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Laboratory Measurement of Sorption in Porous Media

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ABSTRACT

A new apparatus for measuring steam adsorption-desorption isothermally on rock samples has been installed and initial runs made for rock samples from geothermal reservoirs. The amounts adsorbed measured in these experiments are the same order of magnitude as previous experiments.

INTRODUCTION

Adsorption occurs on rock surfaces and in micropores, which are pores less than 20 A in diameter. Micropore adsorption is larger than surface adsorption, thus the distribution and abundance of micropores plays a key role in the amount of adsorbate. Formations with large amounts of space available in the micropores are typically low permeability formations.

Normally in petroleum engineering, gas is believed to be stored as a compressed gas in the pore space and as solution gas in liquids. In coal beds and Devonian shales, methane adsorption is believed to be a major factor in the storage and release of gas. In these systems, adsorption is believed to be the dominant reservoir storage mechanism.

Not long after the tax trial for the Geysers steam producers in 1968, it became evident that steam was stored in the reservoir as a liquid. However, the reservoir pressure was too low for a liquid to exist at the reservoir temperature. Ramey (1990) called this the "Geysers paradox". Adsorption is a mechanism which permits existence of liquid at pressures below the saturation vapor pressure. In this study, reservoir engineering for geothermal systems under adsorption will be considered.

APPARATUS AND PROCEDURE

The most popular method for measuring the equilibrium mass of fluid adsorbed is the BET method named for Brunauer, Emmit and Teller (1938). In this method, porous material is exposed to a known volume of gas. The pressure is allowed to equilibrate. The amount of gas adsorbed can derived from the difference between the amount of gas injected and the amount of gas at the equilibrium pressure. This type of instrument is available commercially for the measurement of adsorption of gas on a solid.

Equilibrium measurements of adsorption were made using a Porous Materials, Inc. (PMI) Sorptometer. The PMI Sorptometer is a fully automated BET type apparatus. This equipment was modified by Porous Materials, Inc. for the Stanford Geothermal Program.

The instrument requires weighing, loading and removing samples. Prior to a run, samples were packed into the sample holder, and were then weighed. The sample was placed in the apparatus and adsorption and desorption was measured. Upon completion of the measurements, the sample was reweighed. This weight was entered into the computer for data reduction.

Sorption isotherms were measured at 100 C for all samples. Most of the runs were measured at pressures from 1 psia to pressures close to 14 psia. Desorption data were measured from the maximum pressure to 0.5 psia. Measurements at 140 C were made from 5 psia to pressures close to 40 psia and back to 5 psia. Attempts were made to reach the flat surface saturation vapor pressure, but the instrument was unable to build enough pressure.

The equilibrium pressures and volumes of steam adsorbed are recorded in a data file. The Sorptometer processes the data by using the ideal gas law to convert steam adsorbed to standard cubic centimeters of water vapor at atmospheric pressure and 0 C per gram of rock. This output was converted to grams of gas adsorbed per gram of rock and pressure was converted to relative pressure (pressure divided by saturation pressure).

RESULTS

Adsorption and desorption isotherms for samples from different geothermal fields were measured using the PMI Sorptometer. The first sample was a piece of graywacke core material from an unknown well in the Geysers shallow reservoir in the southwestern part of the field. The sample was ground into pieces small enough to fit into the sample holder. Figure 1 is the adsorption and desorption isotherms at 100 C for particles larger than 2.362 millimeters.

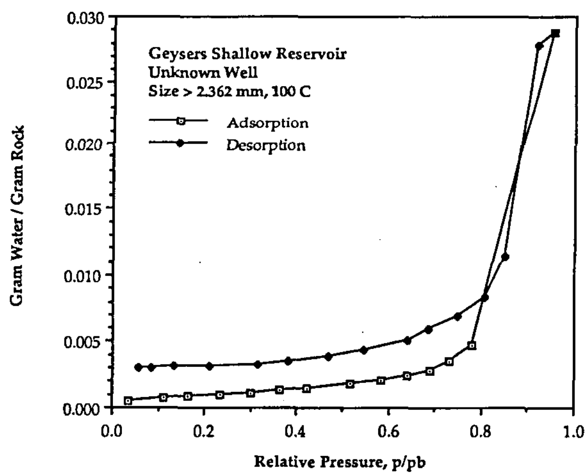

Figure 1: Sorption isotherms at 100 C for an unknown well in the Geysers Shallow Reservoir; particle sizes greater than 2.361 mm.

The second sample was well cuttings from the Geysers Field well OF52-11 from a depth of between 5000 to 5200 feet. The cuttings were cleaned and sieved. A sample of particles greater than a No. 270, 0.0533 millimeters, sieve was used. Adsorption and desorption isotherms measured at 100 C are shown in Figure 2 and results at 140 C are shown in 3.

The maximum amount adsorbed ranged from 0.029 to 0.053 grams of water per gram of rock at 100 C. At relative pressures close to 0.8 the amount adsorbed ranged from 0.0046 to 0.0062 grams of water per gram of rock. Herkelrath measured an adsorption amount of 0.011 gram of water per gram of

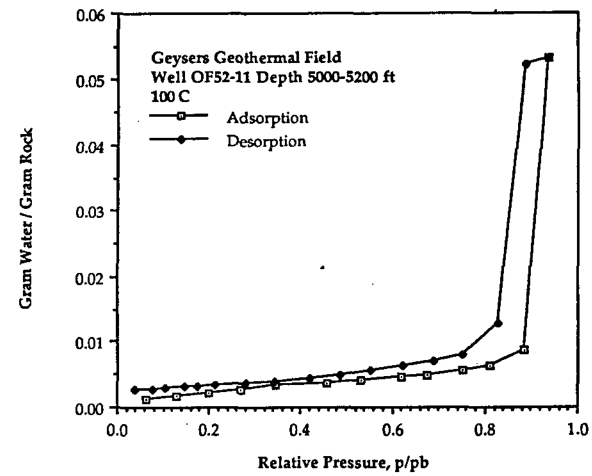

Figure 2: Sorption isotherms at 100 C for the Geysers Well OF52-11 5000-5200 ft. depth

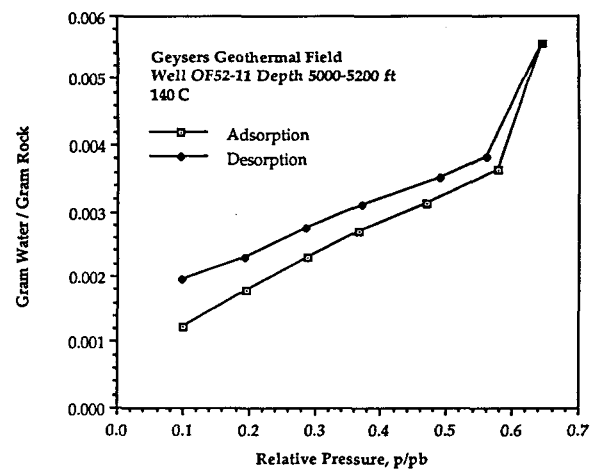

Figure 3: Sorption isotherms at 140 C for the Geysers Well OF52-11 5000-5200 ft. depth

rock at a relative pressure of 0.8 and a maximum of 0.012 grams of water per gram of rock. At a relative pressure of 0.8, the values from this study are approximately one half of those measured by Herkelrath, but the maximum amounts were more than twice of those of Herkelrath.

CONCLUSIONS

A new apparatus has been installed to measure steam adsorption in porous media. Compared to the work of previous researchers, results are of the same order of magnitude. Detail on results are presented by Harr (1991).

Although the equipment appears to be working well and meets most objectives, there are problems which will be checked during the coming year. There appears to be an unusual amount of hysteresis between adsorption and desorption for some runs. We believe rock samples were ground too fine for the initial runs and this may have affected the high adsorption at high relative pressures.

Runs have been made for some limestone geothermal samples from several geothermal fields other than The Geysers. Results require checking. It is intended to run many samples from The Geysers and other fields to explore the range of results to be expected in any geothermal field.

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