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A SUMMARY OF GEOTHERMAL EXPLORATION AND
DATA FROM STRATIGRAPHIC TEST WELL NO. 1
MAKUSHIN VOLCANO, UNALASKA ISLAND

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ABSTRACT

Geothermal resource investigations have been conducted for the past four years on Unalaska Island in the Aleutian Chain. The focus of the work has been Makushin Volcano, about 12 miles from the cities of Unalaska and Dutch Harbor.

In the summer of 1982, three widely spaced deep temperature gradient holes were drilled which encountered high temperatures. During the summer of 1983, a three inch diameter "slim hole" well, ST-1, was drilled to 1,949 feet. A shallow, low pressure, steam zone and a relatively productive hot water zone at total depth were encountered. The lower zone produced 47,000 lb/hr, limited by reaching critical mass velocity at the orifice. The static bottomhole pressure and temperature were 478 psig and 379°F, respectively.

Analysis of transient pressure and flow data yielded a productivity index of 3,470 lb/hr/psi and a permeability-thickness of 50,900 md-ft for the three-foot (at the wellbore) lower zone fracture. A preliminary reservoir/wellbore flow evaluation for a possible power plant indicates two commercial-size wells could fuel a 10 megawatt facility.

INTRODUCTION

Unalaska Island, located approximately 900 miles southwest of Anchorage, Alaska, is one of the Fox Islands in the central portion of the Aleutian Islands arc (Figure 1). Makushin Volcano, the 6,680-foot high active volcano situated on the northern end of Unalaska Island, has numerous fumarole fields on its eastern flanks, suggesting the presence of geothermal resources beneath the volcano.

The cities of Unalaska and Dutch Harbor, which together comprise the primary northern Pacific port for the crabbing and bottom fishing industries, are located approximately 12 miles east of Makushin Volcano on Unalaska Bay. The area's electrical demand of approximately 11 megawatts is presently satisfied by diesel generators. Because fossil fuel costs (and thus electric power costs) are high on Unalaska Island, both the local community and

the state of Alaska have been interested in evaluating the potential for economically exploiting geothermal energy. To this end, in late 1981 the Alaska Power Authority (APA), advised by the University of Alaska and the Alaska Geological Survey, contracted with Republic Geothermal, Inc. (Republic) to explore the vicinity of Makushin Volcano for geothermal resources. The multiyear exploration project was to include geological, geochemical, and geophysical field work and culminate in the drilling and testing of a resource exploration well. Should a commercial resource be identified, additional work beyond the scope of the project could lead to the construction of a small geothermal electrical generating facility to provide economical, reliable electrical energy for the island.

This report first briefly reviews the results of the 1982 exploration program, principally data from three thermal gradient holes and the geothermal resource model that was developed. The focus of the discussion which follows thereafter is the data from the drilling and testing of the first stratigraphic test well, ST-1, completed during the summer of 1983.

DRILLING OPERATIONS AND LOGISTICS

Drilling operations and logistics were unique in many respects because they were significantly influenced by a combination of rugged topography, limited access, available equipment, and adverse weather. The topography of northern Unalaska Island is a mixture of glaciated (U-shaped) valleys, cirques, and aretes; volcanic (lava and pyroclastic) plateaus and cliffs; and deep, steep-sided stream and river valleys. Areas of reasonably gentle relief capable of adequately accommodating a deep wellsite (without the need for extensive earthmoving) were limited over much of the geothermal area.

The rugged topography also limited overland access to the area. Although this problem should not prevent the construction of a road if a power plant is eventually built, budget limitations required that both the exploration program and the deep well drilling be supported entirely by helicopter.

Weather probably provided the biggest operational constraint, because it limited the project to a relatively short summer field season (approximately May 1 to September 15). Snow was up to eight feet deep at the base camp plateau (1,200 feet) in mid-May, and remained on the ground at that elevation well into late-June. Snow and freezing rain were common early and late in the season, and rain was prevalent throughout the operations. The two biggest weather constraints, however, were wind and fog. Winds of 40 to 50 mph were common, and gusts of hurricane force were not infrequent. These conditions often hampered helicopter transport of materials by sling. Fog also frequently grounded the helicopter.

TEMPERATURE GRADIENT HOLES

Following geological, geophysical, and geochemical surveys of the Makushin geothermal area, three $\pm 1,500$ -foot temperature gradient holes were sited and drilled in the summer of 1982(1). Temperature gradient hole D-1 was drilled on a plateau approximately one mile northwest of the base camp (Figure 1). The hole was spudded in glacial boulder till that mantled a sequence of Makushin Volcanics extending to 1,220 feet. The volcanics are a series of essentially unaltered andesite flows with interbeds of cinders, lahars, and gravel. Below the volcanics, from 1,220 feet to total depth (T.D.) at 1,429 feet, the hole

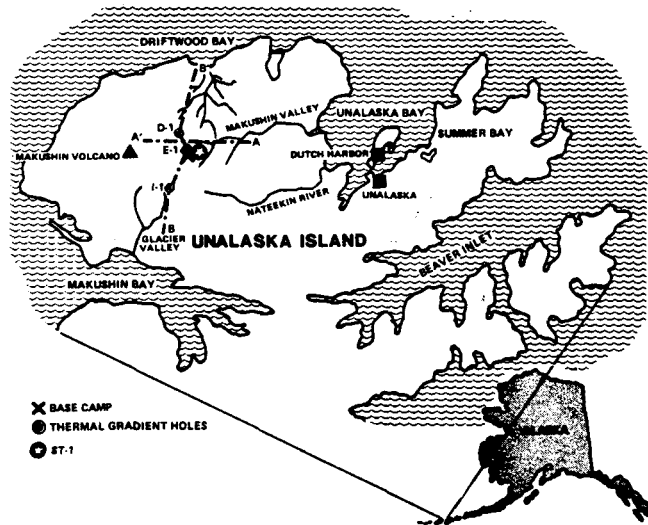


FIGURE 1. UNALASKA GEOTHERMAL EXPLORATION PROJECT LOCATION MAP

penetrated a highly altered and fractured, fine-grained diorite. The diorite was intensely fractured and veined in the upper portion, with most fractures having near-vertical inclinations. Alteration minerals included sulfur, pyrite, kaolinite, calcite, epidote, quartz, anhydrite, and chlorite. Most of these minerals are products of the reaction between the rock and high temperature ($>300^{\circ}\text{F}$) hydrothermal fluids.

Temperature measurements made in D-1 (Figure 2) indicated essentially isothermal convective conditions (ground water circulation) to approximately 700 feet. Below this depth the temperature increased at a high rate ($22^{\circ}\text{F}/100\text{ ft}$) in a conductive (linear) manner to T.D. The elevated temperature recorded at T.D. (212°F), the high gradient, and the high temperature alteration of the surrounding rock all suggest the presence of a relatively shallow ($\pm 4,000$ feet) hydrothermal system.

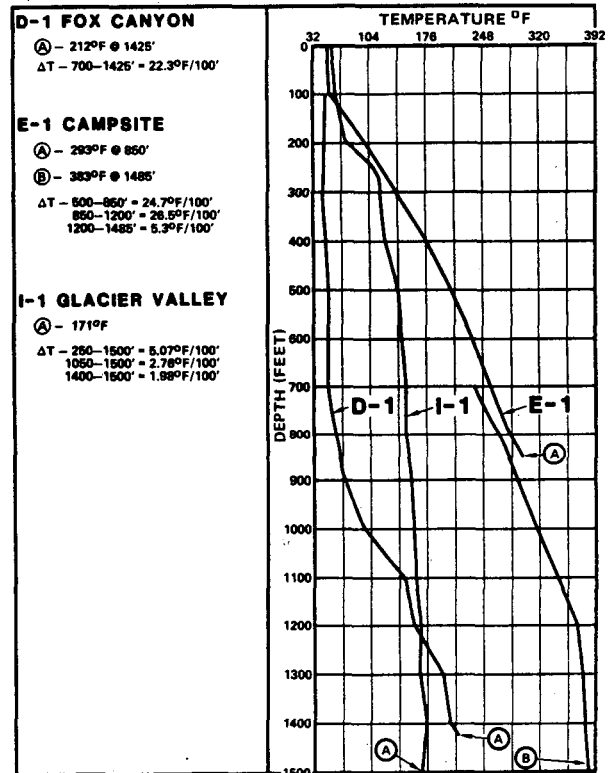


FIGURE 2. TEMPERATURE GRADIENT HOLES

The E-1 hole, located near the base camp, penetrated a sandy tuff from surface to approximately 40 feet (Figure 1). It then encountered weathered diorite which quickly graded into relatively fresh, hard, massive diorite. The diorite extended from 40 feet to T.D. at 1,501 feet, in marked contrast to the D-1 hole in which andesites and other volcanic rocks comprise the first 1,220 feet of hole. Veins and fractures were present throughout the hole, but were commonly found in 10 to 15-foot thick zones separated by massive unfractured diorite. The major fractures were dominantly vertical, with the smaller fractures and veins dipping about 45° to the core axis. The alteration and vein-filling minerals were essentially the same as those in the D-1 hole, with quartz, epidote, and anhydrite representing the higher temperature hydrothermal alteration minerals.

The temperature profile in E-1 was essentially conductive from surface to T.D. Gradients in the first 1,200 feet were quite consistent and high, and averaged 26°F/100 ft (Figure 2). At 1,200 feet, the profile began to roll over and the gradients declined abruptly to about 5°F/100 ft over the last 285 feet. This was taken to indicate that the hole had nearly penetrated the self-sealed zone and that it was approaching a convective hydrothermal system.

Temperature gradient hole I-1 was located in Glacier Valley, approximately three miles south-southwest of the camp and the E-1 site (Figure 1). Stratigraphically, I-1 was very similar to E-1, and confirmed the hitherto unknown wide distribution of the diorite intrusive body. The hole was spudded on the remnant of a terrace underlain by glacial till and pyroclastic materials about 40-feet thick. From 40 feet to T.D. at 1,500 feet, the rock drilled consisted of massive, cryptocrystalline to medium-grained diorite.

The diorite is generally altered, as in E-1, with alteration minerals including chlorite, quartz, carbonate, clay, and epidote. The upper third of the hole contained pervasive fractures commonly lined with pyrite, quartz, and epidote that were deposited during an older, high-temperature hydrothermal episode. Fractures filled with a variety of secondary minerals were, as in the other holes, distributed throughout the bottom two-thirds of the hole.

The temperature data recorded in I-1 (Figure 2) was quite different from that found in the first two holes. The profile indicated two separate thermal regimes. The first was a shallow (surface to 225 feet) system that produced large flows (>150 gpm) of 64°F to 77°F artesian water while drilling. The second system extended from about 250 feet to T.D. and appears to be a relatively conductive system, with gradients of 2°F/100 ft to 5°F/100 ft and a maximum temperature of 176°F at 1,400 feet. The data in Figure 2 also shows that there is a small temperature reversal (4°F) over the last 100 feet of the hole.

The overall temperature regime and profile of this hole indicates that it is on the southern edge of the present geothermal system, at least for this depth range, although the intense fracturing and mineralization indicates the previous presence of a high temperature geothermal system.

The geochemistry of the cuttings from the gradient holes (e.g., enrichments of Hg, F, Li, As, S) suggests the existence of a liquid-dominated reservoir not far below 1,500 feet. The local existence of fumarolic activity and of chloride-poor thermal waters implies that a steam cap overlies the hot-water reservoir. A vapor zone does not appear to be ubiquitous, but may be limited to areas beneath the active

fumaroles where open fractures permit boiling. Lower elevation hot springs in Glacier and Driftwood Bay Valleys are chloride-rich.

The static temperature measured in E-1 suggests that the subsurface geothermal reservoir temperature exceeds 380°F. The geochemical signatures of the core recovered from E-1 imply a fluid temperature greater than 390°F. Calculations utilizing four different geochemical thermometers and samples from the fumaroles and hot springs indicate resource temperatures as high as 570°F.

GEOHERMAL RESOURCE MODEL

The geothermal resource model described below was developed following synthesis of the results of studies conducted on the Makushin volcano geothermal area through 1982.(2) Figure 1 depicts the surface locations of the geologic cross sections contained in Figure 3. These north-south and east-west cross sections best illustrate the proposed model of the Makushin geothermal system. Figure 3 also includes temperature isotherms that have been overlain on the geology.

The heat source of the Makushin geothermal system appears to be a buried igneous intrusion associated with the volcano. Fourteen historical eruptions of Makushin suggest that molten or partially molten rock is currently likely to exist. The temperature and post-glacial volcanic distributions suggest that the heat source for the system is not directly beneath the summit, but rather is offset asymmetrically to the east.

The geothermal reservoir is probably situated primarily within the Makushin dioritic stock at commercially exploitable depths. The occurrence of most of the surface geothermal manifestations within diorite outcrops, the high, conductive temperature profiles recorded in the diorite, and the elevated observed temperatures are all evidence for a diorite reservoir. Some volcanic rocks act as a seal for the reservoir, as seen in D-1, while chemical precipitates appear to have "self-sealed" the diorite, as seen in E-1.

The location of the geothermal reservoir appears to be structurally controlled by a major northeasterly striking fracture zone. This zone is a long, wide, older tectonic feature whose inherent weakness probably played a major role in the intrusion of the original diorite stock. This zone has been re fractured at least twice since the initial dioritic intrusion, as shown by several sequences of vein-filling minerals in the three gradient holes. More recent movement along this northeasterly-trending zone maintains the permeability with fractures in the present-day geothermal reservoir, as well as the ruptures in the impermeable cap along which the majority of the surface geothermal manifestations occur. The gravity data and

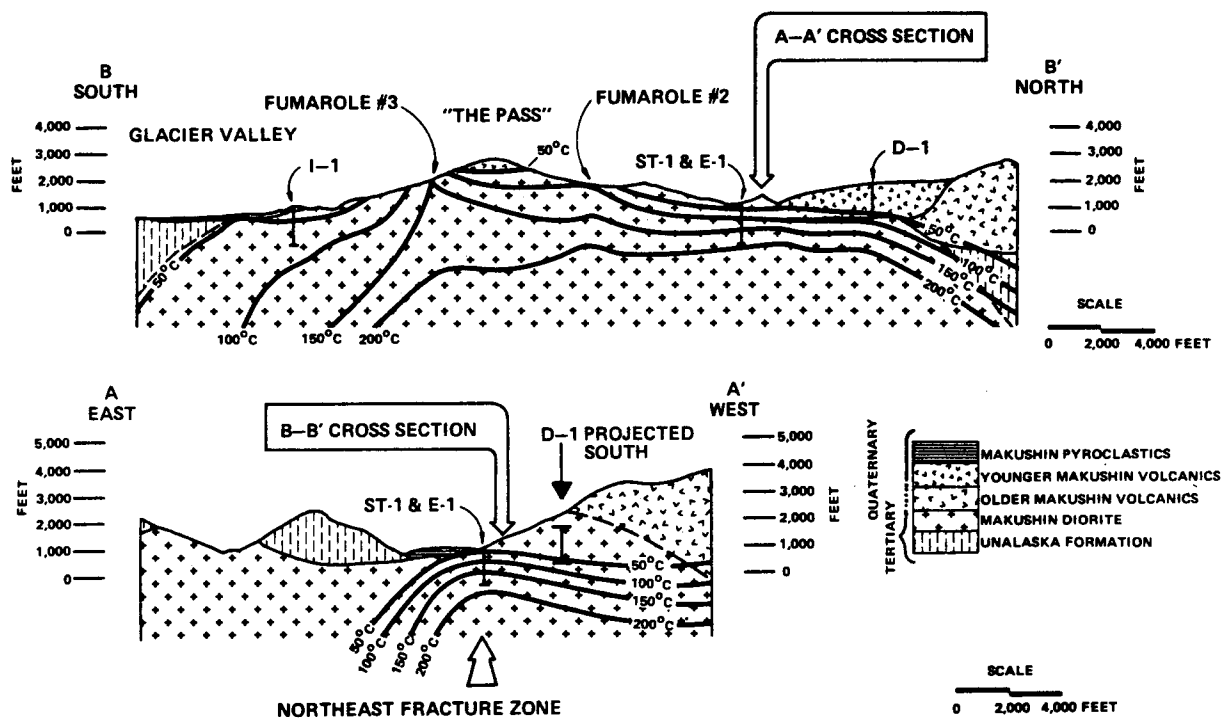


FIGURE 3. GEOLOGIC CROSS SECTIONS DEPICTING THE MODEL OF THE MAKUSHIN VOLCANO GEOTHERMAL AREA

mercury soil anomalies confirm the position and extent of the northeasterly trending fracture zone.

In summary, the Makushin geothermal system appears to be a liquid-dominated resource with temperatures in excess of 390°F. It is situated in fractured diorite within a northeasterly trending zone about two miles wide. The commercially exploitably reservoir is probably below 2,000 feet and may cover more than seven square miles. Reservoir waters rising upward (convecting) boil below an elevation of 1,200 feet in localized open fractures to form a steam cap that is limited in size and extent. Leakage of steam from this cap feeds fumaroles and mixes with ground waters to form chloride-poor hot springs. Reservoir waters appear to be mixing with ground waters before exiting in Glacier and Driftwood Bay valleys as chloride-rich hot springs.

This model of the hydrothermal system, in conjunction with logistical considerations, was used as a basis for selecting the test well location drilled in the summer of 1983.

DRILLING OF ST-1

The decision to support the deep drilling operations by helicopter placed certain limitations on the drilling equipment which could be used. "Helicopter" rotary rigs, which have been modified so that all loads are smaller than 4,000 pounds (the maximum lift capacity of a medium helicopter), have been created for use in similar situations, but few now exist.

The two which were located were both rated to 16,000 feet and would require the support of at least two medium helicopters. This pushed the estimated cost of drilling a full-size deep well to approximately \$6,000,000. Because the Longyear 38 continuous wireline coring rig used to drill the three 1,500-foot temperature gradient holes had performed well, it was decided instead to drill a small-diameter stratigraphic test well using a Longyear 44, a slightly larger wireline diamond core drilling rig. This lowered the cost to about one-third of that estimated for the rotary rig, although the lesser depth capability of the rig (4,000 feet) and smaller diameter of the bottomhole (2-3 inches) somewhat limited the amount of reservoir productivity data obtainable.

Stratigraphic Test Well No. 1 (ST-1) was spudded on July 2, 1983 near the E-1 temperature gradient hole (Figure 1). The well was intended to provide a "slim hole" (three inch diameter) test of the stratigraphy and the geothermal resource to about 4,000 feet. A number of drilling problems were encountered. These were primarily associated with boulders in the shallow volcanic tuff/lahar, lost circulation zones, low strength (small diameter) core pipe, and limited cementing capabilities. Mechanically, the well was completed with H.Q. core pipe (3.06 inches I.D.) cemented to 650 feet, and 2.98 inch diameter open hole below to a total depth of 1,949 feet.

Diorite with varying degrees of alteration and fracturing was cored continuously from below the shallow volcanics (170± feet) to T.D. The first significant open fractures were encountered at 672 feet. Limited testing at this depth indicated a steam zone with a shut-in pressure of +109 psig and bottomhole temperature in excess of 310°F. Flow rates with only 13 psig wellhead pressure were less than 5,000 lb/hr. The zone was mostly shut-off with lost circulation material and cement, and coring continued.

Due to continuing severe lost circulation problems, the wellbore was cemented from 1,056 feet to 550 feet and then redrilled. It is unclear whether these lost circulation problems were due to the breakdown of the zone at 672 feet or to multiple fracture zones below this point. Below 1,056 feet coring continued with 90 percent returns to 1,916 feet, where total lost circulation was experienced again. The well was cored "blind" (no circulation) to 1,926 feet and then a test was attempted, but sustained flow could not be obtained.

After coring blind an additional 20 feet (to 1,946 feet), the drillstring dropped free for three feet, indicating a major void. In a preliminary test, the well flowed steam and water for three hours with a gradually increasing wellhead pressure. After shut in wellhead pressure reached 102 psig, with the well reportedly standing full of water. Preparations for a formal test were begun.

TEST FACILITIES AND INSTRUMENTATION

Logistical considerations severely limited the type of test facilities and instrumentation which could cost-effectively be employed to test ST-1. A relatively simple two-phase orifice meter and James tube were installed at the end of a flow line to measure the flow rate. Upstream/downstream orifice pressures were recorded continuously with a differential pressure flow meter. James tube lip pressure was monitored continuously and manually recorded at frequent intervals using a carefully pre-calibrated test quality gauge. Pressure and temperature were also recorded frequently at the wellhead and elsewhere using conventional gauges.

In the absence of a separator or weir, it was necessary to estimate the fluid enthalpy to calculate a flow rate from the James⁽³⁾ tube pressure. This was done using the two-phase orifice pressure drop data and/or by estimation from the measured pre-flash flowing wellbore temperature adjusted for uphole heat losses.

Downhole pressure and temperature were measured using conventional Amerada instruments modified for high temperature service. Two elements of each type were available and each was calibrated before and after testing.

Temperature elements with a 200-500°F range, sensitivity of one part in 2,000, and accuracy of ±2°F were employed. Pressure elements with a 0-4,000 psig range, one part in 2,000 (±2 psig) sensitivity, and ±8 psig accuracy were used.

The inaccuracy, insensitivity, and erratic response of the pressure elements in the low pressure, 0-500 psig, range later proved to be a major problem. However, it should be noted that initial planning was for reservoir pressures of about 1,600 psig (±4,000-foot T.D.). Even when testing was initiated, about 900 psig was anticipated (1,950-foot T.D., ±100 psig shut-in wellhead pressure). When the critical value of the 0-500 psig range was recognized after the first survey, the end of the "summer" operating season was near. Delay of the testing to locate, modify (for geothermal), and calibrate new instruments was not feasible.

FLOW TEST MEASUREMENTS

The flow test plan was a simple one consisting of: (1) initial static pressure/temperature (P/T) surveys; (2) flow until stable at the highest practical rate with bottomhole P/T measurements; (3) flow at a reduced rate until stable with P/T measurements in the hole during the rate change; (4) shut in and build-up with two pressure instruments in the hole; and (5) final static P/T surveys. Instruments could not be in the hole during the initial drawdown because of the danger of "floating" in the small hole, which could not be evaluated until the rate was known. Extreme turbulence in the two-phase flow region also prevented any meaningful data from being measured above the flash point.

Figure 4 shows static pressure traverses measured in ST-1 before (Run 1) and after (Run 7) the flow period. Figure 5 shows corresponding static temperature data. At the

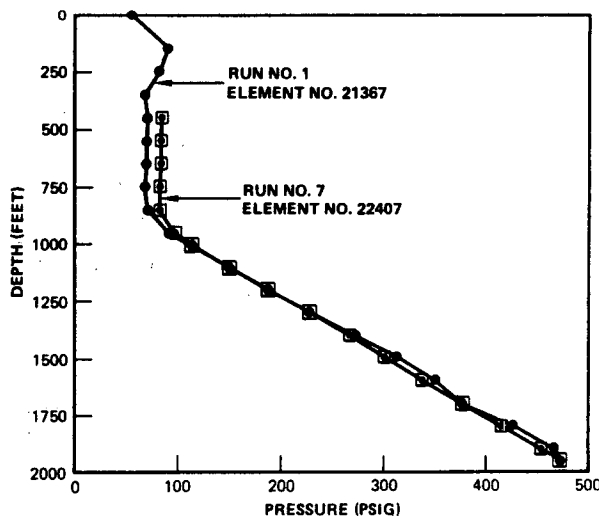


FIGURE 4. MAKUSHIN ST-1 UNALASKA ISLAND STATIC PRESSURE PROFILES

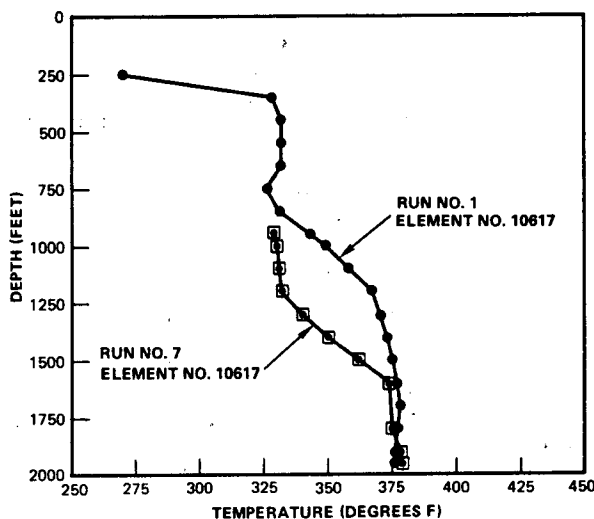


FIGURE 5. MAKUSHIN ST-1 UNALASKA ISLAND
STATIC TEMPERATURE PROFILES

selected bottomhole datum of 1,900 feet, a substantially subhydrostatic initial pressure of 478 psig was measured. After the flow, element No. 21367 returned to 473 psig, which is essentially the same as the initial pressure within the rated accuracy of the instrument. However, element No. 22407 was lower by about 20 psig. This element (No. 22407) suffered severe buffeting in the two-phase zone on its initial run into the well while flowing (Run 3) and is suspect in all its subsequent measurements (even though it recalibrated "OK" after the test). Both temperature runs are in reasonable agreement with a bottomhole temperature of 379°F at 1,900 feet.

The most striking feature of the static surveys is the presence of a gas zone above 900 feet, both before and after the flow. Steam apparently refluxes up to about 300 feet, with a noncondensable gas (> 95% CO₂) "cap" above that. A maximum stable shut-in wellhead pressure of 136 psig has since been measured (two months later). This can only be attributable to noncondensable gas evolution from the shallow dry steam zone, inasmuch as the noncondensables measured in the flowing fluid were extremely low (<300 ppm). Apparent differences in the gas zone pressure between runs may either be attributable to the erratic response of the elements in this low pressure range, to variable shut-in times, or to slight pressure leak-off at the lubricator packing upon initiation of each run.

Two additional features of the static temperature surveys deserve comment. The cooling anomaly in Run 1 at about 700 feet probably reflects the continuous loss of drilling fluids to the lost circulation zone at 672 feet. The apparent cooling in the wellbore above 1,600 feet after the flow (Run 7) is extremely puzzling. Flashing was always above 1,000 feet as shown by the existence of

liquid gradients in the wellbore during flow from T.D. to at least this depth.

The test rate/wellhead pressure history is shown on Figure 6 along with the downhole pressures measured at the 1,900-foot datum throughout the test. Wellhead pressure declined from 108 psig to a stable 36 psig within 15 minutes of opening the well. The rate stabilized at 47,000 lb/hr in the same 15-minute period. Calculations showed that at this rate, the well was limited by reaching critical mass velocity at the orifice. Only minor perturbations associated with running the Amerada instruments in and out were experienced thereafter. The flowing pressure measured at 1,900 feet several hours after opening the well was stable. The absolute value of the indicated drawdown of 25 to 30 psig is suspect (element No. 22407), however, because (as previously noted) the element was possibly damaged during the run-in through the two-phase zone and later returned to a "static" value which was about 20 psig low. The same element 19 hours later again indicated stability, but 5 psig higher.

Upon lowering the rate to 34,700 lb/hr, the wellhead pressure rose to 52 psig within five minutes and was stable until shut in. The downhole pressure showed no change for over an hour after the rate change and then went down about one psig rather than up (No. 22407). While the absolute pressure magnitudes are suspect, both pressure elements also exhibited this phenomena of declining pressure upon shut-in. Both elements exhibit similar character during the buildup, first declining one to two hours after shut-in, then flattening and then rising slowly for many hours, with a curious more rapid rise in the last three hours. The static survey a day later showed that no further pressure increase had occurred.

PRESSURE/FLOW "ANALYSIS"

Any analysis of the transient pressure data described above would be speculative at best at this stage because: (1) the pressure drawdown achievable from this reservoir with a three-inch wellbore is apparently slight; (2) the response of element No. 22407 is suspect for the reasons previously mentioned; (3) the apparently valid response of element No. 21367 is within the range of its rated accuracy (i.e., ±8 psig); and (4) some limited communication between the shallow steam zone and the main liquid reservoir (1,946-49 feet) exists, at least at the wellbore, and may be influencing the apparent responses (e.g., crossflow or high compressibility steam cap).

Nonetheless, the data from element No. 21367 should be analyzable in principle, and may actually represent a valid reservoir response. At a minimum, it is possible to calculate a productivity index (PI) and, from it, a permeability-thickness (kh) based on a porous media, radial flow model as follows:

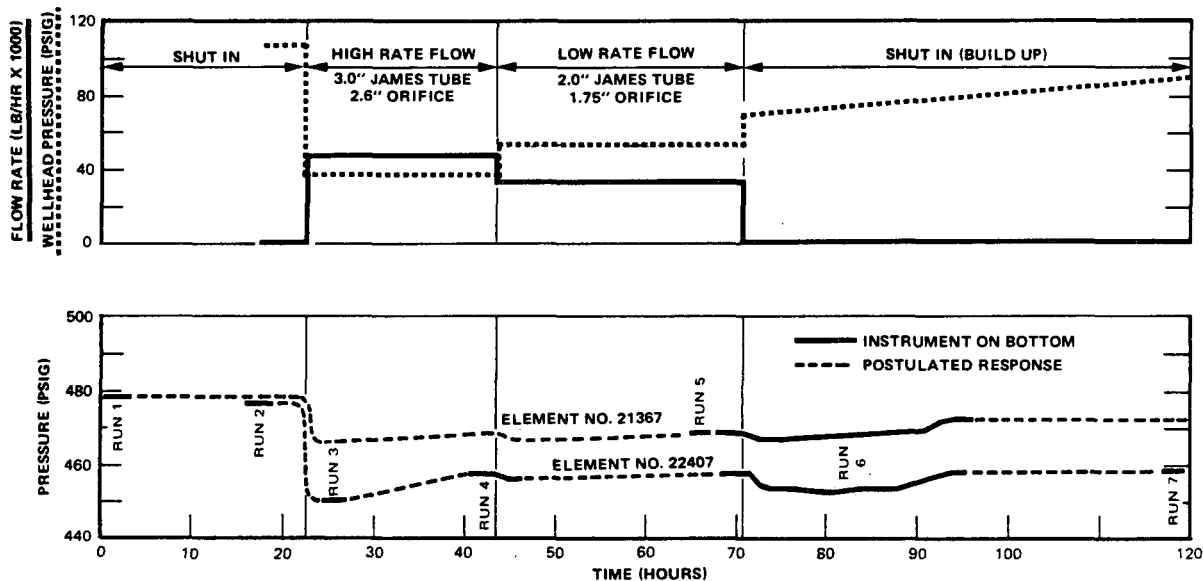


FIGURE 6. MAKUSHIN ST-1 UNALASKA ISLAND FLOW TEST HISTORY AND PRESSURE AT 1900 FEET (8/31/83 THROUGH 9/5/83)

$$PI = \frac{q}{P_i - P_f} = \frac{kh}{(10.21) B\mu \ln(re/rw)}$$

Where:

q = 34,700 lb/hr
(flow rate)

P_i-P_f = 478-468 psig = 10 psig
(initial pressure-flowing pressure)

B = 1.14
(formation volume factor)

μ = 0.14 cp
(viscosity)

ln re/rw = 9 (40-acre radial drainage assumed)
(ratio of effective drainage radius to wellbore radius)

$$PI = 3,470 = \frac{kh}{14.67}$$

$$kh = 50,900 \text{ md-ft}$$

A linear flow model may be more appropriately applied to the Makushin fractured reservoir, but possible interpretations are highly sensitive to assumed fracture dimensions which are unknown. Attempts at matching/analysis of the buildup data employing conventional type curves, etc., were unsuccessful.

It must be concluded that either the reservoir response is exceedingly complex, or that the instrumentation sensitivity/accuracy is inadequate for this application. It is intended that testing over a longer period during the summer of 1984 will be performed employing a quartz crystal pressure transducer and capillary tube in order to at least resolve the instrumentation ambiguities.

POWER POTENTIAL

The estimation of individual well power potential for commercial operations requires the fundamental assumption that an extensive reservoir can be represented by the fluid properties, initial pressure, temperature, and productivity index derived from the slim hole data. Given this as a bases, then a wellbore flow model yielding wellhead pressure vs rate must first be validated against the measured slim hole conditions. Once a match is achieved, then wellhead pressure vs rate curves for various commercial-size wellbore configurations may be generated and related to appropriate power cycles with some degree of confidence.

The flow simulator used for this study was developed by Intercomp(3) and has been used extensively by the industry for geothermal and geopressured wellbore flow calculations for several years. It is a commercially available, vertical, multiphase flow simulator which incorporates treatment for variable well diameter with depth, heat losses, and non-condensable gases. The "nominal" commercial well conditions arrived at were as follows:

Initial Pressure	= 478 psig @ 1,900 feet
Bottomhole Temp.	= 379°F @ 1,900 feet
Salinity	= 6,000 ppm TDS
CO ₂ Content	= 300 ppm
Productivity Index	= 3,470 lb/hr/psi
	13-3/8 inch casing to 1,750 feet
	12-1/4 inch open hole to 1,900 feet

Using these conditions, a cross-plot of a double flash steam cycle and the simulator generated curve for wellhead pressure vs flow rate was constructed. An optimum output of 870,000 lb/hr at 60 psia wellhead pressure was found to generate six gross megawatts of power

(Figure 7). Thus, two commercial-size wells could supply the 10 megawatts desired to service the current needs of Dutch Harbor and Unalaska.

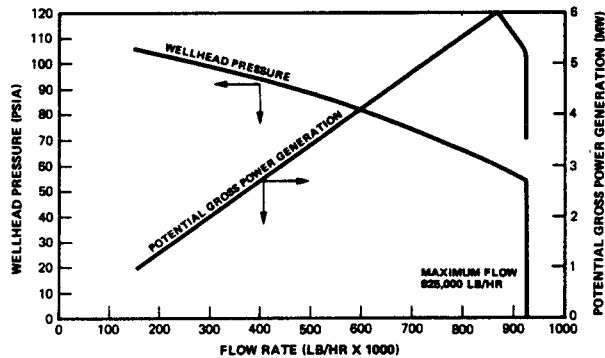


FIGURE 7. COMMERCIAL SIZE WELL - FLOW RATE vs. WELLHEAD PRESSURE AND POTENTIAL POWER GENERATION

CONCLUSIONS

The Unalaska geothermal exploration program has been very successful thus far. Geological, geophysical, and geochemical surveys of the Makushin area resulted in the siting of three temperature gradient holes in 1982. Two of these holes provided strong evidence of a geothermal resource while the third defined a southern limit. The resource model subsequently developed was then tested with the drilling of a deep slim hole production well in the summer of 1983.

Results from the slim hole confirmed the basic model of a shallow steam zone overlying a liquid-dominated reservoir in fractured diorite. Temperature (379°F) was about 10°F lower than predicted, but the well barely penetrated the top of the reservoir at 1,949 feet. Planned deepening next summer (1984) may yield substantially higher temperatures if some of the geochemical indicators are valid.

Flow testing of the well proved that the reservoir is potentially highly productive, with only three feet of fractured interval (at the wellbore) producing 47,000 lb/hr through three inch pipe and little reservoir pressure drawdown. Unfortunately, problems with insensitive and/or inaccurate pressure instrumentation in the unexpectedly low pressure range encountered does not allow rigorous analysis. A "ball park" productivity index of 3,470 lb/hr/psi and permeability-thickness of 50,900 md-ft can be calculated. Additional testing next summer with improved instrumentation is expected to resolve present ambiguities.

Assuming the conditions encountered in the slim hole are representative of an extensive reservoir, the power potential of a commercial-size well is estimated to be in the range of six megawatts. Given the relatively

small requirement for power on Unalaska (currently about 11 megawatts) and the estimated seven square mile resource extent, there is strong indication even at this early stage that a more than adequate geothermal power facility can be developed.

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