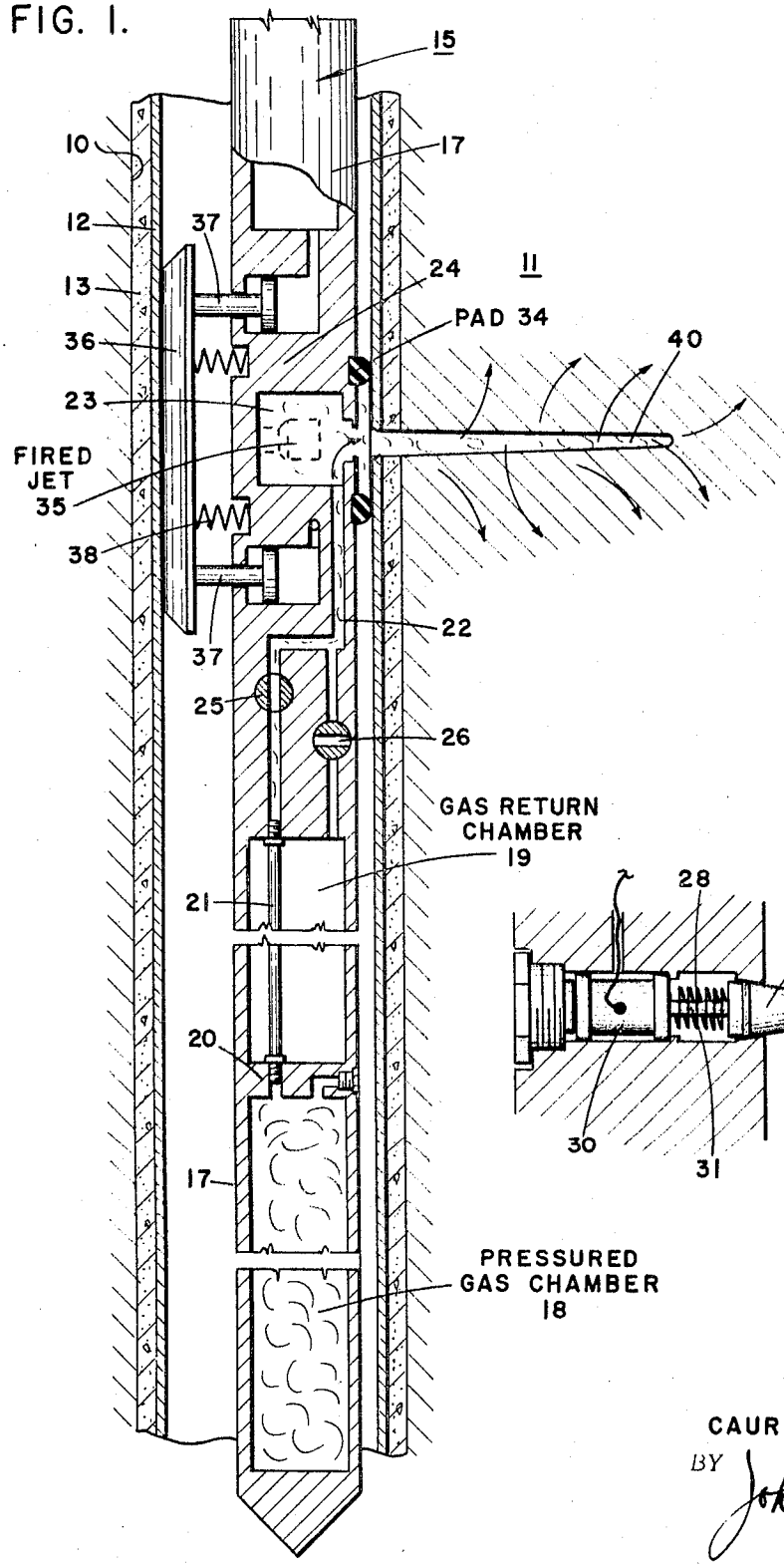
FIP8011 XR 3,456,504 CROSS REFERENCE SEARCH ROOM

July 22, 1969 C. C. BOMBARDIERI 3,456,504

SAMPLING METHOD

Filed Nov. 7, 1966

FIG. 1.



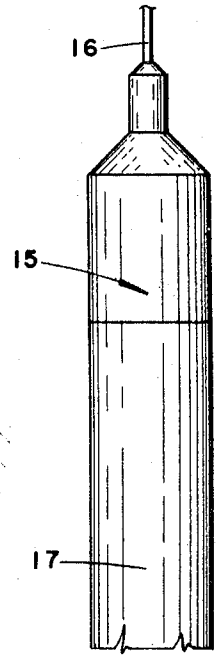


FIG. 1A.

FIG. 2.

INVENTOR.
CAURINO C. BOMBARDIERI,
BY John J. Schneider
ATTORNEY.

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SAMPLING METHOD

Caurino C. Bombardieri, Calgary, Alberta, Canada, assignor to Esso Production Research Company, a corporation of Delaware

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U.S. Cl. 73—151 5 Claims

ABSTRACT OF THE DISCLOSURE

A method for analyzing a subsurface formation which involves the introduction of at least two fluids into said formation in a selected ratio, a further production of fluids from said formation and an analysis of the return fluids for relative amounts of said two injected fluids.

The present invention generally concerns method and apparatus for determining characteristics of subsurface formations. More particularly, this invention concerns method and apparatus for treating subsurface formations surrounding a bore-hole with treating fluids and then sampling and analyzing the treating fluids returned from the formation. Still more particularly, this invention concerns method and apparatus for introducing two treating fluids into a subsurface formation in a predetermined ratio and then sampling and analyzing the treating fluids returned from the formation to determine the ratio of these fluids and thereby the nature of the formation fluids.

In one preferred mode of operation, method and apparatus are described for detecting hydrocarbons in porous rock in which a predetermined ratio of two specific gases, one of which has preferentially high solubility in hydrocarbons compared with its solubility in formation water, and the other of which has low solubility in both hydrocarbons and formation water, is injected under pressure into a porous formation. The gas returned to the borehole is sampled and analyzed, as, for example, by well-known gas chromatography techniques which require only a small amount of returned fluids for an accurate determination of identity and amount thereof. A significant ratio change of the injected gases is an indication of the presence of hydrocarbons, whereas a negligible ratio change is an indication of the absence of hydrocarbons.

Thus, this invention makes use of the high and preferential solubility property of specific gases, e.g., carbon dioxide in hydrocarbons, and the relatively low solubility property of these gases in brine and the relative insolubility of other gases, e.g., nitrogen, in both hydrocarbons and brine. A predetermined ratio of nitrogen to carbon dioxide gas is introduced under pressure into a formation to be treated and a sample of the returned gas is analyzed for both nitrogen and carbon dioxide. Any loss of nitrogen is considered to have dissipated into the formation and it is considered that an equivalent amount of carbon dioxide gas has also been lost by dissipation. Any further and significant changes in the amount of carbon dioxide would be due to solubility of carbon dioxide in hydrocarbons.

The gases to be injected into the formation are placed under pressure in one chamber of a tool which is adapted to provide an isolated flow path for these gases into the formation to be treated. Another chamber in this tool receives a sample of gas returned from the formation through an isolated flow path. A tool for carrying out this technique may be suitably "shoot and test" apparatus such as disclosed and claimed in U.S. Patent No. 3,153,449, entitled "Method and Apparatus for Completing a Well," issued Oct. 20, 1964 to M. P. Lebourg,

modified to provide chambers for the injected and returned gases and suitable valving in place of the fluid treating chambers and valves shown in this patent.

A primary object of the present invention is to provide new and improved method and apparatus for determining characteristics of subsurface fluids and especially the presence of hydrocarbons in subsurface formations.

Briefly, the method of this invention comprises introducing at least two fluids into a subsurface formation in a selected ratio; producing fluids from said formation; and analyzing said returned fluids for relative amounts of said two injected fluids.

The apparatus of this invention briefly comprises a tool having an elastomer, annular-shaped sealing member for isolating an area along the length of the bore from well bore fluid contained in the well bore; means in the tool for engaging the wall of the well bore to promote contact of the sealing member with the well bore and isolation of said area; said tool having a first chamber adapted to contain initially fluid to be injected into a subsurface formation and a second chamber adapted to receive well fluids from said formation; perforator means suitably aligned with a central portion of said sealing member and arranged to develop a perforation in the earth formations in fluid communication with said isolated area; said tool including passageway means adapted to provide isolated flow paths from said first chamber to said isolated area and from said isolated area to said second chamber; valve means arranged in said passageway means adapted to permit and prevent flow of fluids from and to, respectively, said first chamber and to permit and prevent flow of fluids to and from, respectively, said second chamber.

The above object and other objects and advantages of the invention will be apparent from a more detailed description thereof when taken with the drawings wherein:

FIGS. 1 and 1A are views showing the well tool of the invention, partly in section, and in position in a borehole for carrying out the method of this invention; and

FIG. 2 is a detailed view of a suitable valve arrangement usable in the apparatus illustrated in FIG. 1.

As shown in FIG. 1, borehole **10**, in which is arranged a well or casing pipe **12** cemented in place by cement sheath **13**, traverses a subsurface formation **11**. A "shoot and test" tool **15** is suspended in casing pipe **12** by means of a conductor cable **16**. Tool **15** includes a tubular body member **17** provided with reservoirs or chambers **18** and **19** separated by a barrier **20**. Chamber **18** initially contains gases under pressure higher than the formation pressure. Chamber **19** receives well fluids from the formation following injection of the gases initially contained in chamber **18** into formation **11**. Chamber **19** is previously purged of gases and is at a reduced pressure less than formation pressure to permit return flow of well fluids, including liquids and gases initially contained in the formation as well as injected gases, following injection of gases initially contained in chamber **18**. A conduit or passageway **21** fluidly communicates chamber **18** and the upper portion of a conduit or passageway **22**, which passageway extends between chamber **19** and a chamber **23** in the gun block **24** of tool **15**. Valves **25** and **26** are arranged in passageways **21** and **22**, respectively. These valves may be suitably solenoid-operated valves such as illustrated in FIG. 2. As seen in this figure, a valve member **27** is normally biased by spring **28** to a valve seat **29** formed in passageway **21** (and **22**). Actuation of the solenoid **30** causes plunger **31** to dectract and remove valve **27** from seat **29** again the bias of spring **28** and open the passageway(s). An annular sealing pad **34** surrounds chamber **23** in which is located a jet perforator gun **35**; a backoff shoe **36** is positioned on the opposite side of tool **15** from the location of pad **34**. Backoff shoe **36** has connected to

it piston rods **37**, which in turn are connected to pistons which are received in hydraulic cylinders within the tool as shown. Tension springs **38** facilitate retraction of backoff shoe **35** from the wall of pipe **12**. A hydraulic actuating system for piston rods **36** may be of the type illustrated in U.S. Patent No. 2,674,313, issued to Chambers. In operating in accordance with the present invention, tool **15** is lowered to adjacent formation **11**. A section of pipe **12** encircled by pad **34** is isolated from fluids within pipe **12** by actuating pistons connected to piston rods **37** to force backoff shoe **36** against the wall of pipe **12** against the bias of springs **38**. Formation **11** is then penetrated by actuating jet charge **35** to form a perforation **40** in formation **11**. Chamber **23** may be permitted to receive any mud which might be entrapped within the isolated section from the formations by momentary production of the perforation. Valve **25** is then opened and gases contained in chamber **18** flow through passageway **21** and portion of passageway **22** into chamber **23** and into formation **11** through isolated perforation **40**. Valve **25** is then closed and valve **26** is opened to permit well fluids mixed with the injected gases to flow from perforation **40** and through passageway **22** into chamber **19** which is at a lower pressure than the formation pressure. Then, valve **26** is closed. The seal provided by pad **34** is removed by retracting shoe **36** and tool **15** is removed from casing **12** by cable **16**. At the surface, chamber **19** is opened and the fluids contained therein are analyzed.

Assuming that the gas system to be used is carbon dioxide and nitrogen, predetermined ratios of nitrogen to carbon dioxide could vary from 0.1:1.0 to 10.0:1.0 with an optimum amount determined by selective testing. The solubility properties of carbon dioxide and nitrogen gas are discussed in "The Use of Nitrogen and Carbon Dioxide to Improve Well Stimulation Treatments," Spring Meeting of the Rocky Mountain District, American Petroleum Institute, Paper No. 875–17–B, Apr. 24–26, 1963, by J. P. Moran. Other papers relating to the solubility of carbon dioxide in hydrocarbons are "Phase Relations of Carbon Dioxide-Hydrocarbon Mixture," Producers' Monthly, Dec. 19, 1964, vol. 17, by C. Drew, and "Generalized Correlations for Predicting Solubility, Swelling and Viscosity Behavior of CO_2-Crude Oil Systems," Journal of Petroleum Technology, January 1965, vol. 102, by R. Simon and D. J. Graue.

The following example calculations were made based on solubility data set forth in the above-mentioned papers:

Assuming an initial 1:1 ratio of nitrogen and carbon dioxide at a pressure of 1,000 p.s.i., the ratio of the gases upon return for a water-oil ratio of 10:1 in the formation would be 20.7:1 nitrogen to carbon dioxide; a water-oil ratio of 1:1 in the formation would give a ratio of the gases upon return of nitrogen to carbon dioxide of 34.7:1, and a ratio of water to oil in the formation of 1:10 would give a ratio of gases upon return of nitrogen to carbon dioxide of 40.7:1.

Other gas systems in accordance with the principle of the present invention might be used instead of the nitrogen-carbon dioxide gas system. Typical examples of these other gases which have low solubility in water and some

or greater solubilities in oil are acetylene, ethylene, oxygen and carbon monoxide. These and other gases having desirable solubility properties which can be used will be recognized by those skilled in the art.

Although the invention described herein is a method to be used for detecting hydrocarbons, it can also be used to detect other formation fluids, such as brine. In this instance, a gas which has high solubility in brine and low solubility in hydrocarbons could be used as the test fluid. Analysis of the return fluids can also be used to identify the presence of other gases or fluids in the rock formation in addition to the gases injected from the tool.

Various modifications in the invention may be made without departing from the spirit and scope thereof.

Having fully described the apparatus, method and operation of my invention, I claim:

1. A method for determining characteristics of subsurface formation fluids comprising:
   introducing at least two fluids into a subsurface formation in a selected ratio, each of said fluids having different solubilities in said formation fluids;
   producing fluids from said formation; and
   analyzing said fluids produced from said formation and determining the ratio of said introduced fluids in said produced fluids.

2. A method as recited in claim **1** in which one of said introduced fluids has preferentially higher solubility in hydrocarbons and relatively low solubility in formation water and another of said introduced fluids has relatively low solubility in both hydrocarbons and formation water whereby a ratio change of said introduced fluids indicates the presence of hydrocarbons and no ratio change of said introduced fluids indicates absence of hydrocarbons.

3. A method as recited in claim **2** in which said one fluid is carbon dioxide and said other fluid is nitrogen.

4. A method as recited in claim **3** in which said selected ratio of nitrogen to carbon dioxide ranges from 0.1:1.0 to 10.0:1.0.

5. A method as recited in claim **1** in which one of said introduced fluids has preferentially higher solubility in formation water and relatively low solubility in hydrocarbons and another of said introduced fluids has relatively low solubility in both formation water and hydrocarbons whereby a ratio change of the introduced fluids indicates the presence of water and no ratio change of said introduced fluid indicates absence of water.

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RICHARD C. QUEISSER, Primary Examiner

J. W. MYRACLE, Assistant Examiner

U.S. Cl. X.R.

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