# United States Patent

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[54] **METHODS AND APPARATUS FOR DETECTING THE ENTRY OF FORMATION GASES INTO A WELL BORE**


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[52] **U.S. Cl.** ................................**73/153**, 73/19, 73/421.5 R

[51] **Int. Cl.** ........................................................**E21b 47/00**

[58] **Field of Search** .........................73/153, 421.5 R, 19, 38; 175/40



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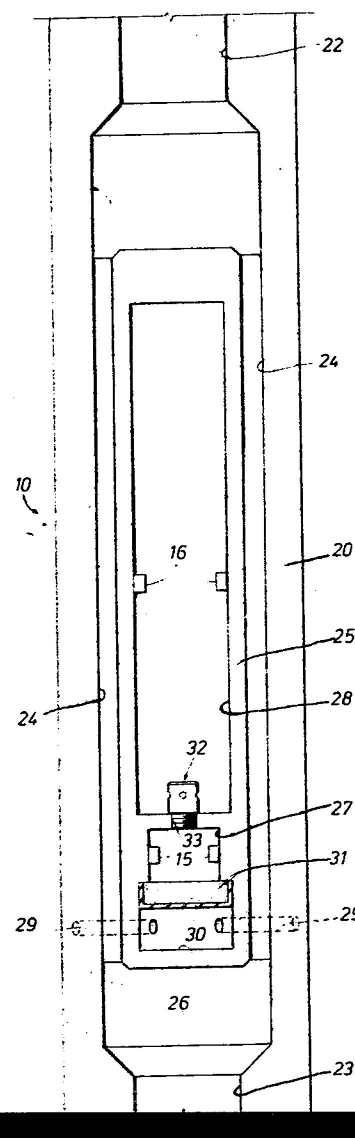
[57] **ABSTRACT**

As a preferred mode for practicing the invention disclosed herein, drilling mud in a borehole is fluidly communicated with an enclosed testing chamber by means of a gas-pervious liquid barrier which is at a reduced pressure so that, should there be higher-pressure formation gases dissolved or entrained in the drilling mud, the gases will be drawn through the barrier into the testing chamber. In this manner, by monitoring either the pressure or temperature within the testing chamber, the presence or absence of formation gases in the drilling mud can be ascertained; and, if desired, these measurements can be employed to at least estimate the percentage of gases in the mud sample. In the representative embodiment of the apparatus of the present invention disclosed herein, a tool arranged for coupling into a drill string is provided with a mud-sampling passage which is fluidly coupled to an enclosed testing chamber by a liquid barrier formed of a gas-pervious material. One or more measuring devices, such as pressure and temperature monitors, are arranged in the testing chamber for detecting the admission of gas into the chamber.

**25 Claims, 3 Drawing Figures**

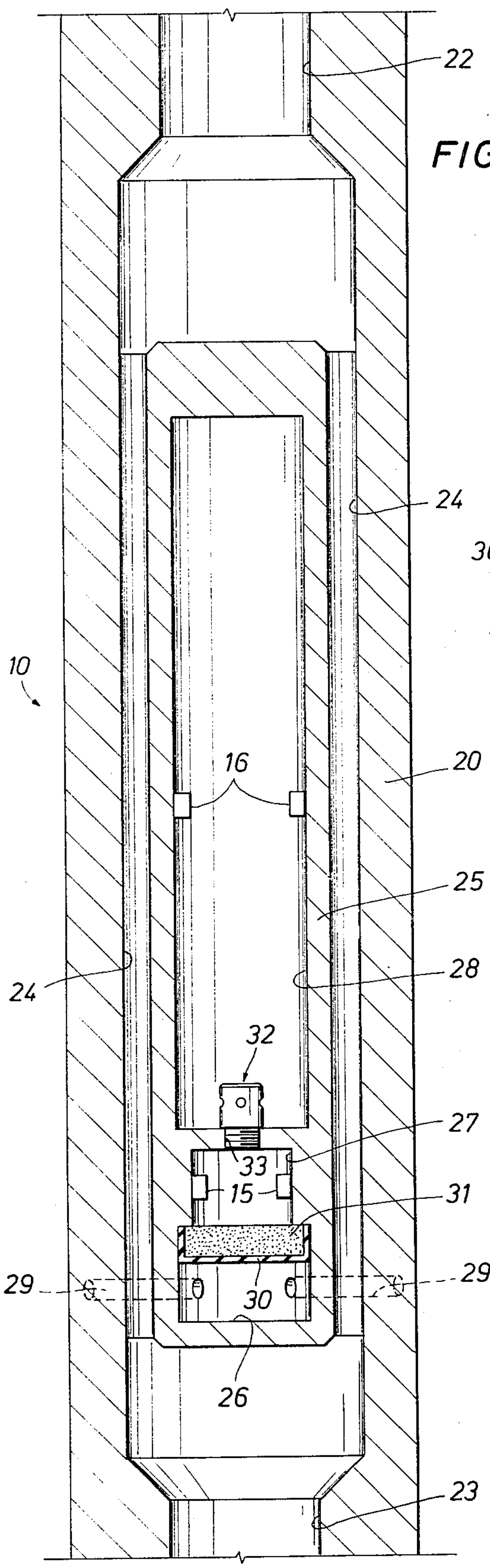



FIG.2

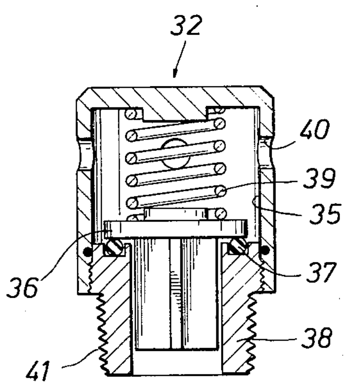



FIG.3

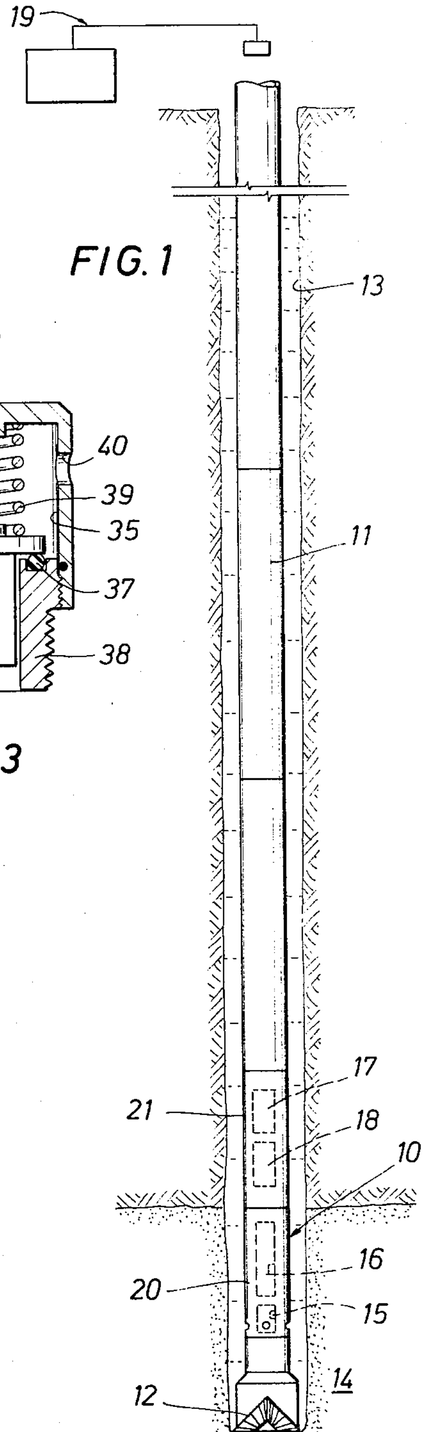



FIG.1

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## METHODS AND APPARATUS FOR DETECTING THE ENTRY OF FORMATION GASES INTO A WELL BORE

Those skilled in the art will, of course, appreciate that while drilling an oil or gas well, a drilling fluid or so-called "mud" is customarily circulated through the drill string and drill bit and then returned to the surface by way of the annulus defined between the walls of the borehole and the exterior of the drill string. In addition to cooling the drill bit and transporting the formation cuttings removed thereby, the mud also functions to maintain pressure control of the various earth formations as they are penetrated by the drill bit. Thus, it is customary to selectively condition the drilling mud for maintaining its specific gravity or density at a sufficiently high level where the hydrostatic pressure of the column of mud in the borehole annulus will prevent or regulate the flow of any high-pressure connate fluids in the formations being penetrated by the drill bit.

It is, however, not at all uncommon for the drill bit to unexpectedly penetrate earth formations containing gases at pressures greatly exceeding the hydrostatic head of the column of drilling mud at that depth which will often result in a so-called "blowout". It will be appreciated that unless a blowout is checked, it may well destroy the well and endanger lives and property at the surface. Thus, to be abundantly safe, it might be considered prudent to always maintain the density of the drilling mud at excessively high levels just to prevent such blowouts from occurring. Those skilled in the art will appreciated, however, that excessive mud densities significantly impair drilling rates as well as quite often unnecessarily or irreparably damage potentially producible earth formations which are still uncased. As a matter of expediency, therefore, it is preferred that the drilling mud be conditioned so as to maintain its density at a level which is just sufficient to at least regulate, if not prevent, the unexpected entry of high-pressure formation gases into the borehole and instead rely upon one or more of several typical operating techniques for hopefully detecting the presence of high-pressure gases in the borehole.

Various techniques are, of course, commonly employed for detecting the presence of such high-pressure gases in the borehole with varying degrees of accuracy. For example, detection techniques which may be used either separately or collectively include observing changes in the rotative torque as well as the longitudinal drag on the drill string, monitoring differences between the flow rates of the inflowing and outflowing streams of the drilling mud as well as measuring various properties of the returning mud stream and the cuttings being transported thereby to the surface. Those skilled in the art have long recognized, however, that no one or group of the several techniques which are presently employed will reliably and immediately detect the entrance of high-pressure formation gases into the borehole. For example, variations of torque or drag on the drill string are not always reliable indicators since borehole conditions entirely unrelated to the presence of high-pressure gases in the borehole mud column can be wholly responsible for causing significant variations in these parameters. On the other hand, although such techniques as monitoring the mud flow rates or measuring the physical characteristics of the returning mud stream may well reliably indicate the entrance of high-pressure formation gases into the borehole, the time interval required for a discrete volume of mud containing such gases to reach the surface is generally in the order of several hours. This, of course, will usually be too late to permit preventative measures to be taken for avoiding a disastrous blowout.

Accordingly, it is an object of the present invention to provide new and improved methods and apparatus for reliably detecting the entrance of formation gases into a borehole as it is being drilled and then immediately providing a positive indication or signal at the surface that such gases are present.

This and other objects of the present invention are attained by communicating the drilling mud in a borehole with an enclosed reduced-pressure chamber by means of a gas-pervious liquid barrier for separating formation gases which may be in the drilling mud and drawing these gas samples into the chamber. The pressure or temperature within the testing chamber is monitored for providing one or more indications at the surface which are characteristic of the presence or absence of gas in the chamber.



To practice the methods of the present invention, the preferred embodiment of the new and improved apparatus described and claimed herein includes a body which is adapted to be tandemly coupled in a drill string adjacent to the drill bit and includes a longitudinal mud-circulation passage for conducting drilling mud to the drill bit. A sampling passage is arranged on the body and terminated in a sampling chamber for receiving drilling mud from the borehole exteriorly of the body. A testing chamber is also arranged on the body and is separated from the sampling chamber by a liquid-impermeable gas-pervious barrier so that so long as the testing chamber is at a reduced pressure, gases entrained or dissolved in the drilling mud entering the sampling chamber will be separated from the mud and pass through the gas-pervious barrier into the testing chamber. Measuring means are cooperatively associated with the testing chamber for providing one or more signals which are characteristic of the presence or absence of gas in the testing chamber. Signaling means are further provided for producing indications at the surface in response to the signals provided by the measuring means. To perform multiple tests, a reduced-pressure gas-collection chamber is arranged on the body and fluidly coupled to the testing chamber by selectively operable valve means which periodically open for reducing the pressure in the testing chamber to allow subsequent test to be made.

The novel features of the present invention are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may be best understood by way of the following description of exemplary methods and apparatus employing the principles of the invention as illustrated in the accompanying drawings, in which:

FIG. 1 schematically illustrates one embodiment of apparatus arranged in accordance with the present invention as this apparatus will appear while practicing the methods of the invention;

FIG. 2 is an enlarged cross-sectional view of a portion of the apparatus of the present invention shown in FIG. 1; and

FIG. 3 depicts one embodiment of a control which may be employed with the apparatus illustrated in FIG. 2 during the performance of the methods of the present invention.

Turning now to FIG. 1, a new and improved well tool **10** arranged in accordance with the present invention is depicted coupled in a typical drill string **11** having a rotary drill bit **12** dependently coupled thereto and adapted for excavating a borehole **13** through various earth formations as at **14**. As the drill string **11** is rotated by a typical drilling rig (not shown) at the surface, substantial volumes of drilling mud are continuously pumped downwardly through the tubular drill string and discharged from the drill bit **12** to cool the bit as well as to carry earth borings removed by the bit to the surface as the mud is returned upwardly along the borehole **13** exterior of the drill string. As is typical, the mud stream is circulated by employing one or more high-pressure mud pumps (not shown) which continuously draw the fluid from a storage pit or vessel for subsequent recirculation by the mud pumps. It will be appreciated, therefore, that the constantly circulating mud stream flowing through the drill string **11** is well suited to serve as a medium for transmitting pressure surges or pulses from the tool **10** to the surface.

In accordance with the principles of the present invention and as will subsequently be explained in further detail, the well tool **10** includes gas-detecting means such as one or more sets of electrical transducers **15** and **16** which, in the depicted preferred embodiment of the well tool, are electrically coupled to an appropriate measurement encoder **17** operatively arranged for producing one or more coded electrical signals that are indicative of the presence or absence of gas in the drilling mud. Signaling means **18** electrically coupled to the encoder 17 are operatively arranged to respond to these coded signals for selectively generating one or more distinctive pressure pulses in the circulating mud stream. To produce these distinctive pressure pulses, the signaling means 18 are preferably arranged as disclosed and claimed in any one of three copending applications filed together on July 30, 1970, and respectively designated as Ser. No. 59,383, Ser. No. 59,394 and Ser. No. 59,395.

Inasmuch as each of these copending applications fully describe their respective inventions, it is believed unnecessary to describe the particular details of these three pulse-producing devices, any one of which can be readily employed for the signaling means 18 incorporated in the new and improved well tool 10 of the present invention. By way of summary, therefore, each of the three new and improved pressure-producing devices include a movable member cooperatively arranged for momentarily and rapidly interrupting the flow of the drilling mud through the drill string 11. To initiate each operational cycle of the pressure-producing device, the movable flow-blocking member and an electrical solenoid are uniquely adapted to respond to a selected electrical signal from the encoder 17 for moving the valve member into momentary seating engagement with a valve seat arranged in the mud-circulation passage in the tool 10. Closure of the valve member will, of course, produce a momentary surge of pressure in the circulating mud stream as its flow is momentarily interrupted. Immediately after closure of the mud-circulation passage, the valve member is returned to its initial passage-opening position to await the next energization of the cycle-initiating solenoid. To power the solenoid as well as any other electrical devices (such as at 15–17) on the tool 10, an electrical generator is coupled to a fluid-powered turbine which is cooperatively arranged to be driven by the circulating mud stream.

It will be appreciated, therefore, that the transistory pressure pulses or surges produced by the pressure-signaling means 18 will be similar to those caused by a so-called "water hammer". Thus, these pressure waves will be transmitted to the surface by way of the circulating mud stream in the drill string 11 and at the speed of sound in that particular drilling mud. Accordingly, as the measurement encoder 17 drives the cycle-initiating solenoid, the pressure-signaling means 18 produce these pressure pulses to provide encoded representations or data indicative of the one or more conditions sensed by the gas-detecting transducers 15 and 16. This encoded data is, in turn, successively transmitted to the surface in the form of a train of pressure pulses for detection and conversion into meaningful indications or records by suitable surface apparatus 19 such as the new and improved apparatus disclosed in either U.S. Pat. No. 3,488,629 or U.S. Pat. No. 3,555,504.

Turning now to FIG. 2, an enlarged view is shown of that portion of the new and improved tool 10 which carries the gas-detecting devices 15 and 16. As illustrated in FIGS. 1 and 2, the tool 10 includes an elongated body 20 which is adapted to be tandemly coupled in the drill string 11 preferably at a selected position a short distance above the drill bit 12 and just below an elongated body 21 carrying the encoder 17 and the pressure-signaling means 18. To conduct drilling mud to the drill bit 12 therebelow, the body 20 is provided with upper and lower longitudinal bores, as at 22 and 23, which are communicated with one another by a plurality of elongated passages 24 appropriately located in the body 20 to bypass an interior portion 25 of the body that is preferably coaxially disposed therein between the upper and lower bores.

In the preferred embodiment of the tool 10, the interior body portion 25 is cooperatively arranged to define three longitudinally spaced interior chambers 26, 27 and 28. For reasons that will subsequently be explained in greater detail, the upper chamber 28 is substantially larger in volume than the two lower chambers 26 and 27. To communicate the drilling mud in the borehole 13 exterior of the tool 10 with the lower or sampling chamber 26, a plurality of lateral mud-conducting passages 29 are cooperatively arranged in the body 20 between the longitudinal mud passages 24 for conducting a representative flow of drilling mud through the sampling chamber during the drilling operation. If necessary, the outer portions of the passages 29 may be directed or shaped so that rotation of the drill string 11 will facilitate circulation of drilling mud through the sampling chamber 26.

As illustrated, the lower sampling chamber 26 is separated from the intermediate or testing chamber 27 by gas-pervious barrier means, such as a sheet of an elastomeric material 30, cooperatively arranged for blocking the flow of liquids between the two chambers without unduly hindering the passage of formation gases from the lower chamber through the barrier and into the intermediate chamber. To support the elastomeric sheet 30 whenever the pressure in the sampling chamber 26 is higher than that in the testing chamber 27, a block 31 of a gas-permeable material such as a porous stone or sintered metal is arranged between the two chambers immediately on top of the elastomeric sheet.

It will be appreciated, therefore, that once the tool 10 is immersed in the drilling mud in the borehole 13, the sampling chamber 26 will be filled with mud and the pressure of the mud in the sampling chamber will be equal to the hydrostatic pressure of the mud column at that depth. Since the testing chamber is initially at atmospheric pressure and this chamber is empty, there will be a pressure differential between the sampling and testing chambers 26 and 27. Thus, although drilling mud cannot flow through the elastomeric sheet, any formation gases which may be dissolved or entrained in the mud within the sampling chamber 26 will readily permeate or pass through the elastomeric sheet 30 and the porous support 31 into the testing chamber 27. It will, of course, be recognized that the pressure of the gases entering the testing chamber 27 will be directly related to the quantity of gas entering the testing chamber.

So long as the tool 10 is immersed in a gas-free mud, the testing chamber 27 will remain free of gas. Once, however, there is a significant entrance of high-pressure formation gases into the borehole 13 as, for example, from the formation 14, as drilling mud carrying this gas enters the sampling chamber 26 the pressure and temperature conditions in the testing chamber 27 will change in relation to the quantity of gas which is separated from the drilling mud and drawn through the gas-pervious liquid barrier 30 into the testing chamber by virtue of the reduced pressure existing in the latter chamber. Thus, if one of the gas-detecting devices 15 is a pressure transducer, entrance of formation gas into the testing chamber 27 will produce an increase in the pressure being monitored by the transducer. Conversely, expansion of the higher pressure formation gas into the low-pressure chamber 27 will produce a corresponding reduction of the temperature therein. Accordingly, by employing a temperature-responsive transducer for the other of the two gas-detecting devices 15 shown in FIG. 2, the entrance of formation gas into the testing chamber 27 will produce correlative signals at the surface showing the concurrent decline in the monitored temperature as the monitored pressure in the chamber rises. Those skilled in the art will, of course, appreciate that the rates at which the temperature and pressure of the gas in the chamber 27 vary will be of as much interest as the absolute pressure and temperature measurements provided by the gas-detecting transducers 15.

It will be recognized that by making the testing chamber 17 relatively small, even minor quantities of entrained or dissolved formation gases entering the sampling passages 29 and the sampling chamber 26 will produce substantial and, therefore, easily recognized changes in the surface indications corresponding to the absolute values of the two measurements being monitored by the transducers 15. Moreover, with a small chamber 27, the rates of change in the two measurements will be more pronounced than would be the case with a larger testing chamber.

Once the testing chamber is filled with a first sample of formation gas, it will be realized that the further entrance of additional samples of gas will be retarded, if not altogether halted, since the pressure differential between the chambers 26 and

27 will be greatly reduced. In any event, only those samples of drilling mud in the sampling chamber **26** containing a gas having a higher partial pressure than the pressure of the gas already trapped in the testing chamber **27** could then enter the testing chamber.

Although a higher pressure gas in the testing chamber **27** could possibly return through the elastomeric sheet **30** should the partial pressure of the gas in the mud in the sampling chamber subsequently drop to a lower pressure, this would be unpredictable. Thus, with only the small testing chamber **27** for collecting gases permeating through the elastomeric sheet **30**, the tool **10** will most likely be limited to only one effective test for detecting the entrance of formation gases into the borehole **13**.

Accordingly, to enable the tool **10** to repetitively detect the entrance of formation gases into the borehole **13**, the upper chamber **28** is cooperatively arranged in the body portion **25** for successively collecting gases from the testing chamber **27** so that the pressure in the testing chamber will be periodically reduced to permit subsequent gas samples to be drawn into the testing chamber during the continuation of the drilling operation. This will, of course, enable the tool **10** to repetitively perform a substantial number of tests before the tool becomes inoperative. It will, of course, be recognized that by making the volume of the collection chamber **28** as large as possible in relation to the volume of the testing chamber **27**, a substantial number of gas samples can be exhausted into the larger chamber before the pressure in the smaller chamber ultimately becomes so high that the tool **10** becomes inoperative. It will also be recognized that each time the testing chamber **27** is exhausted, the resulting reduced pressure in the chamber will always be somewhat greater than achieved by the previous exhaustion cycle. The actual magnitude of the reduced pressure which will be obtained in the testing chamber each time it is exhausted will, of course, be determined by the relative volumes of the chambers **27** and **28**.

To regulate the discharge of gases from the testing chamber **27** to the collection chamber **28**, control means, such as a periodically actuated normally closed valve **32**, are cooperatively arranged for controlling the flow of gases through an intercommunicating passage **33** between the two chambers. In the preferred embodiment of the tool **10**, the valve **32** is cooperatively arranged to temporarily open only when the pressure in the testing chamber **27** becomes substantially higher than that in the collection chamber **28**.

Accordingly, as depicted in FIG. 3, the valve **32** includes an upright body **34** having an enlarged chamber **35** in which a disc-like valve member **36** is operatively disposed for movement into and out of engagement with an annular valve seat **37** arranged around a depending inlet fitting **38**. To normally bias the valve member **36** into seating engagement, means such as a compression spring **39** are arranged in the chamber **35**. Outlet ports **40** are provided as required in the body **34**. Thus, as illustrated in FIG. 2, when the valve **32** is secured, as by threads **41**, in the passage **33** between the chambers **28** and **29**, the valve member **36** will be elevated from the valve seat **37** only so long as the pressure force acting on the underside of the valve member is sufficient to overcome the opposing force of the spring **39**. Then, once the pressures in the two chambers **27** and **28** approach equilibrium, the spring **39** will reseat the valve member **36** on the seat **37**.

It will, of course, be recognized that the tool **10** will typically be left out of the drill string **11** until the borehole **13** is believed to be approaching formations, as at **14**, possibly containing highly pressured formation gases. Once, however, it is decided to employ the new and improved tool **10** for practicing the methods of the present invention, the tool is coupled into the drill string **11** preferably just above the drill bit **12**. In this manner, once the drill bit **12** has reached the bottom of the borehole **13** and the drilling operation is commenced, the circulating mud stream will be driving the mud-powered electrical generator in the tool body **20** so that the several electrical devices, as at **15–17**, on the tool **10** will be operative.

With the tool **10** operative, as samples of the drilling mud pass through the sampling chamber **26** the mud samples will be successively communicated by way of the gas-pervious liquid barrier **30** with the reduced-pressure testing chamber **27** for separating formation gases — if any — from the mud samples and drawing the separated gases into the testing chamber. As previously described, the entrance of such high-pressure formation gases into the testing chamber **27** will simultaneously lower the temperature and raise the pressure in the testing chamber. Thus, by virtue of the one or more gas-detecting devices **15** in the testing chamber **27**, the pressure-producing signaling means **18** of the tool **10** will successively transmit pressure pulses to the surface which are converted by the surface apparatus **19** into meaningful signals which are characteristic of the presence of formation gases in the drilling mud. Conversely, so long as the surface signals from the downhole monitors **15** remain unchanged, it will be known that there are no formation gases in the drilling mud.

Once the entrance of gas samples into the testing chamber **27** has raised the pressure therein to a predetermined level, the valve **32** will momentarily open for discharging a substantial portion of the entrapped gases into the collection chamber **28**. Once the valve **32** recloses, the pressure in the testing chamber **27** will again be lowered but now to a reduced pressure which will be slightly higher than the initial reduced pressure in the chamber to permit subsequent gas samples to be drawn into the testing chamber.

It will be appreciated, of course, that as subsequent gas samples are separated from the drilling mud and drawn into the testing chamber **27**, the repeated discharge of these samples into the collection chamber **28** will ultimately raise the pressure in the two chambers to a level which will halt continued operation of the tool **10**. The pressure and temperature transducers **16** will provide signals at the surface that will enable an observer to determine that the accumulated gas samples in the chambers **27** and **28** must be discharged by returning the tool **10** to the surface and purging the chambers.

Accordingly, it will be appreciated that the present invention has provided new and improved methods and apparatus for detecting the entrance of high pressure formation gases into a borehole as it is being drilled and quickly providing indications at the surface to warn of the potentially hazardous situation. By communicating the drilling mud with a reduced pressure chamber by means of a gas-pervious liquid barrier, formation gases are separated from the drilling mud and drawn into the chamber to produce reliable indications at the surface which are characteristic of the entrance of such gases into the borehole. Conversely, by practicing the present invention, indications are successively provided to assure the drilling operator that no significant quantities of formation gases are present in the borehole.

While only a particular embodiment of the present invention and mode of practicing the invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

**1.** A method for determining whether pressured formation gases are present in the drilling mud in a borehole which is being excavated by a drill bit and comprising the steps of: positioning an enclosed testing chamber which is at a pressure less than that of formation gases which may be present in said drilling mud at a selected depth in said borehole adjacent to said drill bit; communicating said drilling mud with said testing chamber by means of a gas-pervious liquid barrier for separating formation gases from said drilling mud and drawing such separated formation gases into said testing chamber; and monitoring a condition in said testing chamber that is indicative of the entrance of said separated formation gases into said testing chamber for providing a signal at the earth's surface which is characteristic of the presence or absence of said formation gases in said drilling mud.

2. The method of claim 1 wherein said monitored condition is the pressure of gases in said testing chamber.

3. The method of claim 1 wherein said monitored condition is the temperature of gases in said testing chamber.

4. A method for determining whether pressured formation gases are present in the drilling mud in a borehole which is being excavated by a drill bit coupled to a drill string and comprising the steps of: coupling an enclosed testing chamber which is at a reduced pressure to said drill string for positioning said testing chamber at a selected depth in said borehole as said drill bit is excavating said borehole; communicating said drilling mud with said testing chamber by means of a gas-pervious liquid barrier for separating a sample of formation gases from said drilling mud and drawing said gas sample into said testing chamber; monitoring at least one condition in said testing chamber that is characteristic of the entrance of said gas sample into said testing chamber for producing a first signal indicative of the presence or absence of a gas sample in said testing chamber; and, in response to said first signal, producing a second signal that is detectable at the surface of the earth for providing surface indications which are characteristic of the presence or absence of formation gases in said drilling mud at said selected depth.

5. The method of claim 4 wherein said monitored condition varies in accordance with the quantity of said gas sample entering said testing chamber.

6. The method of claim 4 wherein said monitored condition is the pressure of said gas sample in said testing chamber.

7. The method of claim 4 wherein said monitored condition is the temperature of said gas sample in said testing chamber.

8. The method of claim 4 further including the steps of: once said second signal is produced, discharging said gas sample from said testing chamber for returning said testing chamber to a reduced pressure less than that of pressured formation gases in said drilling mud at said selected depth; recommunicating said drilling mud with said testing chamber by means of said liquid barrier for separating a second sample of formation gases from said drilling mud and drawing said second gas sample into said testing chamber; remonitoring said one condition for producing a third signal indicative of the presence or absence of a gas sample in said testing chamber; and, in response to said third signal, producing a fourth signal that is detectable at the surface of the earth for providing surface indications which are characteristic of the presence or absence of formation gases in said drilling mud at said selected depth.

9. A method for determining whether pressured formation gases are present in the drilling mud in a borehole which is being excavated by a drill bit coupled to a drill string and comprising the steps of: coupling an enclosed testing chamber and an enclosed receiving chamber which are respectively at a reduced pressure to said drill string for positioning said chambers at a selected depth in said borehole as said drill bit is excavating said borehole; communicating said drilling mud with said testing chamber by means of a gas-pervious liquid barrier for separating a sample of formation gases from said drilling mud and drawing said gas sample into said testing chamber; monitoring the pressure in said testing chamber for producing a first signal indicative of whether a gas sample entered said testing chamber; producing a second signal in response to said first signal for providing an indication at the surface which is characteristic of the presence or absence of formation gases in said drilling mud at said selected depth; and, upon receiving said second signal indicating that formation gases are present in said drilling mud at said selected depth, communicating said testing chamber with said receiving chamber to lower the pressure in said testing chamber for introduction of another gas sample.

10. The method of claim 9 further including the steps of: monitoring the pressure in said receiving chamber for producing a third signal indicative of whether said gas sample entered said receiving chamber; and producing a fourth signal in response to said third signal for providing an indication at the surface which is characteristic of whether said gas sample entered said receiving chamber.



11. The method of claim 9 further including the steps of: monitoring the temperature in said testing chamber for producing a third signal indicative of whether a gas sample entered said testing chamber; and producing a fourth signal in response to said third signal for providing an indication at the surface which is characteristic of the presence or absence of formation gases in said drilling mud at said selected depth.

12. The method of claim 11 wherein said signals are obtained before and after a gas sample has entered said testing chamber and further including the step of: correlating said second and fourth signals in accordance with the General Gas Law for determining the gas content of said drilling mud at said selected depth.

13. Apparatus for determining whether pressured formation gases are present in the drilling mud in a borehole which is being excavated and comprising: a drill string having a drill bit coupled thereto; means on said drill string defining an enclosed testing chamber which is adapted to initially be at a reduced pressure; a mud passage between said testing chamber and the exterior thereof; means defining a gas-pervious liquid barrier between said mud passage and said testing chamber and adapted for passing only formation gases in drilling mud within said mud passage into said testing chamber; condition-monitoring means in said testing chamber adapted to provide first signals indicative of the passage of a formation gas sample through said gas-pervious liquid barrier into said testing chamber; and signaling means on said drill string and operable in response to said first signals for producing second signals at the surface of the earth which are indicative of the presence or absence of formation gases in drilling mud within said mud passage.

14. The apparatus of claim 13 wherein said condition-monitoring means include a pressure transducer adapted for providing said first signals which are representative of the pressure in said testing chamber.

15. The apparatus of claim 13 wherein said condition-monitoring means include a temperature transducer adapted for providing said first signals which are representative of the temperature in said testing chamber.

16. The apparatus of claim 13 wherein said gas-pervious liquid barrier is comprised of a member of a gas-pervious, liquid-impermeable material sealingly arranged in said mud passage and separating said mud passage from said testing chamber.

17. The apparatus of claim 16 wherein said barrier member is substantially formed of an elastomeric material.

18. The apparatus of claim 13 wherein said signaling means include: means on said drill string adapted for momentarily interrupting the flow of drilling mud through said drill string to produce pressure variations which are transmitted therethrough to the surface; means on said drill string coupling said flow-interrupting means and said condition-monitoring means and adapted for actuating said flow-interrupting means in response to said first signals to produce said second signals; and means at the surface responsive to the arrival of said second signals at the surface for providing characteristic indications representative of said first signals.

19. The apparatus of claim 13 further including: means on said drill string defining an enclosed receiving chamber which is adapted to initially be at a reduced pressure; passage means communicating said testing chamber with said receiving chamber; and valve means in said passage means normally blocking communication between said chambers and adapted to be opened for discharging a gas sample in said testing chamber into said receiving chamber.

20. The apparatus of claim 19 wherein said valve means include actuating means adapted for opening said valve means only in response to an increase of gas pressure in said testing chamber to a predetermined level above the gas pressure in said receiving chamber.

21. The apparatus of claim 19 further including: second condition-monitoring means in said receiving chamber adapted to provide third signals indicative of the discharge of a formation gas sample from said testing chamber into said

receiving chamber; and means coupling said second condition monitoring means to said signaling means for producing fourth signals at the surface of the earth which are indicative of the discharge of a formation gas sample from said testing chamber into said receiving chamber.

**22.** Apparatus adapted for determining whether pressured formation gases are present in the drilling mud in a borehole which is being excavated and comprising: a body adapted for coupling in a drill string and including a passage therethrough for conducting drilling mud from such a drill string to a drill bit coupled thereto below said body; an enclosed testing chamber arranged in said body and adapted to initially be at a reduced pressure; a mud passage in said body communicating said testing chamber with the exterior of said body; a gas-pervious liquid-impermeable barrier sealingly fitted to said body and adapted for blocking the flow of drilling mud into said testing chamber and passing formation gases into said testing chamber when such gases are at a higher pressure than that of said testing chamber; and a condition-monitoring transducer in said testing chamber and adapted for producing electrical signals representative of a selected condition in said testing chamber.

**23.** The apparatus of claim **22** wherein said transducer is adapted for producing electrical signals representative of the pressure of gases in said testing chamber.

**24.** The apparatus of claim **22** wherein said transducer is adapted for producing electrical signals representative of the temperature of gases in said testing chamber.

**25.** The apparatus of claim **22** further including: an enclosed receiving chamber arranged in said body and adapted to initially be at a reduced pressure; a gas passage in said body communicating said testing chamber with said receiving chamber; and valve means in said body normally closing said gas passage and adapted for opening only when the gas pressure in said testing chamber is at a level greater than that in said receiving chamber.

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