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LOW-TEMPERATURE HYDROTHERMAL RESOURCE EVALUATION

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ABSTRACT

The objectives of testing low-temperature hydrothermal wells are to characterize well response to production (injection), determine resource characteristics and project reservoir longevity. Testing procedures and analysis techniques differ in some respects from proven procedures in the oil and gas and ground water fields. This paper presents some basic definitions and standard techniques necessary for the evaluation of a fluid resource in an intergranular permeable reservoir. Problems particular to a non-ideal thermal resource are outlined and some analytical techniques are discussed.

INTRODUCTION

An understanding of ideal low-temperature hydrothermal resource evaluation requires knowledge of how intergranular permeable flow systems operate. Standard ground water terminology will be used to describe such flow. Problems associated with hydrothermal well testing and analysis arise primarily because of the thermal nature of the resource and the fractured nature of the reservoir. Sufficiently accurate instrumentation is very expensive. Most testing procedures and analytical techniques assume constant fluid viscosity and density; for the most part, this does not hold in geothermal well testing. The non-ideal nature of many thermal reservoirs invalidates calculated hydraulic properties and can result in questionable predictions of reservoir behavior.

EVALUATION OF NON-THERMAL IDEAL FLUID RESERVOIRS

One method of evaluating aquifers or reservoirs is through well testing. When a well is produced, the fluid level or potentiometric surface is lowered in the vicinity of the producing wellbore. Water moves from the formation into the well, increasing in velocity and gradient. The shape of the fluid or pressure decline resembles a cone (cone of depression) and the amount of decline is called drawdown. The water is initially derived from aquifer storage. The storage coefficient (S) is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The magnitude of drawdown and the shape of the cone is dependent on aquifer transmissivity. Transmissivity (T) is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Evaluation of an aquifer or reservoir requires calculation of T and S. Theis developed a non-equilibrium formula to make these calculations based on the following assumptions:

1. Aquifer is homogeneous and isotropic.
2. Aquifer is infinite in areal extent and well is infintesimal in diameter.
3. Aquifer is confined and the well is fully penetrating.
4. Flow is isothermal.
5. Water is removed from storage instantaneously with decline in head.

Jacob's modification of the non-equilibrium formula is one currently used convenient technique. This uses an arithmetic plot of drawdown versus the logarithm of time to calculate T and S. T and S are calculated from the following relationship:

$$T = 2.30\ Q/4\ \pi\ s_{10}$$

$$S = 2.25\ t_0\ T\ /r^2$$

$$\text{applicable when} \quad u = r^2 S\ /4Tt \le 0.01$$

EVALUATION OF HYDROTHERMAL RESERVOIRS

Evaluation of hydrothermal reservoirs is also accomplished by well testing. Particular problems are introduced by instrumentation, non-constant thermal conditions and non-ideal reservoir conditions. Most testing instrumentation is not designed for thermal conditions. Downhole probes, as used in high temperature geothermal and oil and gas testing are expensive and cannot readily be placed below a pump. Industrial instrumentation is usually not sufficiently accurate to permit reliable reservoir calculations. Existing or modified inexpensive test equipment can be utilized to produce quality data by modifying testing procedures. Early-time well data is usually meaningless, unless continuous density corrections are applied. Modifying test procedures by "preheating" production (injection) wells can aid in lessening the early-time temporally dependent thermal effects. Late time well data can be influenced by viscosity effects within the reservoir, producing "apparent" reservoir boundaries. The temporally dependent thermal conditions contradicts the Theis assumption No. 4. These complications do not invalidate the data, but necessitate interpretation in light of the thermal conditions and consideration of intrinsic transmissivity for predictive purposes.

The major difficulty in predicting behavior in thermal resource analysis is the fractured conditions of the reservoir. Fracture control appears to be the rule, rather than the exception. This condition contradicts the Theis assumptions No. 1 and 5. A non-homogeneous anisotropic analysis may be feasible, but requires input data from observation wells, usually not available to the geothermal developer. Storativity is not generally available from geothermal well testing because:

1. Fractured media invalidates observation well response.
2. Usually only pumped well data is available.

It has been observed that many constant discharge tests plot as a linear trend on semilogarithmic graphs of borehole or wellhead pressure versus the time since pumping began. In fractured media a practical approach may be to pump at a rate equal to or greater than the intended use and simply extrapolate the straight line segment.

REFERENCES

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