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GEOTHERMAL FLUID INVESTIGATIONS AT REPUBLIC'S EAST MESA TEST SITE

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ABSTRACT

This paper summarizes some of the experiments and tests performed thus far in the northern part of the East Mesa Geothermal Field operated by REPUBLIC GEOTHERMAL, INC. (RGI). The investigations described concern only the fluid characteristics pertinent to future power plant design and operation. Test facilities including test loops, fluid composition, scaling tendencies, pH control experiments and gas behavior ("noncondensables") are briefly reviewed. The data available thus far indicate that the geothermal fluids will present no significant technical problems in a conventional flashed steam power cycle.

1.0 INTRODUCTION

REPUBLIC GEOTHERMAL, INC. is currently conducting extensive test and evaluation work at its East Mesa site. A 48 Mw (net) power plant is now in the final design stage. The current work includes reservoir evaluation as well as a study of the fluid characteristics under simulated power plant conditions.

The present paper describes the fluid study in a summary form. Three additional detailed papers are being prepared under a Department of Energy (DOE) contract. These three reports[1,2,3] will be published within the next few months.

The study was performed jointly by RGI and VETTER RESEARCH. BATTELLE PNL[4] provided valuable support for some later phases of the study with expertise, manpower and instrumentation.

2.0 TEST OBJECTIVES

The main objectives of the tests were to: (1) Determine if there would be problems in a power plant due to scale formation; (2) Predict any problems in the planned flashed steam plant which might be caused by noncondensables; and (3) Suggest technically and economically feasible ways and means to overcome any scale and/or noncondensable problems indicated.

In order to achieve the above goals, it was necessary to conduct a comprehensive study of the geothermal fluids under actual field conditions. This required the design and construction of equipment at the well sites that allowed simulation of the flow conditions encountered in an actual power plant and also, measurements of the pertinent properties and characteristics of the fluids. Of particular interest were the fluid chemistry and phase separation data (e.g., the formation of noncondensables) at different temperature, pressure and flow conditions. In addition, the test equipment had to be designed so that it would not interfere with other concurrent field testing.

3.0 TEST LOOPS

In most geothermal testing, the critical fluid characteristics are supposedly determined by utilizing side streams. The main flow line is tapped and a small stream of fluid is diverted into a "test device" to evaluate a number of characteristics such as corrosion or scaling tendencies. It is then concluded that the reactions observed in the device can be related to similar reactions in the main stream. The general validity of these methods is questionable for the following reasons: (1) It is impossible - in most cases - to draw a representative portion of the fluid into the side stream. This would be possible only if the fluid in the main line is homogeneous, i.e., no separate phases are present (suspended particles, liquid drops, and/or gas bubbles); (2) The flow characteristics of the fluids in the main stream and those in the side stream may be different, leading to a change of the fluid properties; and, finally, (3) The devices themselves may not allow the proper evaluation of fluid properties for an actual power plant. For example, scaling and corrosion properties are different in the devices than they are in various components of a power plant. It is doubtful that even relative comparisons yield valid data, because it is almost impossible to duplicate all the pertinent flow conditions (thermodynamic and hydrodynamic) in such devices.

Pilot plants of any size offer similar problems in investigating fluid characteristics. In addition, a full-fledged pilot plant is much too expensive to build if valid data on the fluid characteristics are not available in advance.

In order to overcome many of these problems, it was decided to add test loops to the standard test facilities. As shown in Figure 1 the test loop is simply an attachment to the flow line leading from the production well to the separator. This device, constructed of common valves and pipe fittings, allows the diversion or by-pass of the total geothermal fluid stream at various flow rates into an area where accurate pressure, temperature and fluid chemistry measurements can be obtained without affecting the well flow. Orifice plates of predetermined size are inserted at various points in the loop in order to simulate the desired pressure or temperature conditions. Valves are provided which allow the loop to be isolated from the well stream for modification, cleaning, and visual inspection.

Such facilities have a number of advantages in that: (1) Their cost of construction is relatively low: (2) They can be run with little extra expense; (3) They are portable and can be moved easily from well to well; (4) They can be operated without interfering with óther reservoir or well test work; (5) They can simulate almost all operations of future power plants using flashed steam power cycles; (6) They can easily be adapted for evaluation of other pówer plant cycles; (7) They can be utilized to investigate scaling and corrosion; (8) They allow evaluation of the effects of fluid alteration by the addition of chemicals (continuous or batch) at any temperature and pressure; (9) They permit obtaining information on the fluid properties at various temperatures and pressures in order to extrapolate the measured data to reservoir conditions (producer or injector); (10) They can be used for evaluation work regarding mineral recovery; and, finally (11) They offer a means of evaluating various types of instrumentation and process control equipment under field conditons.

4.0 TEST FACILITY INSTRUMENTATION

Conventional liquid filled bourdon tube pressure gauges and bimetallic thermometers were used throughout the test loop. Two orifice meters and an automatic level controller are used to measure and control flow rates of the fluids in the liquid and steam exit lines of the separator. This type of instrumentation is generally adequate for evaluation of the data and control of the test facility. However, the accuracy of the gauges is inadequate for some purposes. During the later phases of testing, additional instrumentation was supplied by BATTELLE PNL; e.g., thermoelements, pressure transducers, conductivity cells and pH monitors. The signals from each of these instruments were fed into an automatic data logger. The conductivity cells need further improvement, but the other instrumentation provided valuable data.

5.0 FLUID COMPOSITION

Samples of fluids were collected from the test facility at various times and locations using a variety of sampling methods. These samples were collected in plastic bottles, glass containers and/or stainless steel bombs, with and without, sample preservation. Thousands of samples were analyzed for a large number of chemical constituents by VETTER RESEARCH. Instrumental methods (various types of AA, UV/VIS, GC) and wet procedures were used. The volume of the gathered data prohibits discussion in detail in this summary.

The composition of the unflashed liquid varies slightly from well to well. A typical example is given in Table I.

TABLE I
COMPOSITION OF UNFLASHED GEOTHERMAL WATER
(Well No. 38-30, September 1977)

CONSTITUENT	MG/LITER	CONSTITUENT	MG/LITER
Ag	<0.06	Ba	<0.20
Pb	<0.50	Al	<0.30
Mn	<0.06	Mg	0.06
Zn	0.50	SiO_2	172.0
Hg	0.0008	K	30.0
Fe	0.20	Na	660.0
Cd	<0.03	Ca	2.50
Li	0.92	Cl	535.0
Sr	0.80	TDS	1804.0
B	1.50		

Carbon dioxide constitutes 90± percent of the noncondensables present in the vapor phase. The balance is nitrogen, methane and traces of other gases. No H_2S has been detected. The CO_2 concentration in the single phase water is on the order of 1000 mg/liter. After flashing, noncondensables amount to approximately 0.5 percent of the vapor phase.

6.0 SCALING TENDENCY

The scaling tendency of the fluid is low, but could cause problems in a power plant if not handled properly. Two types of scale were found, calcium carbonate and silica. Approximately 1.5 mg $CaCO_3$ per liter of unflashed water can form. No measurable amounts of $CaCO_3$ are found if the pressure of the fluid is kept above 60 psig, even though a large percentage of the carbon dioxide is already flashed at this pressure. The majority of the $CaCO_3$ scale (more than 50 percent) is formed at pressures below 25 psig. The $CaCO_3$ deposited at these low pressures is a very fluffy porous material; whereas, the $CaCO_3$ formed between 25 and 60 psig is dense and exhibits well formed crystals. The silica forms in measureable amounts below pressures of 25 psig and is masked by the $CaCO_3$ scale. Approximately 1 percent SiO_2 is dispersed in the fluffy $CaCO_3$ scale. No other type of scale has been detected in the test facilities.

7.0 pH CONTROL OF SCALING

A major effort was made to investigate the feasibility of controlling the pH by continuous injection of acid at various production rates. A pH of approximately 6.0 is considered sufficient to keep all the calcium carbonate in solution. A pH of 4.5 or lower may be sufficient to retard (not prevent) the silica precipitation. Figure 2 shows the effect of acid (HCl) addition on the water pH at approximately 25 psig pressure. This figure clearly indicates that the buffer capacity of this water - even at 25 psig - is still too high to make the continuous pH control with HCl an economical method. These pH control experiments proved that most of the acid is utilized to titrate the bicarbonate under line pressure, or, in other words, the first and major portion of the acid drives off the CO_2 instead of lowering the pH.

It should not be concluded that all fluids behave similarly when acid is added. Fluids having a different composition may act differently. These experiments show, however, that effective and economical pH control by continuous injection of acid is not possible at East Mesa.

In contrast, a batch addition of acid can be used to remove the formed $CaCO_3$ without a shutdown of the facilities. Small slugs of acid applied at regular intervals proved to be a much more economical method of scale control. The power plant design will incorporate appropriate provisions to allow for batch acid treatment if it proves to be the preferred method of control.

The cost of acid required to maintain scale-free lines and equipment by batch acid treatment would be less than 0.5 mills/kwh. This is a very small percentage of total plant operating costs and would be acceptable. Concurrently, high temperature scale inhibitors are being tested which may control scale at a cost even less than the batch acid treatment method. By contrast, continuous injection of acid, if it were feasible, would cost on the order of 33 mills/kwh.

8.0 CO_2 VENTING

Another problem in a flashed steam power cycle may be caused by the noncondensables. Gases (mainly CO_2, methane and nitrogen) will break out of solution and enter the turbines and condensers with the steam. The more gas there is, the more costly the power plant becomes due to the larger capital investment and power requirements for vacuum pumps and/or steam ejectors. The actual East Mesa plant design will utilize vacuum pumps to handle the relatively small amount of CO_2.

Field experiments also show that the CO_2 can be handled in another fairly simple and economical way. The main portion of all gases may be vented from the geothermal fluids before these fluids enter the first steam flash stage. Computer modeling of the East Mesa fluids show that almost 50 percent of the CO_2 (capable of forming non-condensables) can be vented by pressure decreases before a 0.1 percent steam flash is experienced. Thus, major portions of the gases can be kept from entering the turbines and condensers. This method of CO_2 venting is favored by economics in fields with high CO_2 content. At East Mesa the more straight forward use of vacuum pumps is preferred because of the low CO_2 content.

9.0 MAJOR CONCLUSIONS

It can be concluded from the collected data that: (1) The liquid in the reservoir is low in TDS and is not saturated with carbon dioxide; (2) Calcium carbonate and small amounts of silica scale can occur in surface installations unless preventive action is taken; (3) No scale problems are expected in pumped producing wells; (4) The boron, H_2S and heavy metal ion content are too low to cause any serious environmental or operational problems; (5) No significant corrosion will occur if oxygen is kept out of the system; (6) Continuous pH control of the fluids by the addition of acid to prevent scale deposition is not economically feasible; (7) Removal of deposited $CaCO_3$ at regular intervals by batch acid treatment is economically feasible; (8) Scale control by chemical inhibitors may be a viable alternative to batch acid treatment; (9) Venting of the CO_2 before steam flash occurs can prevent a major portion of the noncondensables from entering the turbines and is feasible in fields with high CO_2 content; (10) The test facilities with the test loops proved to be an excellent means of studying the behavior of the geothermal fluid.

10.0 REFERENCES

1. O.J. Vetter and V. Kandarpa, "Study of CO_2 Behavior in Geothermal Operations." DOE report being prepared.

2. O.J. Vetter and M.J. Walker, "Test Loops for Geothermal Brines." DOE report being prepared.

3. O.J. Vetter and D.A. Campbell, "pH Control of Geothermal Brines." DOE report being prepared.

4. Sampling and Analysis Methods for Geothermal Fluids and Gases. BATTELLE PNL. Prime contract with DOE (DGE); Contract Number EY-76-C-06-1830.

11.0 ACKNOWLEDGEMENT

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Figure 1

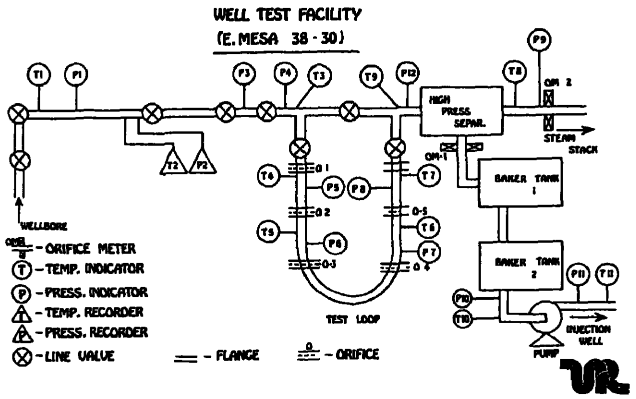

Figure 2