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A PROPOSED GEOTHERMAL SAMPLER DESIGN

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ABSTRACT

Recent geothermal research has indicated a need for study and analysis of an undisturbed fluid sample from a geothermal well. Samplers now in use do not preserve the in situ thermodynamic state of the brine. A suggested design and associated development and testing procedure is presented for a sampler capable of retrieving a fluid sample while maintaining its in situ temperature and pressure. The design also incorporates a log capability for temperature and pressure profiles and is self-contained in that communication with the surface is not required.

INTRODUCTION

With the recent emphasis on alternative energy sources, much effort is being devoted to researching and developing the geothermal resources in the western United States. Early studies have indicated a need for analysis of the geothermal fluid in its in situ, undisturbed state; that is, before phase separation, irreversible thermal cycles, or chemical reactions have occurred. Although several types of samplers have been used, most at only shallow depths, present designs do not preserve the thermodynamic state of the fluid. Thus, the sample must be reconstructed or reconstituted in an attempt to describe the state of the original, in situ brine.

Geothermal brine from the Salton Sea wells contains up to 35% dissolved solids,¹ considerably more than are found in other geothermal brines. Severe problems with corrosion, erosion, and scaling caused by the brine have hampered progress in developing energy applications. Measurement of such items as the vapor phase, dissolved gases, and Ph of the brine in its original thermodynamic state are needed. During pumping, the acidity changes as the brine reacts with several thousand feet of iron pipe. This makes the surface measurements difficult to interpret.

The majority of brine samples from geothermal drillholes have been collected from the surface piping, mainly because of convenience. Obtaining a representative sample along with the appropriate surface measurements to determine the downhole state is difficult and the results are often questionable. A number of downhole sampling vessels have been designed to alleviate some of the difficulties associated with surface sampling analysis. In Ref. 2, several downhole samplers are critically reviewed and a new design used in New Zealand is discussed. These samplers are all lowered downhole on a wire

suspension and collect samples by various means of bottle valve operation. Workers at the United States Geological Survey (USGS)³ have developed a sampler in which gas pressure from the surface operates the valves through the suspension wire, which is a stainless steel capillary tube. The capillary tube arrangement was also used successfully to monitor pressure and collect fluid samples at depth from geothermal wells in Wyoming.⁴ A similar approach was used by the Russians⁵ to study well encrustation due to calcium carbonate in flowing wells. A survey of the basic methods used in collection and analysis of volcanic and hydrothermal gases is presented in Ref. 6.

A number of the samplers in use today control the pressure of the sample to prevent flashing, but apparently none of them attempts to preserve the in situ thermodynamic state. We present here a sampler design which will allow a representative sample of a geothermal fluid to be obtained at a desired depth. During retrieval and surface analysis, the in situ thermodynamic conditions of the fluid will be preserved.

DESIGN CRITERIA

The severe environment of an in situ geothermal fluid places extreme limitations on the design of a sampler, especially in selecting materials and mechanical and electrical components. The design conditions assumed for the proposed sampler were:

- Sampler weight open
- Sampler maximum diameter 12.5 cm
- Sampler volume 50 to 200 cc
- Sampler depth to 1800 m
- In situ pressure to 20 MPa (3000 psi)
- In situ temperature to 450°C
- Geothermal fluid high salinity brine, low pH.

To make the sampler as universally applicable as possible, final sampler design criteria will incorporate the needs of geothermal groups at Lawrence Livermore Laboratory (LLL), USGS, and others concerned with brine analysis.

PROPOSED MECHANICAL DESIGN

Figure 1 is the layout assembly drawing of the sampler. It illustrates the basic features incorporated into the design to permit operation under the very stringent conditions of an in situ geothermal environment. At a maximum sample depth of about 1800 m, brine pressures to 21 MPa (3000 psi) and temperatures to 450°C may be encountered. The sampler should be able to withstand this environment for at least 2 hr,

Fig. 1. Layout assembly drawing for proposed geothermal sampler.

which is estimated as a reasonable turnaround time for the maximum sample depth. Non-corrosive structural materials and seals which maintain their strength and function at high temperatures are required.

In the suggested design, the sample "bottle" will be either a transparent material, such as quartz or Pyrex,* or a stainless-steel, hollow cylinder with transparent windows. An entirely transparent container is desirable for optical analysis techniques and simplicity of design, but stresses encountered may be too great for these materials. Ball valves (shown in Fig. 1) are mounted and sealed to each end of the sample cylinder and a smaller ball valve is attached near the center. During analysis, this valve allows fluid removal through capillary tubes. The design permits a flush-through sample procedure which aids in obtaining a representative sample. The sampler unit is encased in a protective, stainless-steel outer cylinder. Ball valves were selected so that valves could be closed without the sample volume changing, as might happen with plunger-type valves. Although proper sealing of ball valves and other joints is critical, various seals are available for use at the temperatures expected. The transparent bottle or windows will allow visual analysis and use of various optical techniques at the in situ thermodynamic state without transferring the fluid. The outer cylinder has several removable port plugs for observing the brine without disassembly so that possible danger due to fracturing of the glass sample bottle or windows is avoided.

The in situ temperature of the fluid is monitored by thermocouples mounted on the outside of the sample bottle and maintained by a surface heater on the bottle. Such a heater might be a fired-on tin-oxide (transparent) filament or a large pitch, spiral-wound nicrome filament and could also be used to preheat the sample bottle, if necessary, to prevent possible flashing and precipitation on the walls during flushing and sample taking. Pressure is monitored with a strain gage pressure transducer consisting of two surface-mounted strain gages which record the hoop and longitudinal strain in the sample bottle. The strain magnitude is directly related to bottle pressure. Use of two gages allows application of a temperature-compensating circuit which is necessary at the high temperatures expected. Typical downhole pressures are large enough to result in easily measured strains. The outer case can also be instrumented to obtain a temperature-pressure log of the geothermal fluid in the hole.

During operation, the annulus between the sample bottle and outer case must be evacuated and heat shields used to reduce heat loss from the sample bottle. The heat loss is replaced by the surface heater, which maintains the sample at the in situ temperature during retrieval and above ground analysis. The maximum heater load will occur when the sampler is at the surface where an auxiliary power supply will be

* Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Atomic Energy Commission to the exclusion of others that may be suitable.

available. Heat transfer analysis of the brine and sample bottle shows that the heat loss could be reduced to about 40 W if seven heat shields were used and conduction loss at the ends minimized. The pressure of the annular section must be increased to 1 atm for surface analysis. The volume change of the sample bottle due to this outside pressure change from 0 to 1 atm was calculated to be insignificant, on the order of less than 0.1% of the sample volume.

Ball valves, thermocouples, pressure transducers, and the heater are controlled by the electronic package in the stainless steel case at the top end of the sampler. The sample bottle section and the electronic package section can be disconnected at the threaded, sealed joint in the case so that the electronic unit may be used with another sampler. When the entire sampler is brought back to the surface, the electronic control section is disconnected at the joint and the electronic control cables are connected to an auxiliary power supply and control unit. The sampler was designed to be self-contained so that when it is underground communication with the surface is not required. Although surface monitoring of the sampling procedure is desirable, signal transmitting approaches, such as ultrasonic transmission through the suspension wire or the brine, or electrical transmission through a suspended electrical cable, are not practical for the depth and severe environmental conditions.

PROPOSED ELECTRONICS SYSTEM

The sampler electronics must accomplish the following:

- Heat and hold the sample chamber to within $\pm 5^{\circ}\text{C}$ of the brine's ambient temperature during descent, sample taking, and removal from well.
- Open and close ball valves at the proper time to capture a representative geothermal fluid sample.
- Record the temperature and pressure of the sample chamber and outer case during descent, sample taking, and ascent to the surface.

Due to the complexity of control and acquisition requirements, a programmable controller will be employed to sequence the valve and temperature control and to acquire data. The controller will time-initiate the valve sequencing. Temperature and pressure data will be acquired and stored for playback following retrieval of the sampler from the well.

Sixteen analog input channels will be available for acquisition of control and data signals. These analog channels will be multiplexed, the data converted from analog to digital, and the data then stored in a 4096-word Random Access Memory (RAM). This memory size will provide adequate storage for data from 16 channels sampled at 30-sec intervals over a 2-hr period. The sample interval may be decreased or the operating period increased with addition of memory. Controller programs will be stored in Programmable Read Only Memory (PROM). The PROM's may be programmed, if necessary, in the

field. Rechargeable batteries of the NI-CAD or GEL-Cell type will be utilized for system power. The electronics package will be fabricated in cylindrical form with a minimum size of about 6.4 cm diam by about 75 cm long. The electronics/battery section must be protected from high temperatures. Calculations show that by using heat shields the temperature rise of the battery pack and electronics can be kept at an acceptable level during the 2-hr turnaround time.

A LLL transportable, computer-based N.L.S. data acquisition system should be scheduled as onsite support equipment. After retrieval of the sampler from the well, the stored data could be transferred to the N.L.S. system digital magnetic tape for permanent storage. The tape could then be removed and returned to LLL for analysis, or the data could be played back via MODEM and standard telephone to the PDP/8 computer in the LLL Thermophysical Laboratory. In either case, raw data — in engineering units — would be available at the well site via a N.L.S. teletype, printer, and visual readout.

Additional onsite support equipment required includes:

- Sampler electronics to N.L.S. system interface.
- Battery charger — to recharge sampler battery pack.
- PROM programmer — to reprogram sampler controller if necessary.
- Sampler auxiliary power supply/control unit — to be used to maintain the sample environment when the sampler electronics are detached.

IN-HOUSE TESTING

Before field testing at a geothermal well, the prototype sampler will be tested in-house (at LLL) under the most demanding in situ conditions expected. Proper operation of the electronic package, ball valves, and associated monitoring equipment will be verified at expected temperature and pressure conditions of the brine. Seals will be checked and corrosion of the materials used will be examined.

SEQUENCE OF EVENTS FOR SAMPLING

The sampler will be lowered downhole with temperature and pressure logs of the brine recorded. When the desired sample level is approached, the ball valves will be electronically actuated, allowing fluid flushing and temperature stabilization of the sample bottle. After equilibrium is reached, the ball valves will be closed, the temperature and pressure of the sample recorded, and the sampler retrieved. At the surface, the sample bottle and steel container will then be removed from the electronic package and connected to an auxiliary power supply/control unit. The stored data will be permanently recorded and the sample bottle section transferred to a laboratory for analysis.

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