

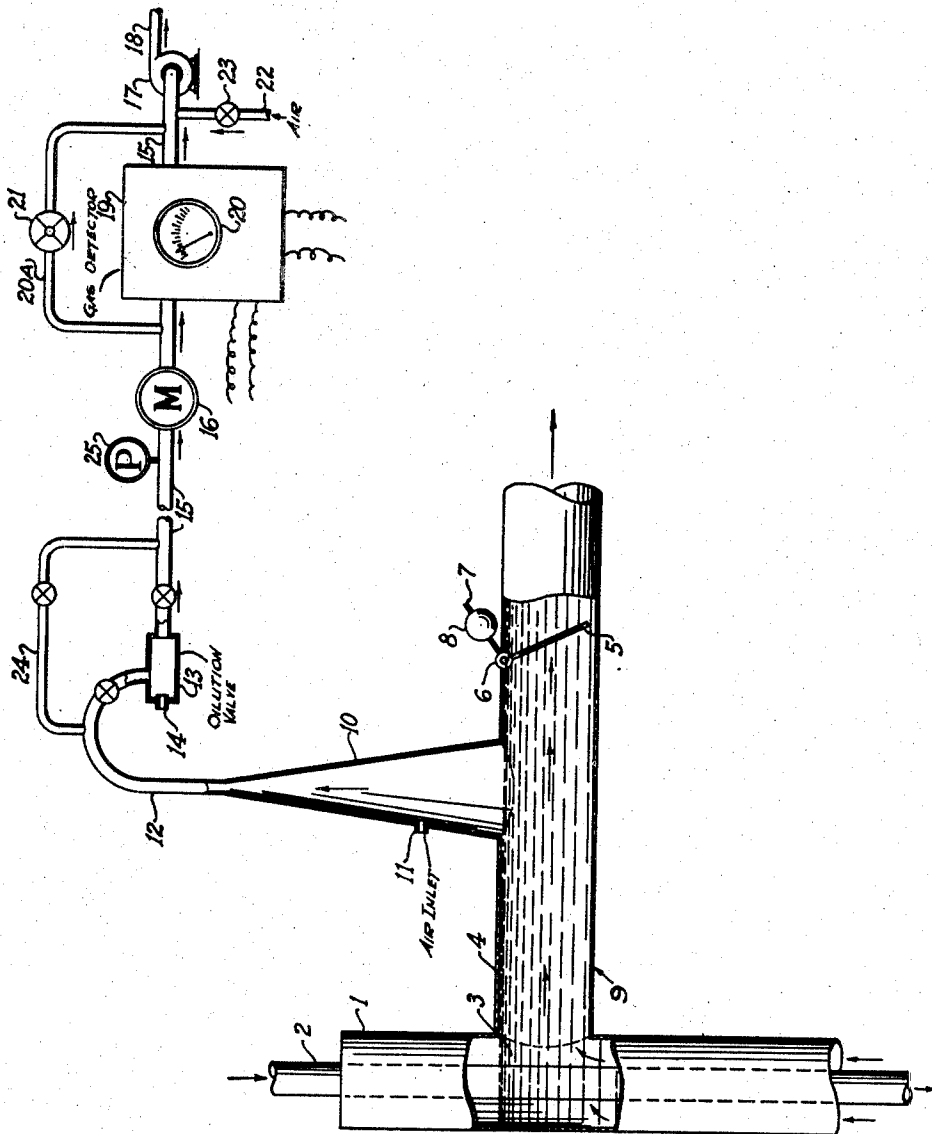
Nov. 22, 1949

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2,489,180

METHOD OF DETECTING GAS IN WELL-DRILLING FLUIDS

Filed April 1, 1939



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UNITED STATES PATENT OFFICE

2,489,180

METHOD OF DETECTING GAS IN WELL
DRILLING FLUIDS

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Application April 1, 1939, Serial No. 265,470

9 Claims. (Cl. 73-153)

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This invention relates to a method for detecting gas and particularly to a method for detecting and measuring combustible gas in hydraulic fluids employed in rotary well drilling.

In the drilling of oil or gas wells, wherein a hydraulic fluid such as a suspension of clay or earthy materials in water and called a "mud-laden fluid" is circulated through the well during the drilling thereof, particularly by rotary drilling, by conventional practice, the specific gravity of the circulating fluid is controlled, ordinarily, so that the head of fluid in the well is greater than the pressure of oil or gas which it is expected will be encountered at points in the well. This procedure is followed in order to prevent the pressure of a gas formation, which may be encountered, from exceeding that of the fluid head pressure and causing "blow-outs," whereby the fluid is blown from the well with disastrous consequences which, in some cases, may result in complete construction of the well and endanger lives and property in the vicinity of the well.

While this procedure is advantageous for protecting the well during drilling, it is disadvantageous in that the excess pressure of the hydraulic fluid prevents the entrance into the well of gas from an encountered gas-containing formation, with the result that such formation may entirely escape detection of the drill operators and become "mudded-off" or sealed by the circulating mud fluid, and erroneously cause the well to become abandoned as a non-producer. Also, as oil is very often found in immediate or adjacent association with gas, failure to detect the presence of gas substantially immediately after penetration by the drill into the gas formation, may cause the driller to continue entirely through the oil-containing formation and also mud-off that formation. This is particularly true where, as is often the case, the oil-containing formation is quite thin, that is, only a few feet thick. The danger is heightened greatly by the fact that oil and gas formations are usually sandy formations, which are relatively soft and will be very quickly traversed by the drill unless comparatively exact knowledge of the location of such formations is known before-hand and the approach of the drill thereto very carefully controlled.

Since as noted, the pressure of the fluid column in the well is ordinarily controlled to exceed that of any gas formation which may be encountered, only that relatively small quantity of gas, which is contained in the "core," i. e., the relatively small cylinder of formation cut out by the drill

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traversing the formation, will escape into the fluid, and recognition of the gas formation must rely wholly upon the prompt detection of this small quantity of gas in the fluid. The following example will serve to illustrate the relatively minute quantities of gas which will be present in the mud fluid under a normal set of drilling conditions: A well is being drilled at a depth of 6000 feet where a gas-containing formation is encountered. The formation pressure is approximately 3000 pounds per square inch. The mud fluid in the well has a specific gravity of 1.38 producing a fluid column pressure at the bottom of the well of approximately 3600 pounds per square inch or approximately 600 pounds per square inch greater than that of the gas formation. Obviously under these conditions, substantially no gas will escape into the well from the gas formation and the only gas entering the circulating fluid will be that relatively small amount of gas present in the cuttings comprising the core or cylinder of the formation being cut out by the drill bit. Assume the diameter of the bore of the well is nine inches, a conventional size. The volume of each lineal foot of the cylinder of gas formation drilled will be approximately 763 cubic inches. If we assume a porosity of 25 per cent, that is, the pore space in the formation in which the gas is held constitutes 25 percent of the volume of the formation, then it is evident that the total volume of gas in one lineal foot of the cylinder of formation will be approximately 191 cubic inches at a pressure of 3000 pounds per square inch. When the fluid containing this quantity of gas reaches the surface of the ground, the pressure will be reduced to substantially atmospheric pressure, and disregarding the factor of temperature, the gas will expand roughly 200 times its previous volume, or to a volume of 38,200 cubic inches. However, as the mud fluid is ordinarily circulated through the well at a rate of approximately 100 barrels per lineal foot drilled, the 38,200 cubic inches of gas will be distributed through 100 barrels of mud fluid, and upon calculation, it will be found that the mud fluid, when it reaches the top of the well, will contain only about 3.9% by volume of gas. Such a small quantity of gas is practically impossible to detect by ordinary inspection methods, due to the fact that the mud fluids ordinarily used in drilling are generally very viscous and have gel-like properties which cause the minute globules of gas to be strongly occluded in the fluid to an extent, in many cases, that substantially none of the gas will escape from the fluid, even when the fluid

is allowed to stand for hours in the open air. As a result of such conditions, the drill may completely traverse the gas formation without detection of the gas formation by the drill operator.

The present invention provides a ready and accurate method for detecting combustible gas, such as hydrocarbon gas, which is dilutedly dispersed in fluids such as the hydraulic mud fluids above described.

Generally stated, and in accordance with this invention, the method of detecting gas which has become dilutedly occluded in the circulating mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum, comprises, causing separation of and collecting gas from the drilling fluid at the top of the well, as the drilling proceeds, in amounts sufficient for analysis, and making analyses of the gas. Preferably, gas portions are collected from successive portions of the drilling fluid, and the percentages of the gas in successive portions are determined. The release of the gas is caused at a rate sufficient for continuous analyses, so that a continuous analysis of the collected gas is made. In accordance with an embodiment of this invention, the gas is separated from the fluid by applying a gas-releasing force to the fluid as by passing air over the fluid.

In accordance with an illustrative embodiment of this invention the dilutedly dispersed gas from a flowing stream of hydraulic fluid, such as well drilling fluids, is mixed with a volume of air which is continuously proportioned to the volume of gas evolved so as to provide a known constant volume of the resulting mixture of gaseous fluids, which is then analyzed, preferably by the well known hot filament method, to determine the percentage of gas in the mixture. The method is preferably applied by flowing the hydraulic fluid through a closed collecting zone to which the vacuum is applied, and admitting the air to the collecting zone through an orifice under the control of the vacuum applied. Thus as the volume of gas evolved changes, the volume of air drawn into the collecting zone will change proportionally so as to provide a constant volume of gas-air mixture in the collecting zone. By continuously withdrawing a constant volume mixture of gaseous fluid from the collecting zone, which is ordinarily effected through a flow meter by the suction applied to produce the vacuum in the collecting zone, the change in the relative proportion of gas in the gaseous fluid can be continuously determined by analysis, and this provides a measure of the rate of evolution of the gas from the hydraulic fluid, whereby the operators will be promptly apprised when the quantity of gas in the hydraulic fluid approaches dangerous proportions, and when sub-surface strata of varying gas content are encountered.

One of the objects of this invention, therefore, is to provide a method of detecting gas, which has become dilutedly occluded in the circulating mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum.

Another object is to detect small quantities of such gas occluded in such fluids by collecting such gases evolved from the fluid, in admixture with air introduced therein by constant volume regulation, as under a vacuum, and analyzing the air-gas mixture.

Other objects and advantages of this invention will be apparent from the following detailed description taken in conjunction with the accompanying drawing which illustrates, more or less, diagrammatically, an arrangement of apparatus which is adapted for successfully performing the method of this invention.

Referring to the drawing, the numeral 1 designates a section of the ordinary surface casing extending into a well which is being drilled by the well known rotary method. A hollow drill pipe 2 extends axially of the casing to the bottom of the well turning the usual drill bit, not shown, in the conventional manner. Hydraulic fluid 3, such as a mud slurry commonly employed in such well drilling and which is ordinarily of such specific gravity as to maintain a fluid pressure in the well bore greater than the pressures in the traversed formations, is circulated through the well in the usual manner through the interior of drill pipe 2 to the bottom of the well where it picks up the cuttings produced there by the action of the drill bit and carries such cuttings together with any naturally contained gas or other fluids upward toward the surface of the ground through the annular space between the drill pipe 2 and the bore of the well, thence through the annular spaces between the drill pipe and the inner wall of surface casing 1 whence the hydraulic fluid cuttings and contained fluids are discharged through a fluid discharge pipe 4 through which the mud fluids and cuttings are conveyed to the usual settling pits, not shown, and thence back to the suction of the conventional fluid circulating pump, also not shown. The portions of the apparatus described but not shown are well known and their functions well understood by those skilled in the art, and, therefore are not further elaborated or illustrated.

A gate 5 is hingedly mounted at 6 in conduit 4 at a point spaced some distance from the point where conduit 4 connects to casing 1 and is provided at its upper end with an angularly extending arm 7 on which is mounted a movable counterbalance 8. By suitable adjustment of counterbalance 8 on arm 7, gate 5 is automatically adapted to be held normally closed or partially closed against the flow of hydraulic fluid through conduit 4 and to thereby maintain the portion of the conduit between casing 1 and gate 5 substantially full of hydraulic fluid at all times. The portion of conduit between casing 1 and gate 5 is designated liquid seal trap 9.

A hollow gas collecting chamber 10 constructed of metal or other suitable rigid material and open at its lower end is connected into the upper surface of conduit 4 between casing 1 and gate 5. The open lower end of chamber 10 being in open communication with the interior of the conduit. The connection between chamber 10 and conduit 4 is made air tight to prevent entrance of uncontrolled extraneous air into the chamber.

An orifice tube 11 of fixed area is positioned in the side of chamber 10 at a point above the normal level of liquid in trap 9 and chamber 10. A tube 12 has one end connected to the upper end of chamber 10 in communication with the interior thereof, and has its other end connected to a dilution orifice chamber 13, which is provided with a replaceable orifice tube 14 in one wall thereof, and with an outlet pipe 15 in another wall thereof. Outlet pipe 15 leads through a meter 16 into a gas detector 17, which is preferably of the electric hot filament type of well known design commonly employed for detecting

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small amounts of combustible gases in air. Detector 19 is preferably provided with an indicating meter 20 which indicates the percentage of gas in the gaseous fluids passing through the detector. It will be understood that indicating member 20 may be of the recording type so as to provide a continuous record of the percentage of gas in the gaseous fluid being analyzed. Conduit 15 extends through detector 19 and connects to a vacuum pump 17, which functions to draw gaseous fluids from chamber 10 through tube 12, orifice chamber 13, pipe 15, meter 16 and detector 19; the gaseous fluid thus drawn through this apparatus being discharged to the air through pipe 18. Since a hot filament detector of the type described is operative generally only with very small amounts of gaseous fluids, a pipe 20A fitted with a valve 21 is provided to by-pass fluid passing through pipe 15 around detector 19 and into the suction of vacuum pump 17. A pipe 22 fitted with a valve 23 is connected into pipe 15 on the suction side of vacuum pump 17 to provide means for regulating the vacuum applied by the pump.

A valved by-pass connection 24 is provided between tube 12 and outlet pipe 15 in order to permit routing of gaseous fluid flowing from chamber 10 around dilution orifice chamber 13, since such dilution orifice is generally required only in connection with those types of gas detectors which are operative for detecting only very small concentrations of combustible gases in air. Where other types of detectors are employed, the dilution orifice chamber 13 need not be used. A vacuum gauge 25 is connected into pipe 15 for indicating the pressure in the apparatus ahead of meter 16.

The above described apparatus is employed in the following manner:

Hydraulic well fluid, such as described above, and containing well cuttings and hydrocarbon gas emerges from the top of the well and overflows from casing 1 through conduit 4 where it flows through liquid seal trap 9 on its way to the settling pits and circulating pumps. As the fluid passes through liquid seal trap 9, it will pass under the open end of chamber 10 in which a slight vacuum is maintained by means of vacuum pump 17. Gas evolving from the fluid, the evolution of gas being assisted by the reduced pressure in chamber 10, will enter chamber 10. At the same time, by virtue of the reduced pressure, a quantity of air will be drawn into chamber 10 through orifice tube 11. The vacuum maintained in chamber 10 is so regulated by means of valve 23 that the quantity of air entering chamber 10 will be sufficient to continuously purge the portion of chamber 10 above orifice tube 11 and the pipes and apparatus connecting the chamber to detector 19 of all the gas being continuously evolved from the hydraulic fluid. The total volume of gaseous fluid drawn through pipe 15 will be measured by means of meter 16 and by holding the metered volume constant by the described pressure regulation, the volume of air drawn into chamber 10 through orifice tube 11 will be automatically adjusted in accordance with the volume of gas evolved from the hydraulic fluid, so that any changes in the rate of evolution of gas from the hydraulic fluid will be immediately reflected in the subsequent analysis in detector 19. By means of the described liquid seal arrangement provided for the open end of chamber 10, no extraneous unknown quantities of air can enter the apparatus to improperly alter the analysis.

The mixture of air and gas produced in cham-

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ber 10 as described will be drawn therefrom under the suction applied by vacuum pump 17, through tube 12 then through dilution orifice chamber 13, where an additional quantity of air, proportioned to the mixture in accordance with the relative areas of orifice 14 and tube 12 and pipe 15, will be mixed with the air-gas mixture from chamber 10 to further dilute the mixture so that the concentration of the gas in the diluted mixture will be within the limits of the particular form of detector 19. This final mixture then passes through meter 16 to detector 19. Since hot filament detectors of the type referred to are operative only on relatively minute amounts of gaseous fluid, about 90 percent of the diluted mixture is ordinarily by-passed around the detector through pipe 20A and valve 21 to the suction of pump 17. The remaining 10 percent passes through the detector 19 and is analyzed therein in the usual way and the percentage of gas in the mixture indicated on meter 20. It will be understood, of course, that the detection and indicating apparatus may be compensated for the fixed dilution effected in dilution orifice chamber 13, so that the reading of meter 20 will give directly the percentage of gas in the mixture from chamber 10. Where a detector is used which does not require the extra dilution effected in orifice chamber 13, this portion of the apparatus may be by-passed by closing the by-pass valves in tube 12 and pipe 15, opening the valve in by-pass 24 and routing the gas-air mixture through by-pass 24 directly to meter 16.

The step of introducing air into chamber 10, as by the orifice 11 in an amount sufficient to continuously purge the chamber and connecting pipes is very important in assuring that changes in the rate of evolution of gas from the hydraulic fluid will be immediately and accurately detected in detector 19.

If no air were introduced in chamber 10 with the orifice chamber 13 omitted, then only pure gas would be drawn through the apparatus and there would then be no way of discovering a change in the rate of evolution of the gas. On the other hand, if a variable or unknown quantity of air were allowed to enter chamber 10, the percentages of gas determined by detector 19 would be meaningless. Again, if less air than is sufficient to completely and continuously purge chamber 10 was introduced therein, excessive percentages of gas would be indicated by detector 19 and would, therefore, be meaningless.

Therefore, by regulating the introduction of air into chamber 10 in the manner described, to maintain a constant flow of air-gas mixture through the chamber and connecting pipes and in an amount sufficient to keep these portions of the apparatus continuously purged, the changes in the quantity of gas evolved from the hydraulic fluid will appear directly in the analysis. At the same time, by adding air to the evolved gas, a sufficient volume of gaseous fluid will be provided to bring the gas, immediately after its escape from the mud fluid, to the detection apparatus, otherwise, when the quantities of gas are small, substantial intervals of time may elapse before the gas can flow from chamber 10 to the detection apparatus. Of course, when no gas is present in the drilling fluid, only air will be passing through detector 19 and no gas indication will appear therein.

It will be evident, therefore, from the foregoing, that a novel method has been disclosed for continuously detecting the presence of gas in drilling

fluid and for continuously detecting changes in the quantity of gas in the drilling fluid during the drilling of a well.

It will be understood that numerous changes may be made in the details of the apparatus described and illustrated. Various modifications of the liquid sealed gas trap, orifices and valves may also be used, all without departing from the scope of the appended claims.

By circulating a measured volume of hydraulic fluid through the well as a measured rate, this method of gas detection may be employed to locate the sub-surface strata from which the gas comes, and the well logged in this manner. Such a logging method is disclosed in my co-pending application Serial No. 187,619, filed January 29, 1937, which is now Patent 2,214,674, for a Method of logging wells.

It will also be understood, that the described method for detecting gas may be applied to the hydraulic fluids, both as such fluids enter and as they leave the well and any changes in gas content of the fluid effected in the well may be determined by this method, by employing a correction factor based upon the volume of fluid flowing through the drill pipe and annular space between the drill pipe and the bore of the well. This comparison method is also described in detail in application Serial Number 187,619, referred to above.

While theories have been put forward, this has been done to facilitate the explanation, and it will be understood that this invention is not limited to any particular theory. It will also be understood that the invention is susceptible of various embodiments within the scope of the appended claims.

What I claim and desire to secure by Letters Patent is:

1. The method of detecting gas which has become dilutedly occluded in the circulating mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum, comprising, causing separation of and collecting gas from the drilling fluid at the top of the well, as the drilling proceeds, in amounts sufficient for analysis and in accordance with increase of gas occluded in successive portions of the fluid and making comparative analyses of the collected gas in order to determine such increase.

2. The method of detecting gas which has become dilutedly occluded in the circulating mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum, comprising, causing separation of and collecting gas portions from successive portions of the drilling fluid, as the drilling proceeds, in amounts sufficient for analysis and in accordance with increase of gas occluded in successive portions of the fluid and determining increases of the gas occluded in the successive portions.

3. The method of detecting gas which has become dilutedly occluded in the circulating mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum, comprising, applying a gas-releasing force to the drilling fluid at the top of the well, as the drilling proceeds, in order to

cause gas to evolve therefrom in accordance with increase of gas occluded in successive portions of the fluid, collecting the gas as evolved from successive portions of the fluid and mixing air therewith, and determining the increase of the gas evolved from successive portions.

4. The method of detecting gas which has become dilutedly occluded in the circulated mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum, comprising, causing separation of and collecting gas from the drilling fluid at the top of the well under atmospheric temperatures, as the drilling proceeds, in amounts sufficient for analysis, and making analyses for the collected gas.

5. The method for detecting gas which has become dilutedly occluded in the circulating mud-laden fluid employed in rotary well drilling while the fluid column is maintained at a head exceeding the head of the stratum being drilled, which comprises, flowing a stream of the fluid through a collecting zone, therein collecting gas evolved from said fluid in passage through said zone, mixing with the evolved gas in said zone a volume of air controllably proportioned to the volume of the evolved gas, withdrawing the resulting mixture of gas and air from said zone, and making an analysis for the gas in said resulting mixture.

6. The method for continuously detecting gas which has become dilutedly occluded in the circulating mud-laden fluid employed in rotary well drilling while the fluid column is maintained at a head exceeding the head of the stratum being drilled, which comprises, flowing a stream of the fluid leaving a well through a collecting zone, therein continuously collecting gas evolved from said fluid in passage through said zone, continuously mixing with the evolved gas in said zone a volume of air controllably proportioned to the volume of the evolving gas, continuously withdrawing the resulting mixture of gas and air from said zone, and continuously determining the gas in said resulting mixture.

7. In the art of drilling wells by the rotary method, where a stream of drilling mud is circulated into and out of the well bore, the method of continuously determining the presence or absence of gas in the returning mud as an indication of the penetration of a gas bearing formation which includes the steps of, allowing the separation of gas from the stream of returning mud, and indicating to the operator that gas is separating.

8. The method of detecting gas which has become dilutedly occluded in the circulating mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum, comprising, causing separation of gas from the drilling fluid at the top of the well, as the drilling proceeds, in amounts sufficient for analysis and in accordance with increase or decrease of gas occluded in successive portions of the drilling fluid, mixing the separated gas with air to provide a continuous and substantially unvarying flow of air-gas mixture in which the gas content varies in response to changes in the amount of gas separating from the drilling fluid, and making continuous quantitative determinations of the combustible gas content of said air-gas mixture.

9. The method of detecting gas which has be-

come dilutedly occluded in the circulating mud-laden fluid employed in the drilling of an oil or gas well by the drilling of a stratum while the fluid column is maintained at a head exceeding the head of the stratum and circulated in measured volume and at a measured rate comprising, causing separation of gas from the drilling fluid at the top of the well, as the drilling proceeds, in amounts sufficient for analysis and in accordance with increase or decrease of gas occluded in successive portions of the drilling fluid, mixing the separated gas with air to provide a continuous and substantially unvarying flow of air-gas mixture in which the gas content varies in response to changes in the amount of gas separating from the drilling fluid, subjecting a constant metered flow of the air-gas mixture to analysis for combustible gas, and making continuous quantitative determinations of the combustible gas content of said air-gas mixture.

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