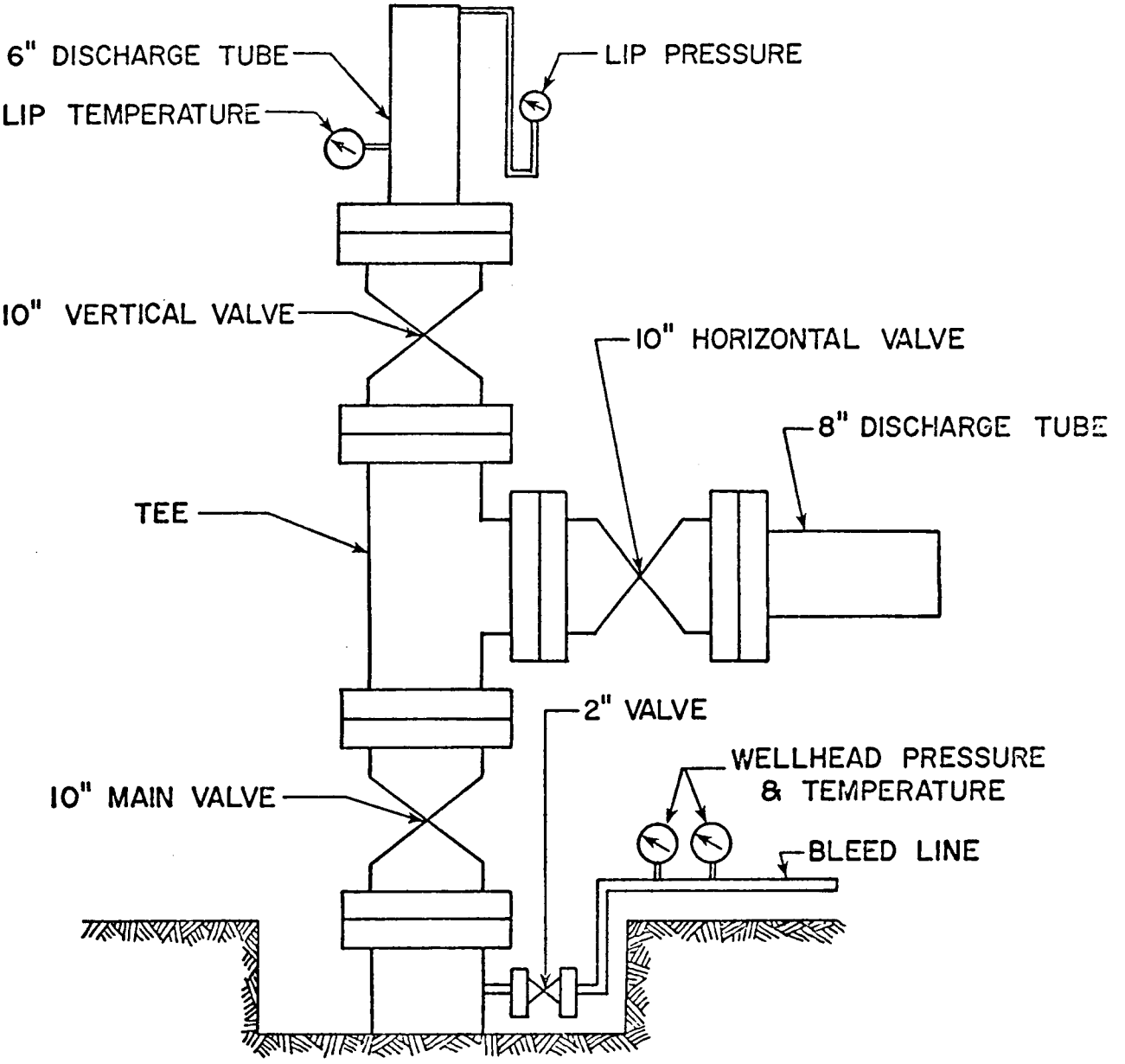
The objectives of the well test and analysis program are:

1. Determine well and reservoir characteristics.
2. Obtain data useful for drilling future wells.
3. Determine problem areas and possible solutions relative to well production.
4. Determine possible environmental problems.
5. Remedy possible skin damage in well.

Drilling of HGP-A was completed on April 27, 1976. The slotted liner at the bottom of the well was installed during the period May 27 to June 1. Water injection tests were completed on June 6 using the mud pumps that were still present at the drill site. HGP-A has been flashed four times for varying periods, once on July 2, a second time on July 19, a third time on July 21 to check instrumentation, and then a longer period of four hours on July 22 to obtain preliminary values for wellhead pressure and temperature, and total mass flow rate. Beginning April 29, temperature and pressure profiles in the wellbore have been obtained at various times, and beginning August 19, water at different depths in wellbore has been sampled in order to obtain chemical analyses of the water.

The four-hour well flashing on July 22 was accomplished using the wellhead instrumentation shown in Figure 1. The sonic flow, lip pressure method of James[1] was used to obtain total mass flow with lip pressure being measured at the end of a vertical 6"

[1] James, Russell, "Measurement of Steam-Water Mixtures Discharging at the Speed of Sound to the Atmosphere." New Zealand Engineering, pp. 437-41, October 1966.



SCHEMATIC OF HGP-A WELLHEAD INSTRUMENTATION

Figure 1

discharge tube. In addition, an 8" discharge tube mounted horizontally was also flowed for a brief time. Wellhead pressure and temperature were obtained from a bleed line controlled by a 2" valve.

Results of the four-hour flashing are shown in Figure 2 which gives wellhead and lip pressure. The lip pressure at the end of four hours was 23 psig, which corresponds to a mass flow of about 220,000 lbs. per hour, assuming a specific enthalpy of 600 BTU per lb. Using this figure for specific enthalpy and assuming a conversion efficiency of 15% leads to a usable electric power equivalent to a little over 5 megawatts.

Figure 3 are plots of temperature versus depth and pressure versus depth for HGP-A for the indicated times after the flashing on July 22, 1976. The temperature profile obtained one week after the flashing was fairly close to equilibrium, except that the portion of the well that is cased continues to decrease slowly in temperature. The temperature profiles also appear to indicate that the major production region is probably between 3,500 and 4,500 feet and that a lesser producing zone of probably lower temperature may exist around 6,000 feet.

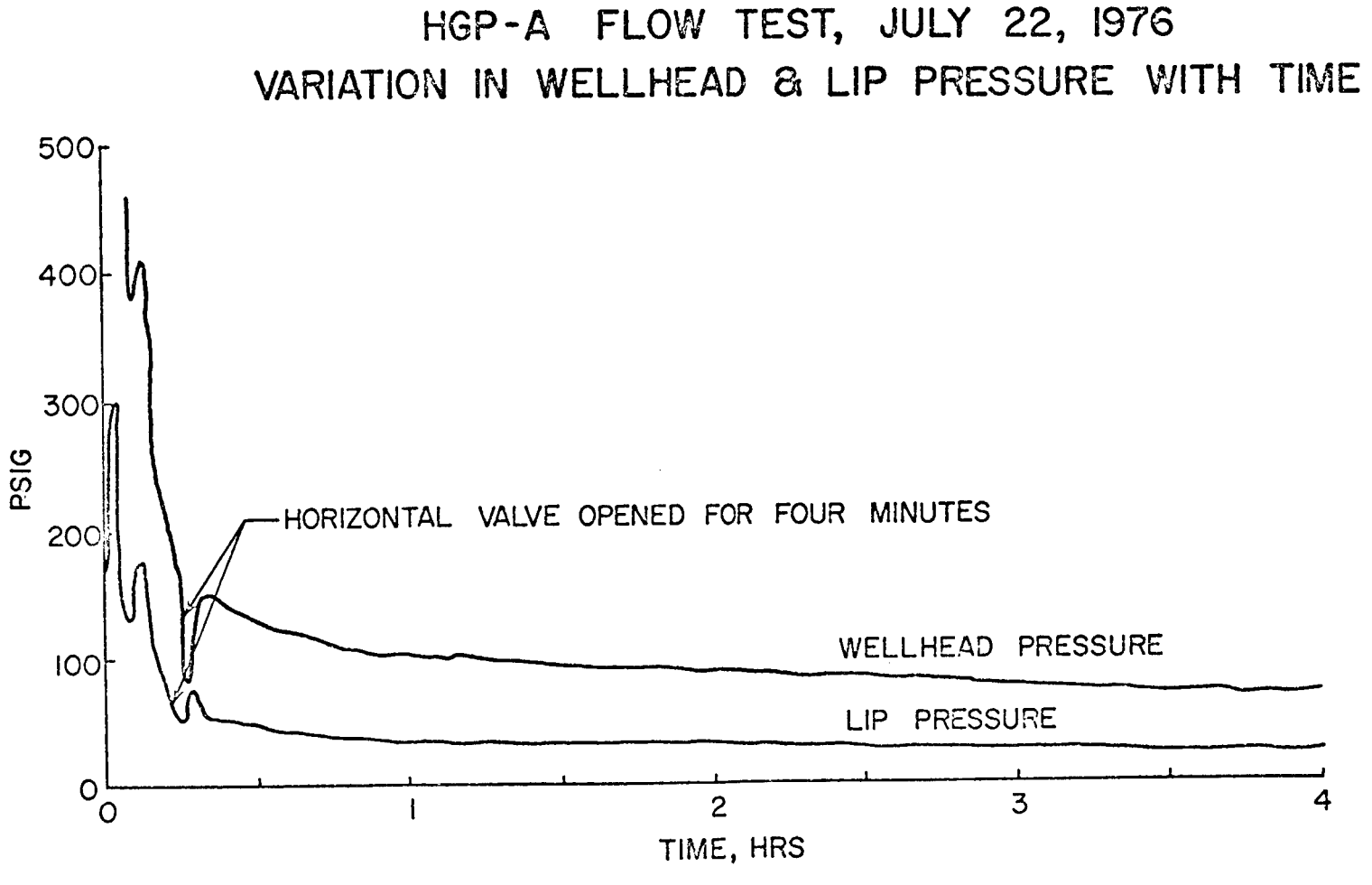
The following tests and analyses are planned for the next period:

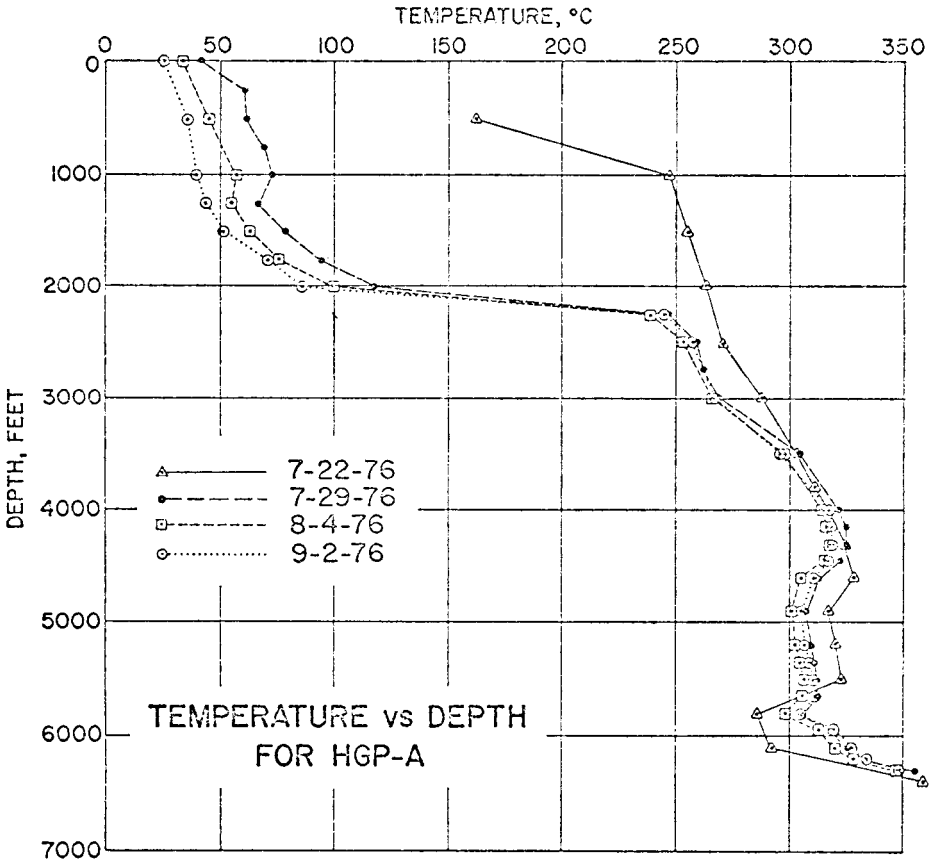
1. Temperature and pressure profiles
2. Sustained long-term discharge
3. Variable flow-rate discharge
4. Pressure drawdown and buildup
5. Steam quality
6. Cold fluid influx
7. Interference tests using observation waterwells
8. Scaling and corrosion effects of effluent
9. Chemical analyses of downhole water samples

Figure 4 is a sketch of the equipment and instrumentation for the discharge test. As shown, the method involves basically the James technique for measuring total mass flow with twin cyclone separators for silencing and separation of steam and water. A 90^{o} V-notch weir is used to measure the liquid flowrate, permitting steam quality and specific enthalpy to be calculated. In addition, a calorimeter will be used to provide an independent measurement of the specific enthalpy. A 2" twin cyclone sampler will be used to obtain gas and vapor samples for chemical analyses and a recovery tube will be mounted on the wellhead to permit temperature and profiles to be obtained during the flow test.

In order to heat up the casing slowly and prevent damage, the well will be flowed through the 2-inch bleed line with the flow

FIGURE 2.


HGP-A FLOW TEST, JULY 22, 1976
VARIATION IN WELLHEAD & LIP PRESSURE WITH TIME
500
400
300
200
100
0
PSIG
HORIZONTAL VALVE OPENED FOR FOUR MINUTES
WELLHEAD PRESSURE
LIP PRESSURE
0
1
2
3
4
TIME, HRS


TEMPERATURE, °C
0
50
100
150
200
250
300
350
DEPTH, FEET
0
1000
2000
3000
4000
5000
6000
7000
7-22-76
7-29-76
8-4-76
9-2-76
TEMPERATURE vs DEPTH
FOR HGP-A

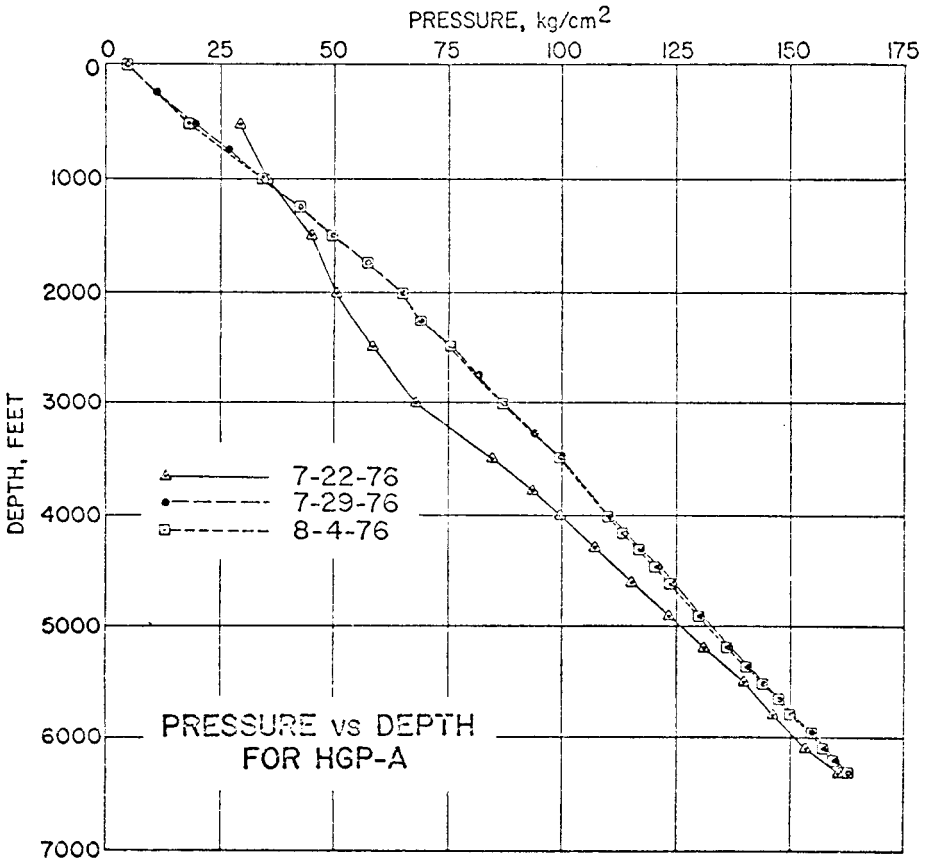
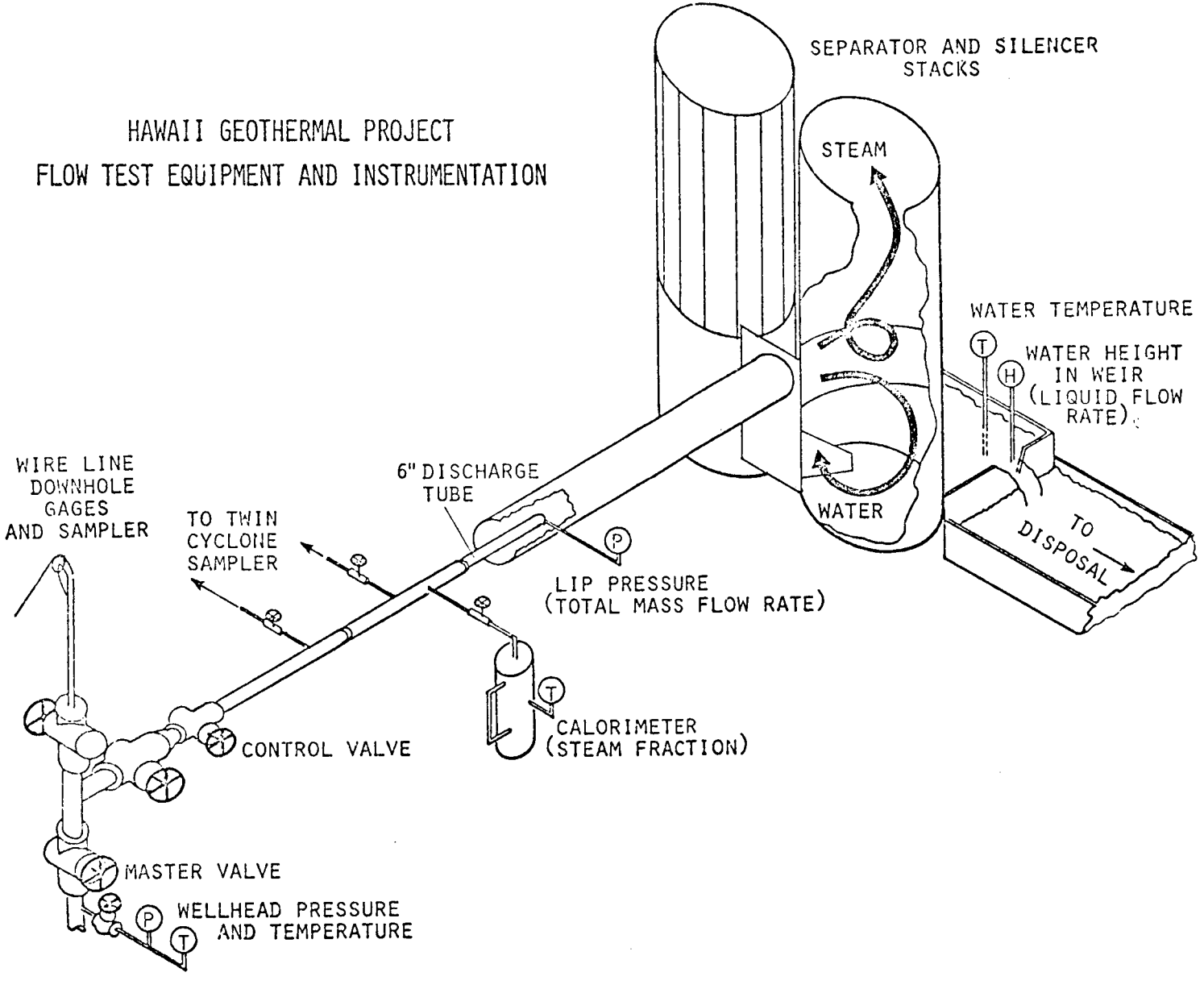

PRESSURE, kg/cm2
0
25
50
75
100
125
150
175
DEPTH, FEET
0
1000
2000
3000
4000
5000
6000
7000
7-22-76
7-29-76
8-4-76
PRESSURE vs DEPTH
FOR HGP-A

Figure 3

FIGURE 4.


HAWAII GEOTHERMAL PROJECT
FLOW TEST EQUIPMENT AND INSTRUMENTATION
SEPARATOR AND SILENCER STACKS
STEAM
WATER TEMPERATURE
WATER HEIGHT IN WEIR (LIQUID FLOW RATE)
WATER
TO DISPOSAL
WIRE LINE DOWNHOLE GAGES AND SAMPLER
TO TWIN CYCLONE SAMPLER
6" DISCHARGE TUBE
LIP PRESSURE (TOTAL MASS FLOW RATE)
CALORIMETER (STEAM FRACTION)
CONTROL VALVE
MASTER VALVE
WELLHEAD PRESSURE AND TEMPERATURE

increased gradually until flashing flow is achieved. Once the temperatures of the system are at operating levels, tests to determine the production capacity of HGP-A will be undertaken. During this phase, the well will be allowed to flow at various fractions of wide open flow. Measurements taken during this series of tests will allow determination of production flow rate and steam fraction as functions of wellhead conditions. This information, along with chemical analyses of samples of steam, liquid, and noncondensable gases, will aid in the future selection of an energy conversion system--whether it be a permanent unit or a small portable unit to be used in conjunction with further testing of HGP-A.

A longer term, sustained discharge test will follow for the purpose of estimating reservoir characteristics. For this phase, the well will be flowed at a constant rate for periods of two weeks or longer and transient pressure measurements taken at the bottom of the well. The pressure drawdown and buildup (after the well is shut in) data will allow a rough estimate of the permeability and extent of the reservoir to be made. Also to be measured are the characteristics of the effluent (temperature, specific enthalpy, chemical composition, etc.) in order to detect any changes in the producing zones or alleviation of possible skin damage.

In conjunction with these sustained long-term discharges, the water levels of several water wells in the immediate vicinity will be monitored. Any measurable changes will be incorporated in the evaluation of the reservoir.

Concurrent with the well production testing and reservoir evaluation phases, tests will be conducted to evaluate the scaling and corrosion effects of the effluent. Specimens of various materials will be located on the separator wall and in the liquid behind the weir.

Throughout the course of the well testing program, downhole water samples and temperature and pressure profiles will be taken during those intervals when the well is shut in or is being bled through the 2-inch bleed line.