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PUMPING EXPERIENCE IN GEOTHERMAL WELLS AT EAST MESA

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ABSTRACT

Republic Geothermal, Inc. is presently carrying out extensive well testing in the East Mesa Field. The testing and development of geothermal well pumps is one important phase of this testing. The intent is two-fold: 1) to test the deliverability of the wells under high rate pumping conditions and 2) to guide the economic selection of well pumps for production to the future power plant. To date, two types of pumps have been tested, a lineshaft turbine pump and an electric submersible pump.

Testing Summary

The two types of pumps undergoing testing differ primarily in the means of transmitting power down the well to the pump. The lineshaft turbine is a downhole multistage turbine pump driven by a motor or engine on the surface through a rotating shaft. The pump is suspended from the surface on a pipe called the pump column through which fluids are pumped to the surface. Control of pump output is achieved by throttling the discharge at the surface or by rpm control with the prime mover or gearbox. The electric submersible is also a turbine pump; however, it is driven directly by a downhole motor(s). Power is transmitted to the motor(s) by an electric cable banded to the side of the pipe on which the pump and motor assembly is suspended. This pipe, or tubing, also conducts the pumped fluid to the surface. Control of pump output is achieved by throttling the discharge at the surface.

Table 1 is a summary of test conditions. The lineshaft turbine pump has been tested for 39 days and 27 days respectively in each of two wells. The pump completed both tests successfully but required extensive repairs after the first run. The electric submersible pump ran 4 days in one well, then failed, was pulled and repaired and is currently running in another well. In both cases the failures are attributable to factors which can be corrected and do not negate the basic ability of the systems to perform in the geothermal well environment.

In the case of the electric submersible, the principal question is whether or not the electric motors and cable will withstand the geothermal well temperatures for extended runs. The first test was terminated after 5 days by a nonelectrical failure, so the durability of the motors and cable in the high temperature environment has not been adequately tested. The failure was a bearing seizure in the seal assembly caused by excessive thrust loads when the producing rate fell below the recommended operating range for the pump.

The principal operating problems with the lineshaft turbine have been associated with the lineshaft bearings and bearing flush water. With results from two tests and competitor experience, the solutions to these problems appear to be virtually in hand. The pump is an enclosed lineshaft design of standard water well construction except that it has increased bearing clearances and carbon-filled Teflon lineshaft bearings. In the first test, in well No. 38-30, severe wear to the lineshaft, bearings and impellers resulted from the fact that initial bearing clearances were too small to offset thermal expansion and the filtered geothermal water used as bearing flush water, carried suspended solids and formed precipitates which abraded the bearings and shaft. In the East Mesa 56-30 installation, lineshaft bearing clearances were increased and a softened flush water filtered with 10-micron filters was used. Some carbonate scale was formed on the shaft because of hardness leakage through the softeners but bearing wear was minimal, i.e. 0.002-0.003 inches. Recent experience of another operator with water lubricated bronze bearings as well as the carbon-filled Teflon bearings has been good.

Technical Applicability of Pumping

In general, pumping is advantageous in a moderate temperature resource where a substantial gain in production over flashing flow can be achieved. Additional advantages of reduced well bore scaling and single-phase surface gathering lines may alone justify pumping in some projects.

East Mesa, a moderate temperature resource with a relatively low noncondensable gas content, is well suited to pumping production. Substantial production increases of 2-3 fold over flashing flow are economically achievable. Also, carbonate scale deposition, although not severe, has been observed to be primarily coincident with steam flash. Pumping with a surface discharge pressure above flash pressure appears to have virtually eliminated well bore scale deposition.

In order to evaluate the technical applicability of pumping to a hot water resource, one must know the resource temperature, the free gas content and scaling tendency of the geothermal fluid as a function of pressure and the inflow performance of the wells, i.e., producing rate as a function of bottom-hole pressure. For acceptable pump life and efficiency, the pump intake must, of course, be set below the depth of steam flashing. Where substantial free noncondensable gas evolves below the flash point, the pump setting depth must be even deeper to avoid cavitation. Further, to avoid scaling in or above the pump, the surface discharge pressure must normally be above steam flash pressure, but in some cases much higher. Where a high surface discharge pressure is required, the energy requirement alone may rule out pumping as a means of controlling scale deposition.

The lineshaft turbine has the following specific advantages over the electric submersible pump:

1. It operates over a broader range of rates than electric submersibles at a given rpm. This advantage is further enhanced by the potential of rpm control at the surface which would allow matching well production to plant demand without wasteful throttling.
2. Its lower rpm probably makes it less susceptible to erosion than a submersible.
3. Its temperature capability is probably quite high since only metal parts are required downhole.

Its principal disadvantage is high capital cost for a deep-set pump due to the high cost of the column and lineshaft assembly.

The principal advantage of the electric submersible over the lineshaft turbine is that its capital cost is substantially lower for deep settings. Its principal disadvantages as mentioned above are susceptibility to erosion in the pump and its relatively narrow operating range. If sustained sand production is not a problem and if the pump capacity is properly matched to the well productivity, then these disadvantages become unimportant. The principal unknown is the ability of the electrical components to withstand the geothermal temperatures for long periods.

Based on published performance data, energy requirements for lineshaft turbine and submersible pumps are quite comparable. The goals of testing are to confirm the published performance in a geothermal application and to estimate the long-term repair and maintenance expense for the two types of pumps. The testing program is beginning to develop this information.

Pump Performance Monitoring

A nitrogen-filled "bubble" tube has been used to measure downhole pressure at the pump during production. (Refer to Figure 1.) These data are essential for monitoring pump performance and can be used to calculate the well productivity index (PI).

The first two attempts to install a bubble tube failed. In both these attempts, in East Mesa 38-30 and one previous well, a 1/4" O.D. stainless steel tube was banded to the outside of the lineshaft turbine pump column as it was being run in the well. In both cases, contact with the well casing crimped the tube and made it unusable. For the East Mesa 56-30 installation, the pump discharge head was modified so that a string of 1/4" line pipe could be run after the pump was installed. This procedure was successful.

In the submersible pump installations, a 1/8" O.D. stainless steel tube was banded to the outside of the 7" O.D. tubing on which the pump was run. The armored electrical cable (~1-1/4" O.D.) was then banded on beside the bubble tube, providing protection from contact with the well casing. Both installations were successful.

Surface bubble tube pressure readings, combined with normal flow rate, temperature and pressure data are used to calculate pump intake pressure, pump submergence, total pumping head and well PI. These calculations, assuming negligible kinetic energy effects, are outlined below.

Pump Intake Pressure

$$p_{in} = p_b + (z_{in} - z_b)\,\gamma_f$$

where

$$p_b = p_{bs} e^{\frac{G\,z_b}{53.3\,T_{avg}\,Z}} \qquad (1)$$

Pump Submergence

$$z_f = \frac{p_{bs} - p_a}{\gamma_f}$$

This assumes that the density of gas in the casing annulus equals that in the bubble tube. In fact, the densities of the two gases are probably not equal, but the calculation provides at least an estimate of submergence to protect the pump against cavitation.

Total Pumping Head

$$h = \frac{p_s - p_{in} + \Delta p_{f_c}}{\gamma_f} + z_p$$

Productivity Index

$$J = \frac{q}{p_e - p_{wf}} \qquad (2)$$

where

$$p_{wf} = p_{in} + \gamma_f\,(z_d - z_{in}) + \Delta p_{f_w}$$

Future Testing

Future pumping tests at East Mesa are aimed at testing the durability of lineshaft turbine and electric submersible pumps and projecting operating and maintenance expenses to guide the economic selection. Larger capactiy pumps capable of 800,000-900,000 lb/hr will be tested. One lineshaft turbine of this size is scheduled for delivery in June, 1978. If results with the present submersible pump are sufficiently encouraging, a larger submersible probably will be ordered and tested.

NOMENCLATURE

G = gas gravity relative to air = 0.967 for nitrogen

h = head, feet

J = productivity index, lb/hr/psi

p_a = casing annulus pressure at surface

p_b = pressure at bottom of nitrogen-filled bubble tube, psia

p_e = external boundary pressure in the reservoir, psia

p_s = pump discharge pressure at surface, psia

p_{in} = pump intake pressure, psia

p_{bs} = surface bubble tube pressure, psia

p_{wf} = bottom-hole flowing pressure at z_d, psia

Δp_{f_c} = pressure loss due to friction in the column or tubing above the pump, psi

Δp_{f_w} = pressure loss due to friction in the well casing below the pump, psi

q = well producing rate, lb_m/hr

T_{avg} = average temperature of nitrogen in bubble tube, ^{o}R. Assume equal to temperature of pumped fluid.

z_b = depth to bottom of bubble tube, feet

z_f = depth to liquid level, feet

z_{in} = depth to pump intake, feet

z_p = depth to top of pump, feet

z_d = datum depth in producing interval

Z = gas compressibility factor

γ_f = static pressure gradient of the produced fluid at flowing conditions, psi/foot.

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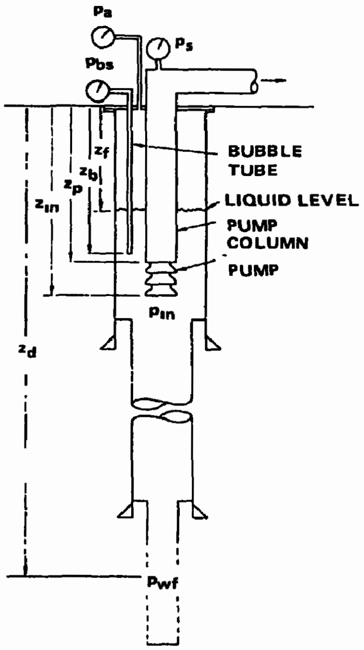

FIGURE 1. PUMP AND WELL SCHEMATIC

TABLE 1 - SUMMARY OF PUMPING TESTS

Well No.	Type of Pump	Pump Setting Depth (feet)$^{(1)}$	Test Duration (days)	Range of Producing Rates (M lb/hr)	Optimum Capacity Range of Pump (M lb/hr)
38-30	lineshaft turbine	400	39	170-350	230-590$^{(3)}$
56-30	lineshaft turbine	840	27	207-520	230-590$^{(3)}$
78-30	electric submersible	1203	4	276-440	320-515$^{(4)}$
16-29	electric submersible	1319	7+$^{(2)}$	320-440	320-515$^{(4)}$

(1) Depth from surface to top of pump.
(2) Test in progress
(3) Range for pump efficiency $\geq$ 70%
(4) Range in which thrust loads are properly balanced in pump