

[54] APPARATUS FOR DETERMINING THE GAS CONTENT OF DRILLING MUDS

[75] Inventors: **Denis R. Tanguy; Joseph F. Kishel**, both of Clarks Summit, Pa.

[73] Assignee: **Schlumberger Technology Corporation**, New York, N.Y.

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[58] Field of Search **73/153, 19, 61 R; 23/230 HC, 232 R**

[56] References Cited

UNITED STATES PATENTS

2,280,086	4/1942	Hayward	175/183
2,799,561	7/1957	Rochon	73/19 X
3,521,478	7/1970	Magorien	73/19

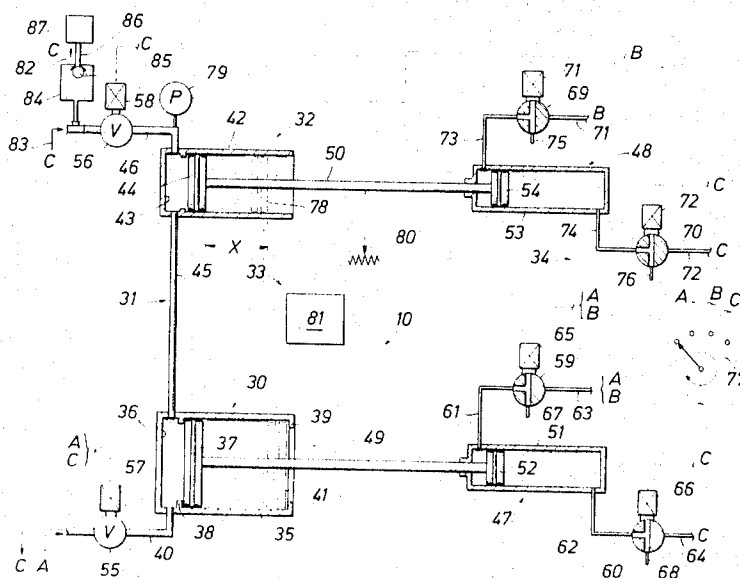
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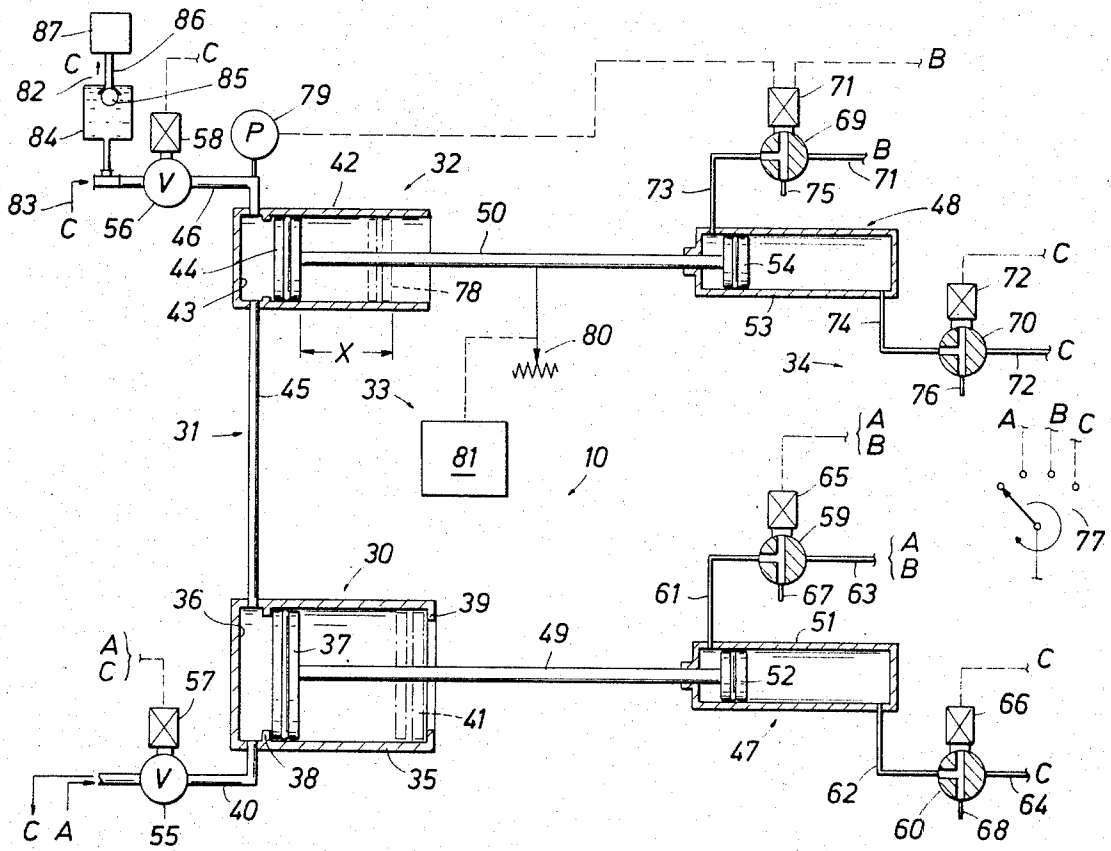
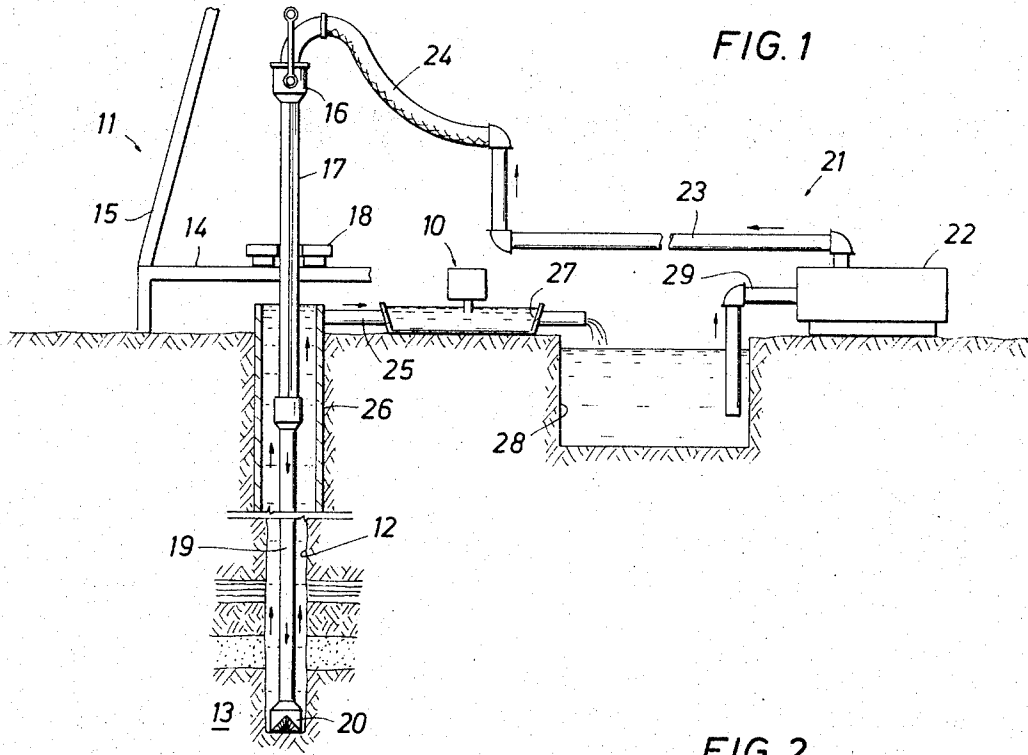
Attorney—Ernest R. Archambeau, Jr. et al.

[57] ABSTRACT

In the representative embodiment of the apparatus of the present invention disclosed herein, first and second selectively-movable pistons are respectively arranged within complementary first and second cylinders having their working chambers in fluid communication with one another to define an expansible sample chamber. Suitable control devices are provided to selectively extend the first piston for inducting a predetermined volume of drilling mud into the sample chamber and thereafter extend the second piston for reducing the pressure in the sample chamber to a predetermined reduced pressure which is preferably somewhat greater than the saturation pressures of any gases which might possibly be entrained in the entrapped mud sample. A suitable measuring device is cooperatively arranged for measuring the extension or displacement volume of the second piston for accurately determining the gas content of the entrapped sample.

20 Claims, 2 Drawing Figures





APPARATUS FOR DETERMINING THE GAS CONTENT OF DRILLING MUDS

Those skilled in the art will, of course, appreciate that while drilling an oil or gas well, a drilling control 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 to the surface, the mud also functions to impose a positive pressure on the earth formations penetrated by the drill bit. Thus, it is customary to condition the drilling mud for maintaining its specific gravity or so-called "mud weight" at a selected level where the hydrostatic pressure of the column of mud in the borehole annulus will presumably be sufficient to prevent or at least regulate the entry of high-pressure connate fluids into the borehole from the formations penetrated by the drill bit.

It is, however, not at all uncommon for the drill bit to unexpectedly penetrate earth formations containing connate fluids at pressures greatly exceeding the hydrostatic head of the column of drilling mud at that depth which will often result in either a so-called "pressure kick" or, even worse, a "blowout". It will be appreciated that unless such a blowout is quickly checked, it may 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 appreciate, however, that excessive mud densities will significantly impair drilling rates as well as quite often unnecessarily or irreparably damage potentially-producible earth formations. 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 measuring devices for hopefully detecting the presence of such gases in the returning drilling mud in time to take appropriate corrective actions.

Typical of these devices is the laboratory apparatus disclosed in U.S. Pat. No. 2,280,086 wherein a sample of drilling mud is drawn into a glass measuring tube and subjected to a reduced pressure to expand the sample for determining the amount of entrained gas. However, in addition to being unduly fragile, it is particularly difficult with this apparatus either to precisely measure the sample volumes at the two test pressures or to accurately determine the reduced pressure during the final step. It will, of course, be appreciated that if either of these measurements are imprecise, the resulting computation of the gas content will be correspondingly affected.

Other more-rugged test devices have also been proposed such as, for example, those described in U.S. Pat. No. 2,138,141 and U.S. Pat. No. 3,521,478. In the two devices shown in these patents, a single piston is mounted in a cylinder and cooperatively withdrawn for drawing a specified volume of mud into the piston chamber. In the first patented device, a gas measure-

ment is purportedly obtained by compressing the sample and measuring the initial and final pressures and volumes. With the second of these two patented devices, the piston is first withdrawn further for reducing the pressure in the piston chamber to a selected value. The piston is then returned to compress the liberated gases to atmospheric pressure before determining the percentage of entrained gas in the mud sample. It will be appreciated, however, that in either test device, only a single piston is provided for hopefully obtaining a precise volumetric measurement of the mud sample as well as for bringing the pressure of the entrained gas to a precise final pressure. As a result, the limited accuracy of these test devices simply precludes reliable measurements of small percentages of entrained gas.

Accordingly, it is an object of the present invention to provide a new and improved testing device for accurately determining the gas content of drilling muds during the course of a typical drilling operation.

This and other objects of the present invention are attained by providing means adapted for entrapping a precisely-measured volume of a gas-bearing drilling mud in a sample chamber and including a first cylinder in communication with the sample chamber and having a first piston member cooperatively arranged therein for selective movement to an extended position for precisely inducting a predetermined volume of mud at a first pressure into the sample chamber; means adapted for precisely reducing the pressure of a sample in the sample chamber and including a second cylinder in communication with the sample chamber and having a second piston member cooperatively arranged therein for selective movement to an extended position for precisely increasing the volume of the sample chamber until the pressure of the mud sample therein is reduced to a second predetermined pressure; and means responsive to the extension of the second piston for accurately determining the increased chamber volume required to obtain this second pressure to provide a precise measurement which is proportional to the gas content of the mud sample.

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 apparatus employing the principles of the invention as illustrated in the accompanying drawings, in which:

FIG. 1 schematically illustrates a portion of a typical rotary drilling rig and its associated mud-circulating system along with new and improved gas-measuring apparatus of the present invention; and

FIG. 2 schematically depicts a preferred embodiment of a gas-measuring system arranged in accordance with the principles of the present invention.

Turning now to FIG. 1, a gas-measuring system employing the principles of the present invention is schematically illustrated as it may be employed in conjunction with a conventional rotary-drilling operation in which a so-called "drilling mud" is circulated. As is customary, the drilling operation is accomplished by means of a typical drilling rig 11 which is suitably arranged for drilling a borehole 12 through various earth formations, as at 13, until a desired depth is attained.

The drilling rig 11 conventionally includes a drilling platform 14 carrying a derrick 15 which supports typical cable-hoisting machinery (not shown) suitably arranged for supporting a swivel 16 and a tubular "kelly" 17. The drilling rig 11 further includes a rotary table 18 operatively arranged on the rig floor 14 for rotatively driving the kelly 17 which supports a depending string 19 of drill pipe and drill collars carrying a typical rotary drilling bit 20.

As is customary, the borehole 12 is filled with a supply of drilling mud for maintaining pressure control of the various earth formations, as at 13; and, as indicated by the several arrows seen in FIG. 1, the drilling mud is continuously circulated between the surface and the bottom of the borehole during the course of a drilling operation for cooling the drill bit 20 as well as for carrying away cuttings as they are removed by the drill bit. To circulate the drilling mud, the drilling rig 11 further includes a mud-circulating system 21 which conventionally has a high-pressure circulating pump 22 coupled to the kelly 17 and the drill string 19 by means of suitable piping 23 and a flexible hose 24 connected to the swivel 16. The drilling mud is returned to the surface by way of a return line 25 coupled to the surface casing 26 typically lining the uppermost portions of the borehole 12 and an open-top trough 27 which is customarily arranged to discharge the returning drilling mud into a so-called "mud pit" 28. A suction pipe 29 in the other end of the mud pit 28 is coupled to the pump 22 for withdrawing the drilling mud contained therein. Accordingly, it will be appreciated that as the pump 22 is operated, the drilling mud is continuously pumped downwardly through the kelly 17 and the drill string 19 and then discharged from one or more ports in the drill bit 20 into the bottom of the borehole 12. As the drilling mud leaves the drill bit 20, the cuttings being removed thereby will be carried in suspension by the column of viscous mud returning to the surface by way of the annulus space defined in the borehole 12 around the drill string 19.

It will, of course, be appreciated that should the drill bit 20 be penetrating an earth formation, as at 13, containing high-pressure gas, there will be a corresponding increase in the gas content of that portion of the drilling mud which is then exiting from the drill bit. Even though there may be a localized area of agitation around the bit 20, experience has demonstrated that there is little or no intermixing of the several incremental portions of drilling mud constituting the outgoing mud stream in the borehole 12. As a result, an increase in the gas content of a given portion of the returning drilling mud can be attributed to the presence of gas in the earth formation, as at 13, which was being penetrated by the drill bit 20 as that portion of mud left the drill bit. Thus, by successively measuring the gas content of incremental portions of the drilling mud entering the mud pit 28, useful indications will be obtained of the nature of the earth formations, as at 13, being penetrated by the drill bit 20. If desired, the gas content of the drilling mud entering the kelly 17 can also be determined to obtain a true differential measurement of the gas content of the outflowing stream of drilling mud. It will, of course, be appreciated that in either situation, appropriate corrections must be made to account for the time required for a given increment

of drilling mud to move between the surface and the bottom of the borehole 12. Such corrections may, of course, be readily ascertained by those skilled in the art.

Turning now to FIG. 2, the new and improved gas-measuring system 10 of the present invention is depicted in a somewhat-schematic form. In general, the gas-measuring system 10 includes sample-inducting means 30 cooperatively arranged for entrapping a precisely-measured sample of potentially gas-bearing drilling mud into an enclosed sample chamber 31, pressure-reducing means 32 adapted for precisely reducing the pressure of the entrapped mud sample to a predetermined lower pressure, and volume-determining means 33 cooperatively arranged for providing a precise measurement representative of the increased volume of the entrapped mud sample at the predetermined reduced pressure. To selectively control the operation of the gas-measuring apparatus 10, a group of controls, such as the automatic system shown generally at 34, is provided.

In the preferred embodiment of the present invention as illustrated in FIG. 2, the sample-inducting means 30 include an elongated cylinder 35 defining an enclosed piston chamber 36 forming part of the sample chamber 31 and carrying a piston member 37 cooperatively arranged for reciprocating movement therein. To precisely delimit the longitudinal stroke or travel of the piston 37 within the cylinder 35, means are provided such as a pair of longitudinally-spaced stop members 38 and 39 which are cooperatively arranged at selected positions within the bore of the cylinder and on opposite sides of the piston. Accordingly, it will be appreciated that since the internal bore of the cylinder 35 is of a uniform diameter and the locations of the fixed stops 38 and 39 are known, the displacement volume of the sample-inducting means 30 is precisely determined. Thus, by coupling a sample conduit, as at 40, to the closed end of the piston chamber 36, movement of the piston 37 from its illustrated full-line position to its extended position, as at 41, will be effective for drawing a precise volume of gas-bearing drilling mud into the sample chamber 31. Conversely, this entrapped volume of drilling mud will be displaced from the sample chamber 31 through the mud conduit 40 whenever the piston 37 is returned from its extended position 41 to its initial position as illustrated in FIG. 2.

The pressure-reducing means 32 are similarly comprised of an elongated cylinder 42 having a piston chamber 43 which is also cooperatively arranged to be another portion of the sample chamber 31 and carries a reciprocating piston member 44. To complete the sample chamber 31, a conduit 45 of suitable size is coupled between the cylinders 35 and 42 in communication with the two piston chambers 36 and 43. Another conduit 46 is coupled to the cylinder 42 to provide communication with the chamber 43.

The measuring system 10 further includes piston-actuating means such as hydraulic or pneumatic actuators 47 and 48 which are respectively coupled by connecting rods 49 and 50 to the pistons 37 and 44. As is typical, the actuator 47 is comprised of an elongated cylinder 51 carrying an actuating piston 52 which is coupled to the connecting rod 49 and cooperatively arranged for movement back and forth in response to the

selective application of a motivating pressure on one or the other side of the piston. Similarly, the actuator 48 includes a cylinder 53 carrying an actuating piston 54 which is coupled to the connecting rod 50 and also moved back and forth as a motivating pressure is applied to one or the other side of the piston.

The control system 34 includes a pair of selectively operated control valves, such as normally-closed solenoid valves 55 and 56 having one or more individual solenoid actuators as at 57 and 58, which are respectively coupled to the conduits 40 and 46 for selectively controlling the entrance of drilling mud into the sample chamber 31 as well as the release of liberated gas therefrom. The control system 34 is also cooperatively arranged for selectively moving the pistons 37 and 44 back and forth within their respective cylinders 35 and 42.

In the preferred embodiment of the gas-measuring system 10, the pressure-responsive actuator 47 is selectively controlled by coupling the outlets of selectively-operated control valves, such as a pair of three-way solenoid valves 59 and 60, to opposite ends of the actuator cylinder 51 by fluid lines 61 and 62 and coupling pressure supply lines 63 and 64 between the inlet of these valves and a suitable source of a pressured fluid (not shown) such as a conventional hydraulic or compressed-air system. As is typical, the three-way valves 59 and 60 are arranged so that when their respective solenoid actuators 65 and 66 are not energized, the outlet conduits 61 and 62 will either be respectively vented, as at 67 and 68, to atmosphere where a pneumatic system is employed or else be returned to a reservoir where a hydraulic system is employed. This arrangement will, of course, require that the solenoid valves 59 and 60 be opened by energizing their respective solenoids 65 and 66 when it is desired to move the actuating piston 52 to a different position.

Three-way solenoid valves 69 and 70 respectively having solenoid actuators 71 and 72 are similarly arranged for selectively controlling the movements of the actuator piston 54. Hereagain, the inlets of the valves 69 and 70 are coupled to pressure supply lines 71 and 72 and the outlets of these valves are respectively connected by conduits 73 and 74 to the opposite ends of the actuating cylinder 53. Pneumatic vent lines or hydraulic return lines 75 and 76 are respectively coupled to the solenoid valves 69 and 70 in the same manner as previously described with respect to the piston actuator 47.

The control system 34 is, of course, cooperatively arranged for selectively operating the several actuator control valves 59, 60, 69 and 70 as well as the sample chamber control valves 55 and 56. Those skilled in the art will, of course, appreciate that many different arrangements of timers, relays, sequence controls, limit switches and various types of switches can be arranged to provide the control functions necessary for operating the measuring system 10. Thus, since the present invention is not limited to any particular arrangement of controls, the control system 34 is schematically depicted including a multi-position rotary switch 77 that is cooperatively arranged for providing the control functions which, as will subsequently be explained, are essential to the operation of the measuring system 10. As illustrated, the switch 77 is arranged to selectively

supply power to the several solenoids 57, 58, 65, 66, 71 and 72 at different times as respectively indicated by the letters A, B and C. To appreciate the effects of opening the several solenoid valves 59, 60, 69 and 70, the same identification characters A, B and C are also used to designate when the motivating fluid (i.e., compressed air or hydraulic fluid) is admitted through a particular valve to the actuators 47 and 48.

In the operation of the new and improved gas-measuring system 10 of the present invention, a mud sample is first drawn into the sample chamber 31 by opening the sample valve 55 and moving the piston 37 from its full-line position as depicted in FIG. 2 to its fully-extended position as at 41. The sample valve 55 is reclosed to close off the entrapped mud sample in the sample chamber 31. Thereafter, the piston 44 is moved from its full-line position toward an extended position, as at 78, for reducing the pressure in the sample chamber 31 to a predetermined value which is known to be higher than the saturation pressure or flashing pressure of the liquid phase of the entrapped mud sample. These three steps are essential for achieving the objects of the present invention; and it will, therefore, be appreciated that the control system 34 can be arranged in various manners to accomplish these objects without departing from the scope of the invention.

To understand the principles of the present invention, it must be recognized that the physical characteristics of the mud sample entrapped in the sample chamber 31 will determine the distance which the piston 44 must be moved outwardly to reduce the pressure in the sample chamber to the aforementioned predetermined value. First of all, those skilled in the art will appreciate that if only a gas instead of a gas-bearing liquid was entrapped in the sample chamber 31, outward travel of the piston member 44 from its fully-retracted position shown in FIG. 2 to an extended position, such as depicted at 78, would simply expand the gas in direct relation to the distance traveled by the pressure-reducing piston. Thus, in this unlikely situation, outward travel of the piston 44 will simply reduce the pressure of the entrapped gas sample in keeping with the general gas laws.

The situation just described will, of course, be significantly different where an entirely-liquid sample is entrapped in the sample chamber 31. Assuming that the actuator 48 is incapable of pulling the piston 44 outwardly with sufficient force to reduce the pressure of the entrapped liquid sample to or below its saturation pressure and thereby induce flashing of the liquid sample, it will be appreciated that there will be no perceptible movement of the piston 44 away from its fully-retracted position illustrated in FIG. 2 before the pressure in the sample chamber 31 is reduced to the aforementioned predetermined value.

In the usual situation, however, there will generally be at least a minor quantity of gas entrained or dissolved in a given mud sample trapped in the sample chamber 31. It has been found that the percentage of gas contained in such a gas-bearing sample can be computed by the following equation:

$$\% \text{ gas} = [(100P_2/(P_1 - P_2))(A/V_1)]X \quad \text{Eq. 1}$$

where,

P_1 = initial pressure of mud sample, psia

P_2 = final reduced pressure of mud sample, psia

A = area of piston member 44, sq. in.

V_1 = volume of mud sample, cu. in.

X = distance piston member 44 extended to reach final pressure P_2 , in.

Accordingly, in the operation of the gas-measuring apparatus 10, the several movable elements of the apparatus are initially positioned as illustrated in FIG. 2. For reasons that will subsequently be explained, it is preferred that the sample chamber 31 (i.e., the piston chambers 36 and 43 as well as the interconnecting conduit 45) be initially filled with water. Thereafter, with the control system 34, movement of the rotary switch 77 to the A position will simultaneously apply power to the solenoids 57 and 65 to open the actuator 59 for effecting outward movement of the sample-induction piston 52 as well as to open the sample valve 55 for allowing a sample of drilling mud to be inducted into the sample chamber 31 as the sample-inducting piston is moved outwardly to its extended position as at 41. The power could just as well be applied successively to the solenoids 57 and 65 so long as a sample of drilling mud is pulled into the chamber 31.

It will be appreciated, therefore, that since the volume of water initially trapped between the closed valves 55 and 56 and in front of the pistons 37 and 44 when they are in their fully-retracted positions is precisely known, movement of the sample-inducting piston to its outward position 41 will induct a precisely-determined volume of the drilling mud into the sample chamber 31. Thus, once the piston 37 has reached its outward position 41, the volume, V_1 , of the mud sample will be accurately established to permit precise determination of the gas content therein by means of Equation 1.

Once the sample-inducting piston 37 has reached its extended position 41, the rotary switch 77 is advanced to the switch position B. As illustrated in FIG. 2, the actuator valve 59 is left open to insure that the sample-inducting piston remains in its fully-extended position. With the control system 34, the advancement of the switch 77 will also simultaneously apply electrical power to the solenoid 71 for opening the actuator valve 69 to admit the pressured motivating fluid into the left-hand end of the actuator cylinder 53 for carrying the piston 44 outwardly toward, for example, the extended position indicated by 78. It will, of course, be appreciated that the actuator valve 69 could also be opened by means of a limit switch (not shown) which would be arranged to respond to movement of the sample-inducting piston 37 to its position at 39.

As previously described, however, outward movement of the pressure-reducing piston 44 is continued only until such time that the pressure in the sample chamber 31 is reduced to a predetermined minimum. Thus, in the preferred manner of accomplishing this, a pressure-responsive switch 79 is cooperatively arranged for sensing the pressure in the sample chamber 31 and cutting the electrical power supplied to the solenoid 71 for reclosing the valve 69 once the pressure in the sample chamber has reached this predetermined minimum. This will, of course, halt the pressure-reducing piston 44 so that a typical position transducer 80 coupled thereto will provide an immediate reading, as on a recorder 81, which is indicative of the outward displacement, X , of the pressure-reducing piston. Thus,

since all of the several factors in Equation 1 except for the displacement distance, X , are predetermined constants, once the recorder 81 has recorded either the extent of the displacement of the pressure-reducing piston 44 or a function thereof, the gas content of the sample of drilling mud will be precisely determined. Thereafter, the rotary switch 77 is advanced to the position C for returning the pistons 37 and 44 to their respective retracted positions as well as opening the valves 55 and 56 to discharge the mud sample back through the conduit and into the mud trough 27 as well as to purge the sample chamber 31 of collected gas as at 82.

It will be appreciated that by leaving the valves 55 and 56 open, fresh water, as at 83, can be introduced into the sample chamber 31 for washing out any residual traces of the drilling mud or cuttings which would otherwise tend to accumulate in the sample chamber and progressively decrease the volume of the sample chamber and thereby impair the accuracy of the measurements. In the preferred embodiment of the gas-measuring apparatus 10, fresh water is admitted to the sample chamber 31 and gas is purged therefrom by means of an inverted gas-collection chamber 84 which is coupled to the inlet of the valve 56. Since the gas-collection chamber 84 will ordinarily be filled with water, a float-operated valve, as schematically depicted at 85, is cooperatively arranged for preventing water from entering a gas outlet conduit 86 on top of the collection chamber and coupled to typical gas-analysis device 87.

Accordingly, once gas is purged from the sample chamber 31 by returning the pistons 37 and 44 to their retracted positions, the gas will be collected in the upper portion of the collection chamber 84 and thereby cause the float-operated valve 85 to open. Once the valve 85 opens, the collected gas will be displaced from the chamber 84 by the water entering the bottom of the collection chamber and dispatched through the outlet conduit 86 to the gas-analysis device 87. The valve 85 will, of course, reclose once the water refills the collection chamber 84.

As previously mentioned, so long as the valves 55 and 56 remain open, water will be flushed through the sample chamber 31 to assure there is no debris or residue left in the sample chamber. Thus, until the rotary switch 77 is advanced from its C position to its initial starting position, this flushing action will continue. This can, of course, be accomplished either by a controlled sequence or by selection.

Accordingly, it will be appreciated that the present invention has provided new and improved testing apparatus for accurately determining even minute quantities of entrained or dissolved gases in typical borehole drilling muds. By arranging the new and improved testing apparatus of the present invention to include first and second pistons and cylinders which are cooperatively coupled together to define a common sample chamber, the first piston and cylinder can be selectively sized for inducting a precise quantity of drilling mud into the sample chamber and the second piston and cylinder can be selectively sized for expanding the total volume of the sample chamber as required to reduce the pressure of the mud sample to a predetermined reduced value. Thus, in clear contrast to the prior-art testing devices, the measuring apparatus of the present

invention is cooperatively arranged in a unique fashion both to collect a precise volume of drilling mud and to reduce the pressure of this mud sample to a precise predetermined pressure.

While only a particular embodiment of the present invention has 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. Apparatus adapted for determining the gas content of a drilling mud and comprising:

means defining a sample chamber;

first means adapted for inducting drilling mud into said sample chamber and including a first piston cylinder in communication with said sample chamber, a first piston cooperatively arranged in said first cylinder and adapted for movement therein from a predetermined retracted position to a predetermined extended position, and first actuating means coupled to said first piston and adapted for selectively moving said first piston from its said retracted position to its said extended position to induct a predetermined volume of drilling mud into said sample chamber corresponding to the displacement volume defined in said first cylinder between said predetermined positions of said first piston;

second means adapted for reducing the pressure of a sample of drilling mud inducted into said sample chamber and including a second piston cylinder in communication with said sample chamber, a second piston cooperatively arranged in said second cylinder and adapted for movement therein from a retracted position to extended positions, and second actuating means coupled to said second piston and adapted for selectively moving said second piston away from its said retracted position to reduce the pressure of a sample of drilling mud in said sample chamber in accordance with the gas content of a sample of drilling mud in said sample chamber and the increased volume therein as said second piston is moved away from its said retracted position;

pressure-responsive means adapted for determining when the pressure of a sample of drilling mud in said sample chamber is reduced to a predetermined value in response to movement of said second piston away from its said retracted position; and

third means operable upon movement of said second piston away from its said retracted position for determining the increase in the volume of said sample chamber upon movement of said second piston to an extended position where the pressure of a sample of drilling mud in said sample chamber is reduced to said predetermined value.

2. The apparatus of claim 1 wherein said pressure-responsive means include means operatively associated with said second actuating means and adapted for discontinuing operation of said second actuating means whenever the pressure of a sample of drilling mud in said sample chamber is reduced to said predetermined value.

3. The apparatus of claim 2 wherein said third means include means operatively associated with said second actuating means and adapted for providing an indication representative of the distance between said retracted position of said second piston and said extended position thereof whenever the operation of said second actuating means is discontinued.

4. The apparatus of claim 1 wherein said third means include means operatively associated with said second actuating means and adapted for providing an indication representative of the distance between said retracted position of said second piston and said extended position thereof when the pressure in said sample chamber is reduced to said predetermined value.

5. The apparatus of claim 1 further including means selectively operable for introducing a flushing agent into said sample chamber and said first and second cylinders after a sample of drilling mud has been discharged therefrom.

6. The apparatus of claim 1 further including gas-receiving means in communication with said sample chamber and adapted for receiving gas contained in a sample of drilling mud in said sample chamber after such a sample has been discharged therefrom.

7. The apparatus of claim 1 further including control means operatively associated with said first and second means and adapted for sequentially operating said first actuating means to move said first piston to its said extended position and thereafter operating said second actuating means to move said second piston away from its said retracted position.

8. Apparatus adapted for determining the gas content of a drilling mud and comprising:

means defining a sample chamber and first and second piston chambers in fluid communication therewith;

first means adapted for inducting a predetermined volume of drilling mud into said sample chamber and including a mud conduit in communication with said sample chamber, a mud-control valve in said mud conduit and operatively arranged to be opened and closed for controlling the flow of drilling mud between said sample chamber and a source of drilling mud to be tested, a first piston cooperatively arranged in said first cylinder and adapted for movement therein between predetermined retracted and extended positions, and first actuating means coupled to said first piston and adapted for selectively moving said first piston from its said retracted position to its said extended position to induct a predetermined volume of drilling mud into said sample chamber corresponding to the displacement volume defined in said first cylinder between said predetermined positions of said first piston;

second means adapted for reducing the pressure of a sample of drilling mud inducted into said sample chamber and including a second piston cooperatively arranged in said second cylinder and adapted for movement therein between retracted and extended positions, and second actuating means coupled to said second piston and adapted for selectively moving said second piston away from its said retracted position to reduce the pressure of a sample of drilling mud in said sample chamber in accordance with the gas content of a

sample of drilling mud in said sample chamber and the increased volume therein as said second piston is moved away from its said retracted position; pressure-responsive means adapted for providing a control signal whenever the pressure of a sample of drilling mud in said sample chamber is reduced to a predetermined value in response to movement of said second piston away from its said retracted position; indicating means operable upon movement of said second piston away from its said retracted position for indicating the volumetric increase of said sample chamber upon movement of said second piston to an extended position where the pressure in said sample chamber is reduced to said predetermined value; and control means operatively associated with said actuating means and said pressure-responsive means and adapted for operating said first actuating means to move said first piston from its said retracted position to its said extended position for inducting said predetermined volume of drilling mud into said sample chamber and thereafter operating said second actuating means to move said second piston from its said retracted position until said pressure-responsive means provides said control signal.

9. The apparatus of claim 8 wherein said indicating means include means responsive to movement of said second piston for providing an output signal representative of the distance said second piston is moved away from its said retracted position for determining the volume increase in said sample chamber required to reduce the pressure therein to said predetermined value.

10. The apparatus of claim 9 further including recording means operatively associated with said indicating means and adapted for recording said output signal.

11. The apparatus of claim 8 wherein said control means further include valve-actuating means operatively associated with said mud-control valve and adapted for opening said mud-control valve at least before said first actuating means move said first piston away from its said retracted position and closing said mud-control valve after said first piston reaches its said extended position and at least before said second actuating means move said second piston away from its said retracted position.

12. The apparatus of claim 8 further including a fluid conduit in communication with said sample chamber, a conduit-control valve in said fluid conduit and operatively arranged to be opened and closed for controlling the flow of fluid through said fluid conduit, and means coupled to said fluid conduit and adapted for introducing a flushing fluid into said sample chamber and said first and second cylinders after a sample of drilling mud has been discharged therefrom upon opening of said valves.

13. The apparatus of claim 8 further including a fluid conduit in communication with said sample chamber, a conduit-control valve in said fluid conduit and operatively arranged to be opened and closed for controlling the flow of fluid through said fluid conduit, and means coupled to said fluid conduit and adapted for receiving

gas contained in a sample of drilling mud in said sample chamber after said pistons have been moved to their respective said extended positions and at least after said conduit-control valve is opened.

14. Apparatus adapted for determining the gas content of a drilling mud and comprising:

means defining a sample chamber having upper and lower fluid openings;

first means adapted for inducting a predetermined volume of drilling mud into said sample chamber and including a mud conduit coupled to said lower opening, a mud-control valve in said mud conduit, first valve-actuating means coupled to said mud-control valve and adapted for opening and closing said mud-control valve to control the flow of drilling mud between said sample chamber and a source of drilling mud to be tested, a first piston cylinder in communication with said sample chamber, a first piston cooperatively arranged in said first cylinder and adapted for movement therein from a predetermined retracted position to a predetermined extended position, and first piston-actuating means coupled to said first piston and adapted for selectively moving said first piston from its said retracted position to its said extended position to induct a predetermined volume of drilling mud into said sample chamber corresponding to the displacement volume defined in said first cylinder between said predetermined positions of said first piston;

second means adapted for reducing the pressure of a sample of drilling mud inducted into said sample chamber and including a fluid conduit coupled to said upper opening, a fluid-control valve in said fluid conduit, second valve-actuating means coupled to said fluid-control valve and adapted for opening and closing said fluid-control valve to control the flow of fluids through said fluid conduit, a second piston cylinder in communication with said sample chamber, a second piston cooperatively arranged in said second cylinder and adapted for movement therein from a retracted position to extended positions, and second piston-actuating means coupled to said second piston and adapted for selectively moving said second piston away from its said retracted position to reduce the pressure of a sample of drilling mud in said sample chamber in accordance with the gas content of a sample of drilling mud in said sample chamber and the increased volume therein as said second piston is moved away from its said retracted position;

pressure-responsive means in communication with said sample chamber and adapted for producing an output signal when the pressure of a sample of drilling mud in said sample chamber is reduced to a predetermined value in response to movement of said second piston away from its said retracted position;

control means cooperatively associated with said actuating means and said pressure-responsive means and adapted for sequentially operating said first and second valve-actuating means and said first piston-actuating means to open said mud-control valve, close said fluid-control valve and enable said first piston-actuating means to move said first

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piston from its said retracted position to its said extended position for inducting said predetermined volume of drilling mud through said mud conduit into said sample chamber and thereafter operating said first valve-actuating means and said second piston-actuating means to close said mud-control valve and enable said second piston-actuating means to move said second piston from its said retracted position until said second piston-actuating means halt in response to said output signal to stop said second piston at one of its extended positions; and

indicating means cooperatively associated with said second piston-actuating means for providing an indication representative of the increased volume of said sample chamber required to reduce the pressure of a sample of drilling mud in said sample chamber to said predetermined value.

15. The apparatus of claim 14 wherein said indicating means include means responsive to movement of said second piston for providing an output signal representative of the distance said second piston is moved away from its said retracted position for determining the volume increase in said sample chamber required to reduce the pressure therein to said predetermined value.

16. The apparatus of claim 15 further including

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recording means operatively associated with said indicating means and adapted for recording said output signal.

17. The apparatus of claim 14 wherein said control means further include means operable after said second piston-actuating means halt for operating said actuating means to return said pistons to their said retracted positions and open said control valves for displacing drilling mud from said sample chamber through said mud conduit and displacing gas from said sample chamber through said fluid conduit.

18. The apparatus of claim 17 further including gas-collection means in communication with said fluid conduit and adapted for receiving gas displaced from said sample chamber upon return of said pistons to their said retracted positions.

19. The apparatus of claim 17 further including chamber-flushing means in communication with said fluid conduit and adapted for discharging a flushing agent through said sample chamber upon return of said pistons to their said retracted positions.

20. The apparatus of claim 19 further including gas-collection means in communication with said fluid conduit and adapted for receiving gas displaced from said sample chamber upon return of said pistons to their said retracted positions.

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