Title
A REVIEW OF LBL GEOTHERMAL WELL TESTING EQUIPMENT

Authors
Goranson, C.
Haney, J.
Solbau, R.
et al.

Publication Date
1979-07-01

2

To be presented at the 1979 Annual Meeting,
Geothermal Resources Council, Reno, NV,
September 24-27, 1979

LBL-9462

CONF-790906--11

A REVIEW OF LBL GEOTHERMAL WELL TESTING EQUIPMENT

J. Haney, C. Goranson, R. Solbau, and R. Schroeder

July 1979

MASTER

Prepared for the U. S. Department of Energy
under Contract W-7405-ENG-48

DISCLAIMER

A Review of LBL Geothermal Well Testing Equipment

J. Haney, C. Goranson, R. Solbau, R. Schroeder

Earth Sciences Department, University of California, Lawrence Berkeley Laboratory, Berkeley, California 94720

ABSTRACT

The high temperatures and hostile environments of geothermal reservoirs have prevented the use of high precision downhole well testing instrumentation. For the measurement of temperature, pressure, and flow at temperatures in excess of 150°C, reservoir engineers have had to rely on less accurate non-electrical instrumentation. Sandia's development of high temperature electronics and the introduction of high temperature cable has now increased the temperature range of certain instruments utilizing downhole active electronics to 275°C. However, this instrumentation is not yet commercially available. Development of high temperature instrumentation with moderate accuracy utilizing passive electronics downhole has only been limited by the non-availability of high temperature multi-conductor cable. With the recent introduction of 275°C multi-conductor cable, the simultaneous measurement of moderate to high precision temperature, pressure, and flow is possible this year. The accurate measurement of two-phase flow at the surface will also soon be technically possible. The involvement of the LBL Geothermal Reservoir Engineering Group in the development and evaluation of geothermal well testing instrumentation is presented.

INTRODUCTION

The development of a geothermal resource requires detailed information on the hydraulic and thermal properties of the reservoir. Well testing is the best technique for the study of the in-situ response of the reservoir to production and/or injection. Well testing can provide reasonable estimates of effective reservoir porosity, permeability, geometry, lateral-vertical continuity, and areal extent. Well testing is also used in the assessment of near well phenomena such as wellbore damage, the influence of fractures, and the mixing of vertically separated production or thief zones. Well testing includes pressure buildup-drawdown, flow, injection, interference, pulse, and drill-stem tests. All of these require accurate measurement of temperature, pressure and flowrate.

The LBL Geothermal Reservoir Engineering Group has been involved with the testing of geothermal wells since 1975. LBL activities have included the detailed assessment of several geothermal resources, the development of improved techniques for interpretation of field data, and the evaluation and modification of available well testing instrumentation.

The measurement of reservoir pressure under transient conditions (production-injection) is fundamental to well testing. The measurement of downhole (reservoir) pressure changes in single phase fluid production wells is accomplished with downhole instrumentation or is obtained from wellhead measurements by taking into account gravity changes and frictional losses in the wellbore. For two-phase production wells, flow analysis is not sufficiently accurate to obtain downhole pressure from wellhead data. The Sperry Sun Pressure Transmission System* is presently the only commercially available method of continuously monitoring downhole pressures in high temperature (>150°C) production wells for long periods (>3 days). The Sperry Sun system utilizes a pressure transducer linked to a downhole chamber by capillary tubing. When the tubing is charged with fluid, either gas or liquid, the pressure transducer indicates downhole pressure minus a value for capillary fluid head. LBL has extensively used this approach for pressure measurements. Experience has demonstrated that great care must be taken when the well test is designed, instrumented, and analyzed. It was observed that temperature changes along the length of the tubing (both downhole and surface portions) resulted in substantial (up to 300%) variation in the pressure signal recorded at the surface. To maximize the usefulness of field data, the pressure response of fluid-filled capillary tubing was studied (Miller, 1978). The results of the computer modelling indicate that downhole pressure changes are not immediately sensed at the surface due to the compressibility and/or viscosity of the fluid used. The pressure signal is also distorted during transmission, with high frequency signals being more damped than low frequency signals. Temperature changes >0.5°C greatly increase this distortion. Temperature effects can be minimized by incorporating small flow rate changes into the test and by insulating and/or heating all tubing remaining

*Reference to product names is not intended to be a DOE endorsement for that product.

at the surface to constant temperature. When the test segments are analyzed, the first 10 to 20 minutes of transient pressure data is usually the response of the tubing not the reservoir. Without early time data, near well phenomena cannot be determined.

LBL has also gained substantial experience using the commercially available Kuster pressure probe. The tool is clock driven with pressure vs. time being recorded downhole on a brass chart. Although the tool is rated for only 3 hours downhole at 300°C, it has proven very useful for pressure vs. depth surveys and for short-term (less than 3 days) measurement of transient reservoir pressure at lower temperatures.

Sandia Laboratory's high temperature (275°C) well testing instrumentation has been developed and field-tested. The temperature, low resolution pressure, and flow tools each utilize active electronics downhole and are run separately on single conductor cable. The development of a high resolution pressure tool, multiplexing of signal frequencies for tandem tool use, and tool commercialization is scheduled for completion in two years.

Denver Research Institute and S^3 have independently developed temperature-pressure instrumentation using only passive sensors downhole. The S^3 tool has been autoclave tested to 203°C and field tested to 180°C. (Ginne). Using this concept of only passive sensors downhole, LBL has designed and fabricated a single tool for the simultaneous measurement of temperature, pressure and flow. The tool consists of a platinum RTD, a Bell and Howell CEC 1000-04 pressure gauge, and a Kuster flow meter converted to electrical output. The prototype tool, to be used in conjunction with PFA/TFE seven conductor cable, will be field tested at up to 275°C later this year. LBL is also evaluating other temperature, pressure and flow sensors for incorporation into the final tool design. Upon completion of the testing, geothermal downhole well testing instrumentation with moderate resolution will be available for long term use (up to 2 weeks downhole) in 92% of all geothermal resource areas greater than 150°C listed in the 1978 USGS Assessment of Geothermal Resources of the U.S. (Circ 790).

LBL is also evaluating low cost, low temperature geothermal instrumentation. A temperature tool has been designed and fabricated for use in heat flow or temperature gradient test holes. The tool, 1.9cm (0.75") O.D., uses a four wire platinum RTD for temperature measurement. The tool is designed for use in water or drilling mud at temperatures up to 225°C. The LBL Reservoir Engineering Group has also designed and fabricated five high resolution pressure-temperature tools for use in well logging surveys, downhole production-observation well monitoring, and wellhead measurements. The tools incorporate Paro Scientific quartz pressure transducers and platinum RTD's. They are capable of continuous use at temperatures up to 125°C and have a resolution of 0.01 psi and 0.1°C. One of the tools is also adapted for use with the modified Kuster flowmeter. LBL is also evaluating all available temperature sensors for general low temperature use. One of the more promising sensors is the A.D. 590 integrated circuit temperature transducer. This I.C. provides a current that is proportional to temperature (1μA/°K). Preliminary results indicate that the transducer is well suited to temperature logging for depths less that 1000 feet at temperatures less than 150°C. The transducer requires only two conductor cable and does not require length compensation or additional signal conditioning. The I.C. has substantial potential as a low cost temperature monitoring and logging sensor, since the I.C. costs approximately $15.

The LBL Reservoir Engineering Group is evaluating single-phase flow sensors for surface measurements. Insertion turbine meters and pitot tubes are presently being evaluated. Although LBL is not actively involved in the development and evaluation of two-phase flow measurement instrumentation and techniques, the progress of other research organization is closely followed. Two promising areas of research are: 1) the pulsed-neutron activation (PNA) technique, and 2) the use of multiple single phase flow sensors combined with a gamma beam densitometer. Argonne National Lbaoratory has used the PNA technique to directly measure the mass flow rate of two-phase flow . The flow is activated with a short burst of neutrons from a small portable neutron source, and subsequently the activity-time distribution is measured downstream. The transit time is used to calculate mass flow velocity, the total activation is used to calculate density. PNA appears very suitable as a standard for the measurement of phase velocity, density, mass flow measurements. (Kehler, 1979) EGG, Idaho has evaluated the performance of a combination drag-disc turbine transducer and a gamma densitometer for the measurement of two-phase flow. (Nalezny, 1979) Accuracies of ±10% are obtainable using this approach. (Nalezny)

For field data management, a micro-computer system is presently being assembled. The computer is designed for raw data analog to digital conversion, magnetic tape and floppy disc data logging, and for real-time analysis of data. Prior to the actual well test, the assumed parameters will be used to calculate the expected results. During the test, the observed pressure-temperature response will be used to verify or update the assumed parameters. The required production or injection time for the analysis of barriers within the test area, for example, will be based on these updated parameters. The real-time analysis of the well test data can then be used to determine when the test should be terminated.

This has been only a partial description of the LBL geothermal reservoir engineering well testing instrumentation evaluation, modification, and development program. Instrumentation evaluation procedures and results, and tool modification design details are available to the geothermal industry from LBL through published documents and through informal exchange of information.

ACKNOWLEDGMENTS

This work is supported by the U.S. Department of Energy under contract No. W-7405-ENG-48.

REFERENCES

Ginne, W., Systems, Science and Software, Personal Communication.

Kehler, P., "Accuracy of Two-Phase Flow Measurements By Pulsed Neutron Activation Techniques," Second Multi-Phase Flow and Heat Transfer Symposium-Workshop, Miami Beach, Florida, (April 1979).

Miller, C.W. and J. Haney, "The Pressure Response of Fluid Filled Capillary Tubing", Invitational Well Testing Symposium, Lawrence Berkeley Laboratory, Berkeley, California, (October, 1978).

Nalezny, C.L., L.L. Chen, and C. W. Solbrig, "The Performance of a Loft Drag-Disc Turbine Transducer and Gamma Densitometer Under Transient Two-Phase Blowdown Conditions," Second Multi-Phase Flow and Heat Transfer Symposium-Workshop, Miami Beach, Florida, (April, 1979).

Nalezny, C.L., E.G. & G., Idaho, Personal Communication.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720