SGP - TR - 30

CONF-781222-17

PROCEEDINGS
FOURTH WORKSHOP
GEOTHERMAL RESERVOIR ENGINEERING

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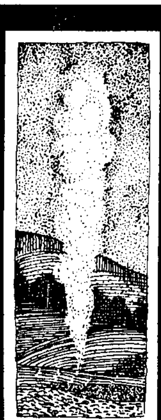
Editors

December 13-15, 1978



Stanford Geothermal Program
INTERDISCIPLINARY RESEARCH
IN ENGINEERING AND EARTH SCIENCES
Stanford University, Stanford, California

LOCATING THE PRODUCING LAYERS IN HGP-A

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The characteristics of the Hawaii Geothermal Project well HGP-A were presented last year in terms of flow rates under throttled conditions, downhole pressure and temperature profiles, and pressure drawdown and buildup tests. In particular, the more recent pressure buildup analyses have indicated the possibility of multiple production zones. In an attempt to locate these production zones, two tests have been conducted during the past six months.

A direct means of determining the locations of the permeable layers is to measure the flow rates at the suspected depths. However, two difficulties immediately arise. Since the flow in HGP-A is a mixture of saturated liquid and vapor, the mass flow rate cannot be measured using a conventional spinner (which is a volumetric flow meter). Furthermore, the temperature encountered in the wellbore exceed the temperature limits of that instrument. To circumvent both of these difficulties, the well was allowed to produce only under severely throttled conditions. This had the effect of keeping the well fluid in a liquid state at temperatures well within the capability of the flow meter. The flow meter setup used for the production and pumpdown tests is shown in Figure 1.

The presence of a slotted liner in the bottom 4200 feet of the wellbore does not allow unequivocal interpretation of the data; however, a comparison of the maximum flow rate measured within the slotted liner and that measured at the weir on the surface shows that only a small fraction of the flow passes through the annular region outside the slotted liner.

The results for a flow meter run are shown in Figure 2. The well was producing at a flow rate of 44 gallons/minute of liquid only (22,000 lb/hr) as compared to 100,000 lb/hr of 65% quality steam at wide open conditions. This indicates that for these slow, all-liquid flow conditions, roughly 75% of the production is occurring between the depths of 4550 to 6250 feet.

The second series of tests consisted of cold water being pumped downhole at 115 gallons/minute while temperature and flow rate were monitored at selected depths. In all of the attempts,

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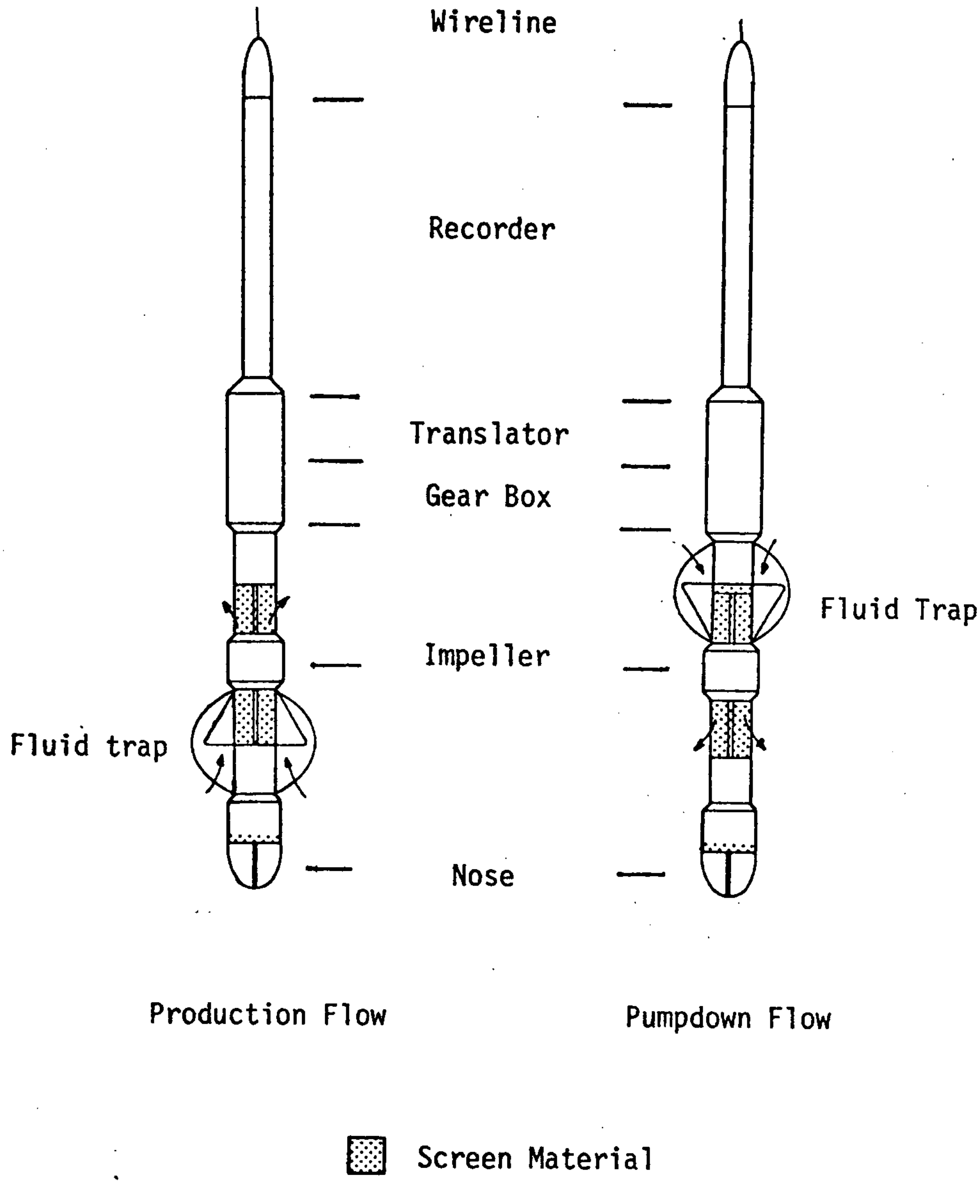

Figure 1. Flowmeter Setup

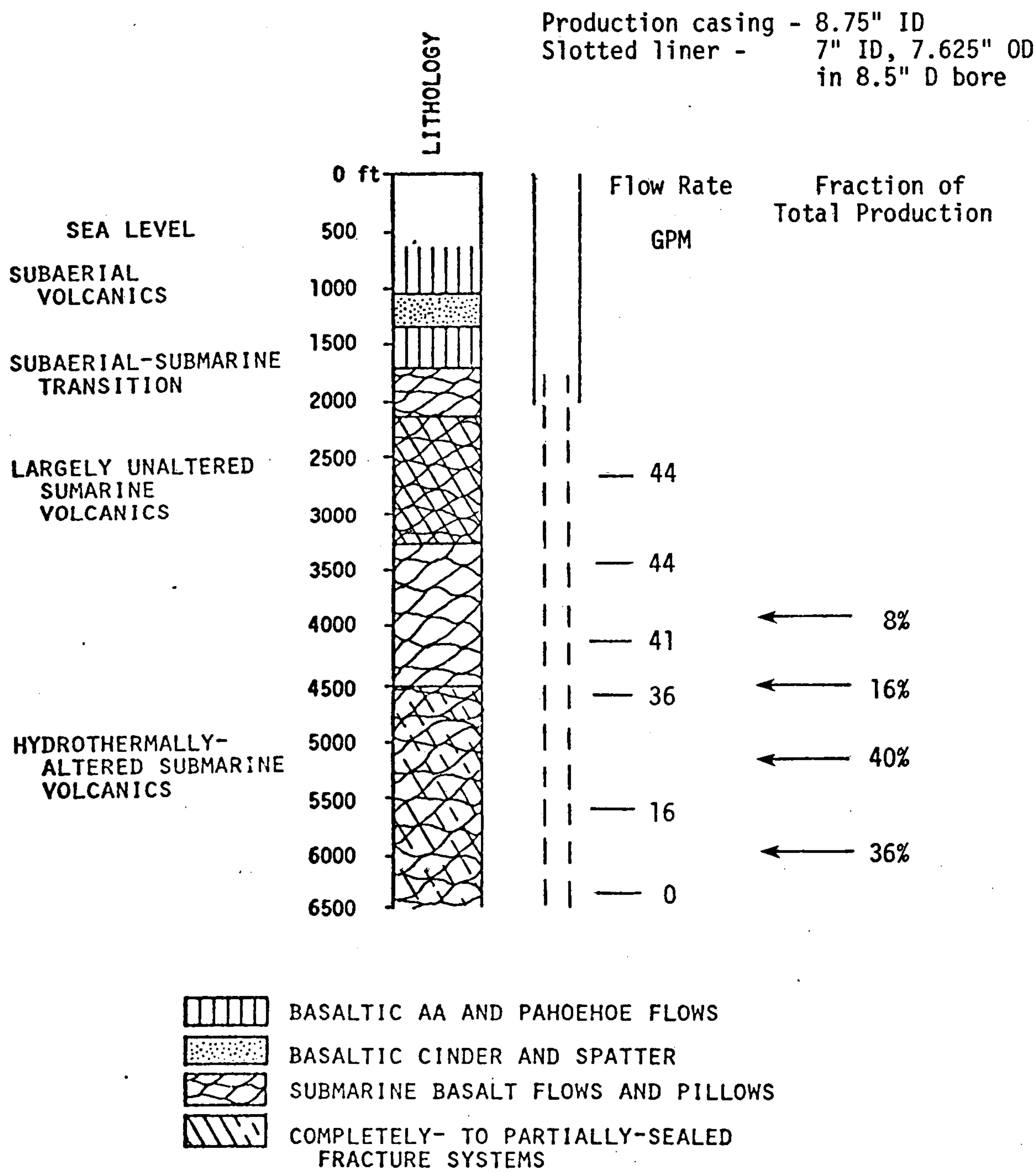

Figure 2. Summary of Flow Meter Test

a substantial amount of debris, analyzed later to be silica crystals, got past the filter screens, clogging the impeller which prevented the proper functioning of the flow meter.

The temperature profiles obtained during these tests are plotted in Figures 3 and 4. In both of these figures the temperatures measured prior to pumping (static condition A) are shown as circles while triangles and squares indicated temperatures measured while cold water was being pumped down (conditions B and C). The curve labelled (A on B) is the static temperature profile (A) moved parallel to itself so that a reasonable fit with profile (B) is obtained.

The matching of the displaced temperature profiles would lend weight to the assertion that the cold water being pumped down is pushing wellbore fluid down the wellbore and forcing the fluid back into the reservoir near bottomhole.

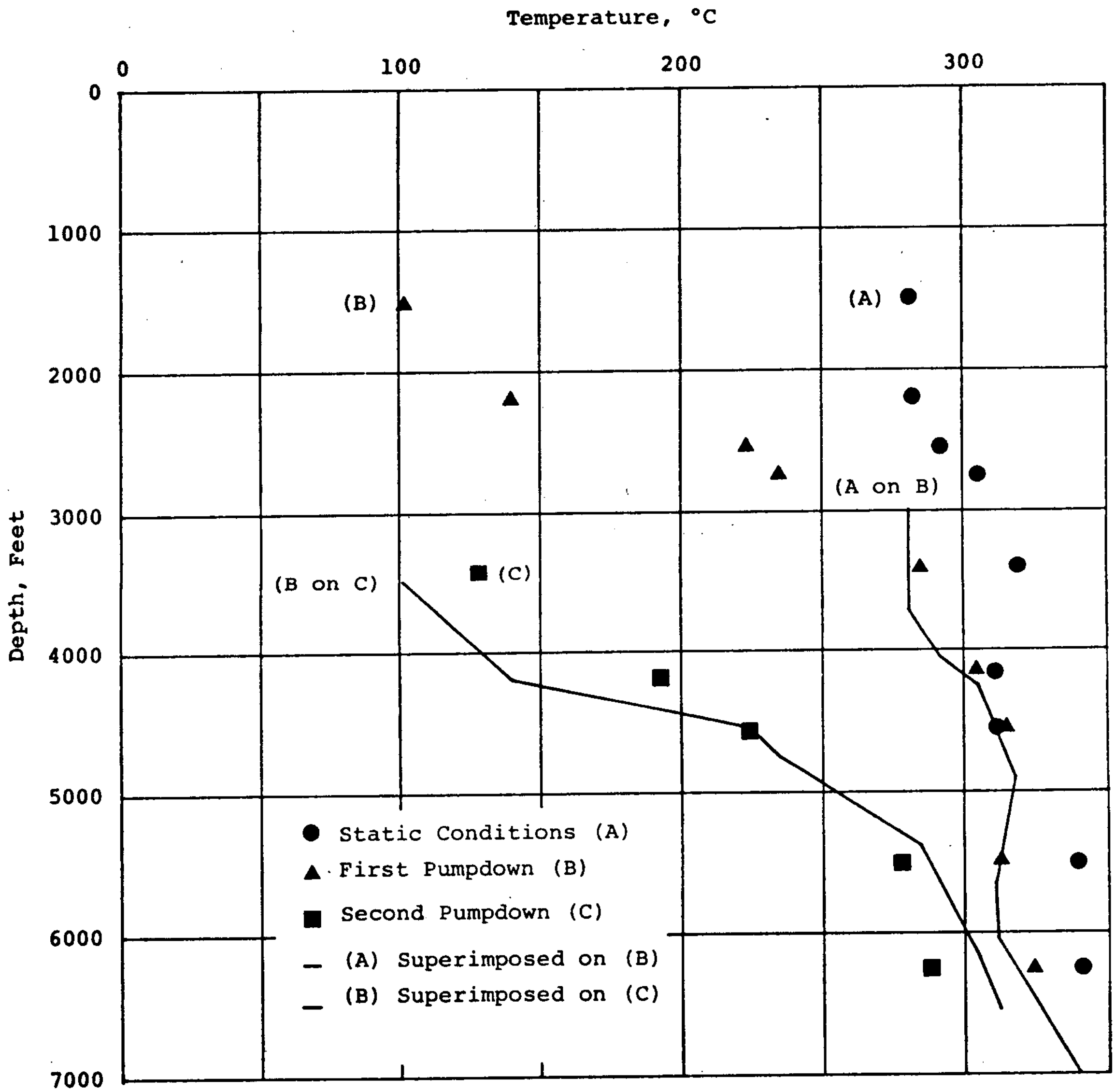

Figure 3. Results of First Pumpdown Test

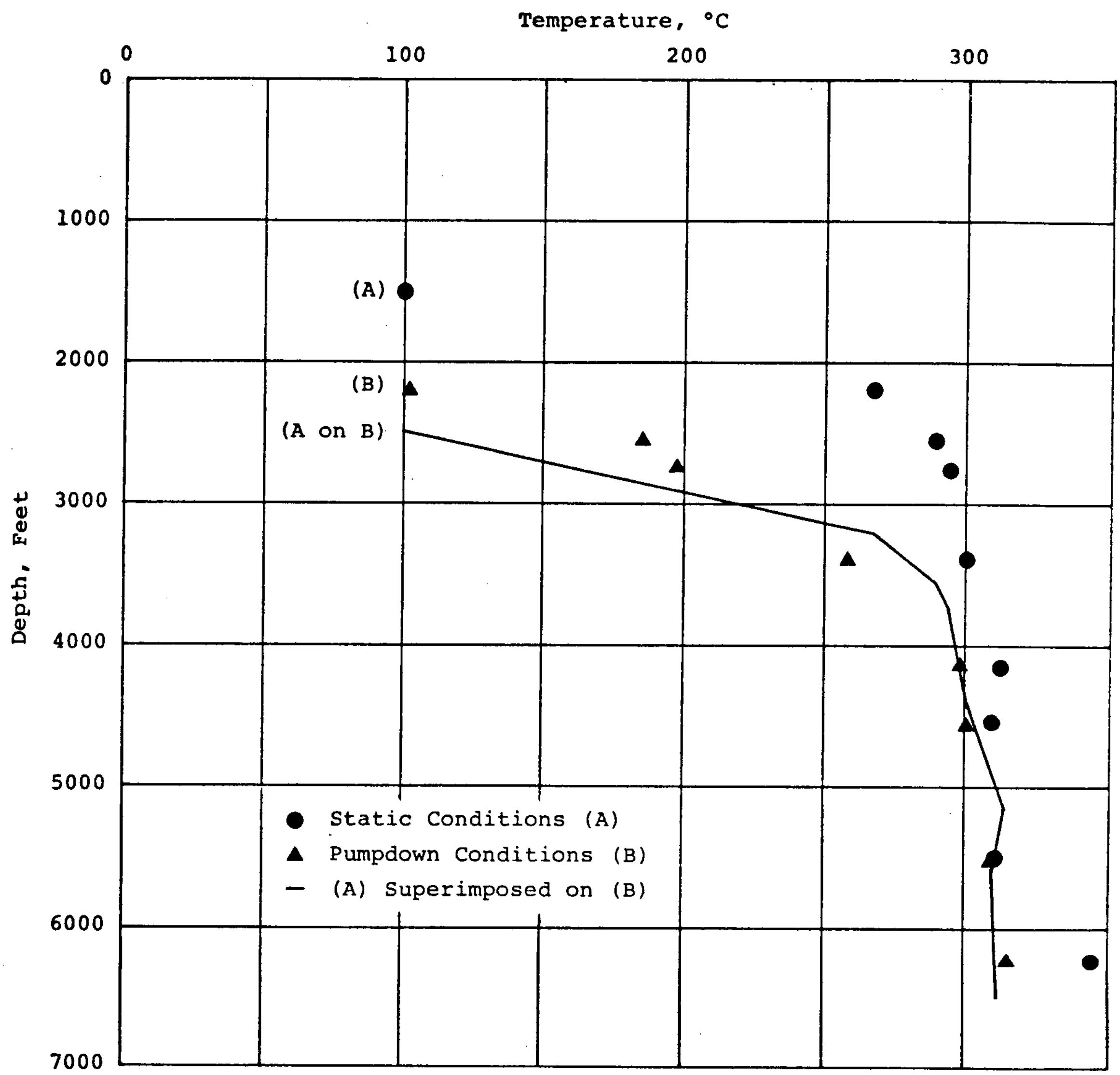

Figure 4. Results of Second Pumpdown Test