WELL TESTING SYMPOSIUM

Program and Abstracts

October 19 to 21, 1977

Horizon Room
Claremont Hotel
Berkeley, California

Sponsored by

United States Department of Energy
Office of Energy Technology
Division of Geothermal Energy

through the

Earth Science Division
Lawrence Berkeley Laboratory
University of California, Berkeley

WELCOME

May we take this opportunity to welcome you to Berkeley. Your attendance and participation will help make this Symposium one of the best ever.

Since the greater San Francisco area offers endless attractions to participants and their spouses, the only scheduled social event will be the Reception and Banquet in the Empire Room on October 20 at 6:00 pm.

We shall be delighted to assist you in making your stay more enjoyable.

Organizing Committee,

P. A. Witherspoon
J. H. Howard
M. J. Lippmann
T. N. Narasimhan
R. C. Schroeder
W. J. Schwarz
C. F. Tsang

SESSION III - 8:30 am to 12:00 noon, Thursday, October 20, 1977

Session III — Field Applications

I. R. Ershaghi - Chairman
University of Southern California

SESSION IV - 1:30 pm to 5:00 pm, Thursday, October 20, 1977

Session IV — Analysis and Interpretation

H. K. van Poollen - Chairman
H. K. van Poollen & Associates

Thursday October 20, 1977

6:00 pm - 7:00 pm

No Host Reception

Empire Room

7:00 pm

Banquet Dinner

Empire Room

Speaker

Arthur C. Wilbur
Director

Geothermal Energy Division

San Francisco Operations Office

Department of Energy

SESSION V - 8:30 am to 12:00 noon, Friday, October 21, 1977

Session I Paper 2

PETROLEUM ENGINEERING WELL TEST ANALYSIS - STATE OF THE ART

H. J. Ramey, Jr.
Stanford University

It is hard to find a subject in oil production which epitomizes the development of petroleum technology better than well-test analysis. One of the earliest endeavors of petroleum technologists was testing wells for a variety of purposes: What was wrong with poorly performing wells? Was it possible to forecast large production rate performance from tests made at low producing rates? Was it possible to forecast long-term behavior from short-duration well tests? What kind of well stimulation should be done, if any? What would be the result?

Development of this technology began almost with the drilling of the Drake well, Intensified during the early 1900's, and reached a modern level os sophistication by 1950.

In the next decade, more than 200 papers were published on this subject. By early 1960, the consensus was that all important work on the fundamentals had been completed. This sort of conclusion has occurred in almost all petroleum specialties at one time or another. The state of this art was so well-developed and considered so important, that the Society of Petroleum Engineers selected it for the first topic in a new monograph series. The monograph, "Pressure Buildup and Flow Tests in Wells," by Matthews and Russell was published in 1967, and a second topic, "Advances in Well Test Analysis," was presented by R. C. Earlougher, Jr., in 1977.

new school of thought began to develop in the early 1960's. What could be done with field test data for well tests that had not been run long enough for conventional analysis methods? Were there methods which could guarantee that the proper portion of the data had been analyzed?

These second-generation studies were aimed at problems considered too complex for useful analysis. Naturally, the final analysis was simple, and important results began to appear by the early 1970's. These included development of pulse testing and interference testing, log-log type curve analysis, and real gas type potential applications.

There are many parallels between developments in well test analysis, other branches of petroleum technology, and business science. The elements are generally: (1) a well-established technology, (2) an exploding electronics technology producing computers, ultra-sensitive sensors, and pertinent software, and (3) an exploding technology not fully-appreciated by the industry.

The result is a period between development and wide acceptance of new technology. The new technology appears impossible or magical to practitioners of the established technology. The time period between concept and industry-wide acceptance is about 15 years. An important objective of current activities is to reduce this time lag to optimize the impace of well test analysis on meeting national energy production objectives.

Session I Paper 3

AQUIFER TESTS - THE STATE OF THE ART IN HYDROLOGY

E. P. Weeks
U.S. Geological Survey

Numerous developments have been made in the theory and design of aquifer tests since C. V. Theis published his famous paper in 1935, and it is now possible to analyze data obtained under geohydrologic conditions that depart in a number of ways from those assumed in his development. Concerning the aquifer itself, several theories have been developed and applied to describe and analyze flow in leaky aquifers, in aquifers which are anisotropic with respect to distribution of hydraulic conductivity between different horizontal directions, and in unconfined aquifers. Well characteristics can be delt with by equations now available for analyzing flow toward production wells that partially penetrate the aquifer, that have significant storage in the well bore, or that exhibit significant well losses. In regard to the type of discharge or head control imposed at the production well, equations are available for analyzing the effects of various types of discharge variation with time, for effects of constant drawdown, and for effects of an instaneous change in head (the "slug" test).

The equations developed for various aquifer and well conditions provide tools for analyzing data from many different geohydrologic situations. However, many of the aquifer-test solutions result in curves of similar shape, and therefore, are not unique to only one flow system. Consequently, careful site evaluation and aquifer-test design are essential to ensure the success of planned aquifer tests. Pretest prediction of aquifer response, based upon best estimates of the properties of the aquifer and confining bed and upon the hydrologist's analysis of the geohydrologic setting is highly desirable in designing an aquifer test. Such a prediction will enhance the probability that the test is run long enough and the observation wells are spaced such that proper and adequate drawdown data are available for analysis and definition of the flow system.

TECHNOLOGY AND NEEDS FOR DRILLING AND WELL TESTING INSTRUMENTATION

William J. McDonald
Maurer Engineering Inc.

Detailed information on the physical properties of geothermal reservoirs is required for effective and economic development and operation of these energy resources. Since drilling and reservoir development accounts for approximately half of geothermal energy development costs, it is important that this information be available as quickly and as accurately as possible. While many methods are available to obtain needed information, two of the most important are measurements-while-drilling and well testing. These are complementary in time and in information provided.

Methods of well testing include pressure build-up, draw-down, flow, injection, interference, pulse, and drill-stem tests. All require sensitive, accurate, and reliable measurement of pressure and temperature. Recent developments promise improved data acquisition by surface automation and computer processing, while reducing instrumentation costs by improved pressure sensors. Temperature limitations remain a problem and are one of the great needs in geothermal applications.

Economic incentives have created great interest and activity in measurements-while-drilling (MWD) systems. Four telemetry methods are under development: mud pulses, hard-wire, acoustic and electromagnetic systems. Over forty-five companies are involved in this work with at least fifteen hardware systems under development. Commercial systems should become available the next one to two years. These instruments must be simple, reliable, and economic. They must offer a broad range of capability from directional measurements to formation and formation fluid properties. With these capabilities we will be able to reduce goethermal development costs while increasing the effectiveness of geothermal energy recovery.

Session II Paper 1

OIL AND GAS WELL INSTRUMENTATION

William E. Kenyon
Schlumberger-Doll

The evaluation of oil and gas wells has depended heavily on downhole measurements which determine rock or fluid characteristics. This paper reviews recent trends in this type of measurement and speculates on some future possibilities. Also discussed are possible long range effects of relaxed government control of production rates.

Dielectric logging is a technique which distinguishes water from other formation liquids. It is performed by measuring the velocity of propagation of electromagnetic waves within the formation. It is useful for determining oil saturation where water salinity is unknown or variable.

X-ray spectroscopy is a technique which has been promising for a long time. The possibility of using natural, capture, inelastic or activation α's offers the possibility of detecting many of the chemical elements in very low concentrations. One useful but marginal application is the carbon/oxygen log for determination of hydrocarbon saturation behind casing. Another possible application is in detecting tracers for example, in flood front profiling.

The process of applying the computer in oil and gas instrumentation started many years ago, and continues slowly. Computerized logging trucks are a recent development. But the main benefit of computers will be in digesting large amounts of data. Spectroscopy and sonic waveform data are prime examples of this.

Session II   Paper 2

CONTINUOUS BOTTOM-HOLE PRESSURES MEASURED BY NON-ELECTRIC SYSTEM

Ted J. Ashby
Sperry-Sun

In recent years, as Geothermal activity has increased, the need for precision instruments to provide information of bottom-hole pressure and well-bore configuration has become important to define reservoir limitations. The need for precision bottom-hole pressure equipment has been developed in the Pressure Transmission System. This system does not use electronic or mechanical equipment downhole for pressure measurement; therefore it can be used in a high temperature environment for prolonged periods. The Pressure Sensing Element and Recording System are located at the surface. Bottom-hole pressures are transmitted to the surface through a capillary tube that is charged with an inert gas, normally, Nitrogen or Helium.

Additional equipment with the same accuracy and sensitivity as the Pressure Transmission System is the Precision Pressure Gauge. The gauge is widely used in the oil and gas industry. This is a self-contained gauge and has a temperature limitation based on the electronics available to the industry.

The capillary tube used with the Pressure Transmission System is being used successfully in the oil and gas industry for injection of chemicals at a optimum depth in the well bore to treat well-bore fluids, minimizing the cost of treating lost production and damage to production string.

The use of thermal shields with directional survey equipment provides data of well-bore configuration and bottom-hole location of the well bore.

Session II Paper 3

HIGH TEMPERATURE INSTRUMENTATION

A. F. Veneruso
Sandia Laboratories

Methods for obtaining geothermal borehole measurements and making appropriate interpretations are limited at present by technical deficiencies in that logging tools developed for the oil and gas industry rarely encounter temperatures above 150°C. Also, most of the required logging tools, cables and seals are rated only to 180°C whereas in geothermal wells temperatures frequently range up to 350°C. This paper reviews the Geothermal Logging Development Program being conducted by Sandia Laboratories for ERDA's Division of Geothermal Energy. This program is an industry-based program to develop and apply high temperature instrumentation technology which is needed by the wireline logging industry to serve the rapidly expanding geothermal market. In order to satisfy critical existing needs, the near-term goal is for operation at or above 275°C in pressures up to 48.3 MPa (7,000 psi) to be available by the end of FY-80. The long-term goal is for operation up to 350°C and 138 MPa (20,000 psi) by the end of FY-82. To meet these goals, existing hardware will be upgraded and new components will be developed and evaluated in critically needed prototype tools such as the temperature, flow rate and high resolution downhole pressure sondes. Most of the development and service activities will be contracted to industry with work by Sandia and other ERDA laboratories as necessary to expedite the industry effort.

Session II Paper 4

DOWNHOLE HYDROLOGY LABORATORY

Llewellyn A. Rubin
William L. Still
Ensco, Inc.

Several years ago, a suggestion was made to ERDA, Richland, by Fenix & Scisson, Inc. (its drilling consultant) that a worthwhile research project would consist of emplacing a downhole borehole laboratory in the basaltic flows under Richland. Its purpose would be to gather data prior to eventual mining out an underground storage cavern for high-level nuclear waster.

Recently, funding became available for a pilot project of this type and Fenix & Scisson was asked to undertake the design and construction of a prototype system. Fenix & Scission in turn contracted with ENSCO, Inc. for this work. The basic requirement of the contract is to provide a completely self-contained measurement system with a downhole (3,300 feet below the surface) unit in an 8-5/8" borehole in basalt. The primary purpose of the system is to measure and record the moisture migration from the rock mass into the borehole. In addition, the contract requires the placement of additional sensors in the package that would be helpful in evaluating the rock mass for its intended purpose.

The system is intended to be emplaced for a period of five years with a requirement of at least one year without the need to withdraw the downhole package. The level of moisture migration is well below the limits of conventional hydrological measurement. Thus, it was required that an innovative technique be employed.

ENSCO chose to put all of the calibratable measurement equipment in the uphole portion of the system connected with the downhole acquisition section by tubing. The system will operate in a continuous closed-loop fashion, such that the entire operation is conservative. Very dry air is circulated from the surface, down the hole to a measurement zone approximately eight feet long. Here it collects moisture from the surface of the rock and is brought to the surface, where the moisture is removed and measured. The air is then recirculated. Temperature and pressure sensors are incorporated as part of the feedback system at discrete points. The downhole package contains a scanning subsystem that is capable of generating information about the vector nature of the source of moisture. This, however, is not the primary moisture measuring sensor.

The moisture is measured in the uphole unit by a combination of refrigeration and dehydration, again using a closed-loop-feedback system constituting a regenerative refrigeration/dessication moisture extraction unit.

In addition to the moisture measurement subsystem, the downhole unit is capable of measuring acoustic wavespeeds (both P and S), seisms, and microseisms.

This first system, while quite minimal, is a reasonable step forward. Nothing like this has existed before this time and there is no question that others of this type will inevitably be built in the future. The system will be nearly complete by the end of November of this year and will be tested in shallow boreholes in basaltic outcrops early in 1978, followed by pre-emplacement testing of the deep borehole and finally emplacement and check out of the system by the end of FY1978.

Session III Paper 1

WELL TESTING ANALYSIS:
A GUIDE TO PRACTICAL OIL AND GAS FIELD DECISIONS

William C. Miller
Shell Oil

Examples from oil and gas field evaluation, development, well stimulation, and supplemental recovery projects emphasize the wide scope of questions which can be effectively answered with comprehensive interpretation of both routine and specially designed well tests. In our experience, far too often the complex nature of the reservoir properties and processes demand more powerful analysis methods than those provided by the literature. But flexible couplings of a non-linear least-squares-fit computer program to a general purpose reservoir simulator is extending our interpretation of such engineering problems.

From the examples presented, it is obvious that such "automated" history matching of well test response (multi-fluid production, observation well pressures, post-fracturing performance) should not be regarded at all as an "automatic" procedure. The engineer's ingenuity and experience are much more critical factors than the mathematical elegance of the computation scheme. Furthermore, despite the prevalent concern voiced about the possible non-uniqueness of the prototype which is deduced by such a well test analysis procedure, from a decision-making standpoint, without such a method, complete inability to explain the observed performance of an expensive field test occurs all too frequently and is a much more serious obstacle.

FIELD STUDIES OF DISPERSION IN SHALLOW GRANULAR AQUIFERS

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J. A. Cherry
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Field studies of dispersion in granular aquifers can be conducted by means of tracer experiments using radioactive or non-radioactive solutes, isotopes of hydrogen or oxygen, or water of a different temperature. Studies of the concentration distributions at sites at which contaminant enclaves already exist can also yield information on dispersive properties of the geologic materials. The key element in field studies is the scale of sampling. Dispersivity is defined as a characteristic macroscopic property of the porous medium. For dispersivity values obtained from field tests to actually represent this property of the medium, the concentrations of tracers or contaminants obtained from field tests must represent the actual macroscopic concentrations in the aquifer. To obtain concentration data of this type, sampling devices that collect fluid from small (almost point-source) domains are most suitable. Observation wells that have screens that penetrate through zones of different hydraulic conducitivity are generally unsuitable because of the effects of mixing in the aquifer caused by pumping and because of mixing in the well bore of water from different strata or lense-type heterogeneities. This can produce apparent dispersion that cannot be separated from the component of real dispersion.

This paper describes field experiments with radioactive and non-radioactive tracers in which multi-level point sampling devices were used in three-dimension studies in sand and gravel aquifers. These devices enable real rather than apparent dispersivity values to be obtained. Investigations are being conducted to determine if dispersivity tests of this type are suitable as a means of obtaining input for predictive models that can be used in assessment of the long-term consequences of shallow waste-burial operations.

APPLICATION OF WELL TESTING TO LIQUID-DOMINATED GEOTHERMAL SYSTEMS

T. N. Narasimhan
Lawrence Berkeley Laboratory

Since late 1975, Lawrence Berkeley Laboratory has successfully conducted several well tests on the liquid-dominated geothermal reservoirs at East Mesa in Southern California and at Raft River in Idaho. These tests included productivity index tests, production - build up tests and interference tests. Although these studies have confirmed the applicability of the well-testing techniques of hydrogeology and petroleum engineering to geothermal reservoirs, the experience gained so far has clearly shown that geothermal well testing is often beset with special practical problems relating to instrumentation, control of test conditions, and processing and interprestation of raw data. From the point of view of instrumentation related to conventional well-testing, there is a special need to develop automatic recording pressure devices that can function over prolonged periods of time at temperatures in excess of 400°F. The raw data collected is often not only voluminous but also characterized by a variety of extraneous noises. Preprocessing of raw data is therefore a significant task in the interpretation of geothermal well test data. Data collected from distant observation wells may often show small but significant pressure transient trends and in order to interpret these trends reliably, it is imperative to collect sufficient background data, prior to production or injection. Moreover, due to a variety of reasons, it is often extremely difficult to maintain constant production or injection rates throughout a given test. There is thus a great need for generalized interpretation techniques such as the variable discharge analysis recently developed at the LBL. Looking into the future, there is undoubted need to enlarge the scope of conventional well-test methods to include the temperature, phase-change and chemical changes, which form intrinsic parts of geothermal wells and reservoirs. A great deal of field work and theoretical work is required to be carried out in these areas.

The purpose of this paper is to highlight the current status of geothermal well-testing, identify the problem areas and to assess the directions in which future work might proceed.

TESTING AND SAMPLING PROCEDURES FOR A GEOPRESSURED WELL

M. H. Dorfman and W. E. Boyd
University of Texas at Austin

Test wells to tap and sample geothermal-geopressured formations at 15,000-20,000 feet in the Gulf Coast area can be drilled routinely utilizing available equipment and methods. Electrical logs, surveys and fluid samplers can be used to obtain accurate and relaiable information as to depths, temperatures, pressures, and fluid content of the geopressured formations before the well is completed. But it will be necessary to set casing and flow the well, at least temporarily, to secure fluid production volume and pressure data to evaluate the producibility of the geopressured resource.

Electric logging and wireline survey methods are fully developed techniques for measuring the parameters needed to assess a geopressured zone before setting casing. Formation subsidence, though it may be slow to develop, can be measured using radioactivity tracer surveys.

It is concluded that existing well logging and surveying methods and equipment are generally satisfactory for testing and sampling a geothermal-geopressured resource. There are no significant areas of research needed to predict, detect, and evaluate geopressured formations for their potential as geothermal resources. Static and dynamic testing procedures using existing technology are satisfactory to test, sample and analyze a geopressured reservoir.

ANALYSIS AND INTERPRETATION OF OIL, GAS AND GEOTHERMAL WELL TESTS

William E. Brigham
Stanford University

The purpose for any well test is to determine quantitative information about the reservoir which the well (or wells) penetrates and quantitative information about the condition of the well. These data, in turn, can be used to answer a variety of important questions—What will be the long term producing rate versus time? What are the total reserves? Should we attempt to stimulate the well? How has the reservoir pressure changed?—and a host of others. At the heart of these analyses is the fact that the pressure changes linearly with the logarithmic of time; and the quantitative answers are extracted from the slope and intercept of such a graph.

Unfortunately, we find in practice that it is often difficult to identify the correct semi-log slope. At early times the condition of the well causes distortion of the pressure-time curve. Such things as the wellbore volume or the presence of fractures at the well will often cause such distortions. At later times the reservoir geometry will similarly affect the semi-log slope; nearby faults, abrupt changes in the reservoir flow properties, or multiple zones are examples.

Since 1970 there has been a virtual explosion of information on ways to handle these early and late time problems. Many of them have now been solved analytically. Further, through the use of log-log type curve matching one can often diagnose the well behavior and be certain that the correct slope has been found and the analysis of the data is correct.

Most of these techniques were developed for oil and gas flow, but in recent years they have been applied to geothermal systems—both hot water and steam—with considerable success.

In interference testing the properties between wells are analyzed by determining the pressure-time behavior of a shut-in well when the production rate is changed in an offset well. Historically, this has been used successfully in both the oil and gas industry and in hydrology through use of log-log type curves and the classic line source solution. This technique has also been used successfully in geothermal systems.

Recently, well test problems have been attacked that appear unique to geothermal systems. A number of new solutions have been generated that embody differing reservoir geometries and have been found to match field data. Other problems need to be addressed quantitatively; for example, the problem of water boiling near a producing well. In addition, reliable measuring equipment needs to be developed which can stand the high temperatures and salinity seen in geothermal systems. Since well testing has been found to be useful in geothermal systems, there is considerable incentive to expand its use to the fullest extent possible. For this reason, I am confident that many new and useful solutions to well testing problems will become available in the near future.

INTERPRETATION OF TRACER TESTS
BY MEANS OF TYPE CURVES
APPLICATION TO UNIFORM AND RADIAL FLOW

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Bureau de Recherches Géologiques et Minières

It is shown that in uniform or radial flow it is possible to characterize the response to continuous injection or instantaneous pulse by a set of type curves in dimensionless coordinates depending only on one parameter similar to a Péclet number. These curves allow a simple and efficient eye identification of dispersion parameters.

Application to field experiments shows that:

- in practice, tracer tests in uniform flow should be avoided in absence of precise knowledge of the effective direction of flow;
- on the contrary, pulse injection into satellite piezometers of a central pumping well yields a good and economical method when the flow is effectively radial.

ROLE OF PARAMETER IDENTIFICATIONS IN THE DESIGN AND ANALYSIS OF PUMPING TESTS

Shlomo P. Neuman
University of Arizona, Tuscon

The results of conventional pumping tests are usually interpreted on the basis of analytical solutions in which the aquifer (or reservoir) is assumed to be homogeneous and possesses an idealized geometry. Such tests rely further on the introduction into the system of a single control signal (e.g., a constant or piece-wise constant rate of pumpint) at a single well location. In practice, aquifers tend to be inhomogeneous and have a complex geometry. The need to maintain a prescribed rate of pumping in only one well, while shutting down neighboring wells to prevent interference with the test, is often costly and at times impractical. Moreover, the parameters determined for such tests tend to have only a local significance. It is suggested that numerical modeling coupled with parameter identification techniques should make it possible to design large scale tests in which several wells pump simultaneously at variable rates. Such tests will cause minimum interference with normal field operations and will yield more reliable parameter estimates than those obtained by conventional methods. A blue print for the design of such tests is presented in this paper.

MULTIPLE-WELL VARIABLE-FLOW WELL TEST ANALYSIS BY A COMPUTER-ASSISTED OPTIMIZATION PROCEDURE

Chin Fu Tsang
Lawrence Berkeley Laboratory
University of California

The use of fast digital computers and efficient algorithms for multi-parameter least square minimization provides a powerful alternative to the conventional well test analysis by curve-matching procedures. Furthermore, the availability of portable, telephone-coupled computer terminals make such computer assisted methods practical in field applications. There are two major advantages to the computer-aided procedure. First, it minimizes the human bias. Secondly, it not only generalizes the solutions that are used in curve matching but also simultaneously considers more than three unknown parameters in achieving the fit. In the conventional curve-fitting process, the maximum number of unknown parameters that can be conveniently handled is three.

In the present work, the expression for pressure drawdown, as a function of time and position, due to a system of flowing wells each with arbitrarily varying rates are constructed from the solution of a linearly varying line source problem by the principle of superposition. The solution of the linearly-varying line source is obtained by convolution from the standard formula for an instantaneous line source. The effects of boundaries, well-bore storage and skin effect are also included. Verification with known analytic solutions has confirmed that the technique indeed gives very satisfactory results. The method developed can be easily extended to include other type curve situations such as leaky multiple aquifer systems or flow to a well in the presence of horizontal or vertical fractures.

The success of the present approach greatly enlarges the capability of parameter evaluation for a reservoir. Instead of being limited to a short period of constant-flow well testing during the initial assessment of the field, we are now able to obtain estimates of reservoir parameters while normal field operations are in progress, so long as the flow rates of all the wells are recorded and the pressure responses of observation wells monitored.

TRANSIENT FLOW IN TIGHT FRACTURES

Joseph Wang
Lawrence Berkeley Laboratory

Methods are developed to analyze packer-test data from a well intersected by one or more tight fractures. In a geological formation such as a granite rock with fractures being the main conduits of water, the permeability of fractures to water intrusion and leakage is an important consideration in deciding the suitability of a site for waste storage. In a packer test, a pressure pulse is applied to the water sealed between two packers and the pressure decay at the wellbore is monitored. When the well intersects fractures, the pressure decline is due to the flow into the fractures. In this study the diffusion equation governing the transient flow in the fracture is solved and boundary conditions at the wellbore-fracture interface discussed. Analytic and numerical solutions for different geometrical arrangements of single and multiple fractures are given. Since the conductance of the fracture depends on the cube of its aperture, the "short-time" pressure decay tests can be effectively used for the fracture aperture estimation. Further information about the shape, continuity and connectivity of the fracture system requires "long-time" data.

PRESSURE BEHAVIOR OF WELLS INTERCEPTING FRACTURES

Raj Raghavan
University of Tulsa

The pressure behavior of wells intercepting fractures is of considerable interest to the petroleum industry due to the large number of wells that have been hydraulically fractured to improve well productivity. This procedure is recognized as one of the major developments in petroleum production technology within the last 30 years. As a result of extensive research to resolve differences between field results and expectations based on analytical studies, a considerable body of knowledge on the performance of fractured wells has been accumulated. This paper is a brief survey of the current level of understanding of this aspect of pressure transient analysis by petroleum engineers.

The topics considered here include the following: (i) the effect of vertical, horizontal, and inclined fractures on pressure behavior at the well, (ii) the influence of fracture flow capacity on pressure versus time data, (iii) the effect of wellbore storage and damage on pressure response, (iv) the influence of closed (depletion or zero recharge) or constant pressure (complete recharge) boundaries. Both flowing and shut-in pressure behaviors are discussed.

This survey also indicates some of the problems that should be solved to improve our understanding of fractured well behavior.

APPLICATION AND INTERPRETATION OF DRILL STEM TESTS

Merlin Anderson
Halliburtan Services

The drill Stem Test is one of the most useful tools available for evaluating potentially productive formations. Advances in DST technology has provided the equipment and versatility to safely obtain reservoir parameters from almost any formation. Unrestricted flow passages through the tools allow prolific wells to be produced at the high rates necessary to achieve sufficient draw down for adequate reservoir analysis. Wire line equipment can be run through the tools to allow the zone to be perforated after the tools are in place. The formation can be tested, treated through the DST tools and then retested to evaluate the results of the treatment all on one trip in the hole. Proper evaluation of the results obtained is very important on any test. An initial visual interpretation of the bottom hole pressure recordings will give an indication of the reservoir characteristics and determine if the test is a mechanical success suitable for further analysis. Often insufficient attention is given to this phase of the test. This paper presents the current tools and equipment available for drill stem testing. Test procedure and visual interpretation of the pressure recordings are discussed.

WELL TESTING PRACTICE AND ANALYSIS IN FISSURED AQUIFERS

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Bureau de Recherches Géologiques et Miniéres

A new method for interpreting pump test data in fissured aquifers is discussed. The pumped well behavior is analysed in terms of an equivalent anisotropic porous medium, with a single fracture intersecting the wellbore. By means of type curves, it is possible to calculate the directional permeabilities of the aquifer, and the direction and volume of the "equivalent single fracture", which provides a measurement of the fissure density. Field data are presented, which indicate that accurate very early time measurements (of the order of a few seconds) are required in many cases for the method to be applicable.