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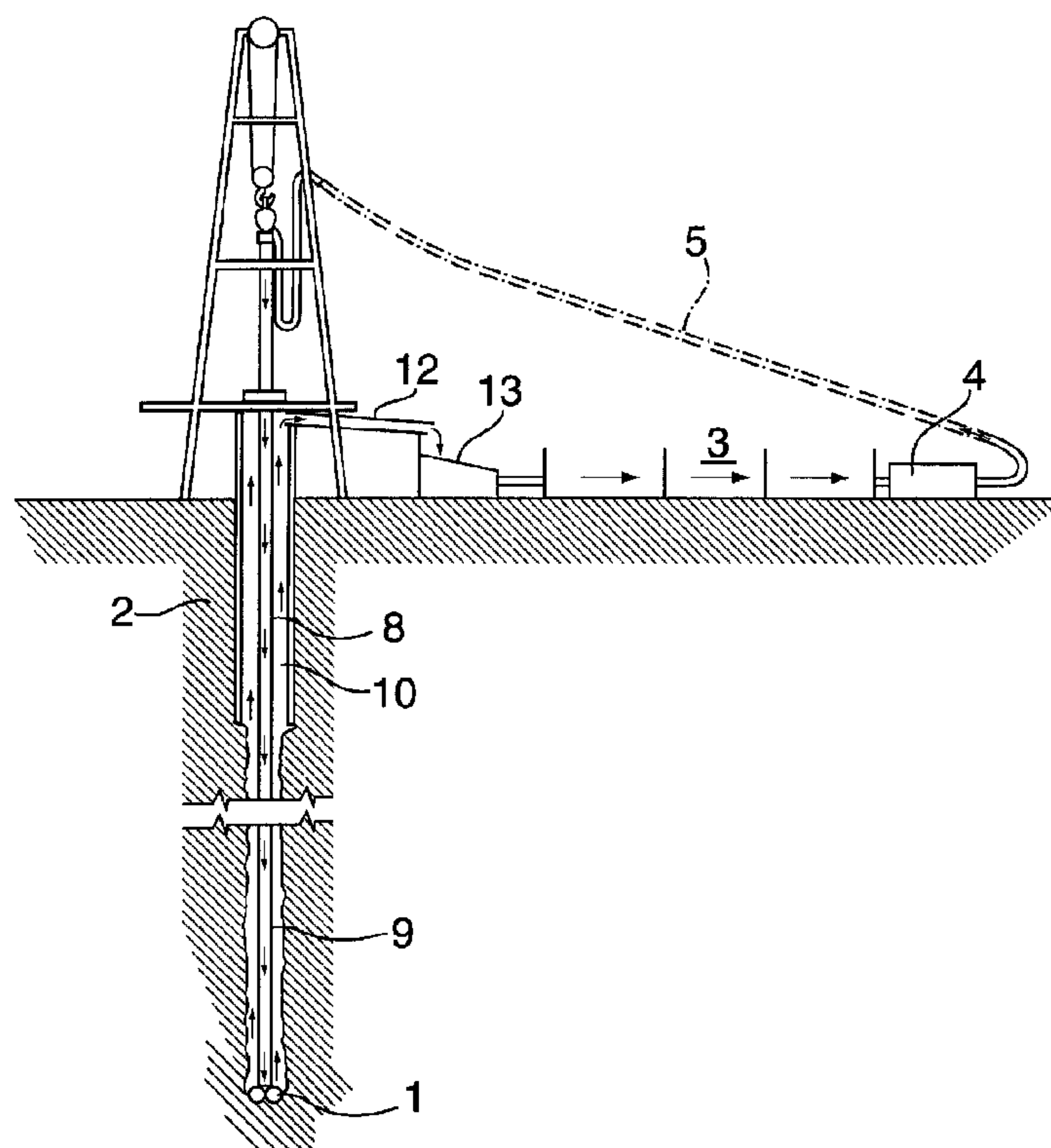
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(54) Titre : METHODE POUR DETERMINER L'USURE DU TREPAN

(54) Title: METHOD FOR DETERMINING DRILLING BIT WEAR



(57) **Abrégé/Abstract:**

A method for determining drilling bit condition during a drilling operation is disclosed. The method includes analyzing drilling fluid returning from a well to determine the hydrogen gas concentration of the fluid; observing fluctuations in the hydrogen gas concentration during a drilling operation; and, comparing the fluctuations to known hydrogen gas concentration fluctuations indicative of drilling conditions. The method provides an accurate, substantially real-time way of determining the condition of the drilling bit without changing the structure of the bit and without pulling the drilling bit up to the surface for visual inspection. The method also provides a way to determine if there exists non-lithological debris down hole and to measure the success of fishing operations to remove non-lithological junk. The method can be used without the modification of standard drilling techniques.



ABSTRACT OF THE INVENTION

A method for determining drilling bit condition during a drilling operation is disclosed. The method includes analyzing drilling fluid returning from a well to determine the hydrogen gas concentration of the fluid; observing fluctuations in the hydrogen gas concentration during a drilling operation; and, comparing the fluctuations to known hydrogen gas concentration fluctuations indicative of drilling conditions. The method provides an accurate, substantially real-time way of determining the condition of the drilling bit without changing the structure of the bit and without pulling the drilling bit up to the surface for visual inspection. The method also provides a way to determine if there exists non-lithological debris down hole and to measure the success of fishing operations to remove non-lithological junk. The method can be used without the modification of standard drilling techniques.

METHOD FOR DETERMINING DRILLING BIT WEAR

FIELD OF THE INVENTION

The present invention is directed to a method for determining drilling bit wear and, in particular, to a method for determining drilling bit wear without visual inspection of the bit.

BACKGROUND OF THE INVENTION

A drilling bit used in drilling wells has a finite life. For standard petroleum wells, the life span of a drilling bit is in the order of 150 hours or less. To optimize the drilling procedure, it is necessary that the drilling operation be carried out with a good drilling bit, while at the same time controlling costs. To change a drilling bit it is necessary to pull the bit and the drilling string back to surface and out of the hole. Once on surface, the drilling bit is inspected and, because of the effort, time and money required to pull it out of the hole, it is often replaced regardless of whether it is spent or not. Because of the time and money required to change a bit, it is desirable to ensure that when a bit is pulled out of the hole it is indeed at the end of its useful life.

It is difficult to determine when a bit has reached the end of its useful life. Generally, the decision to pull the bit is made when the speed at which the bit is drilling through the rock formation begins to show a marked decrease. This technique is fraught with problems, most notably the fact that a marked decrease in the speed of advancement of a drill through a formation can also be indicative of the drills passage into a formation having greater hardness than the one it was in previously.

Naturally, if the bit stops drilling completely then it can be assumed that it is near the end of its life. Unfortunately, when this happens it is often the case that the end of the bit's life has been passed by a significant margin, and that in consequence parts of the bit will be left at the bottom of the hole.

5 Another method available to engineers for determining the end of a bit's life is by knowing how well previous bits of the same type have performed in the same formations under the same drilling conditions and changing the bit when a predetermined number of drilling hours are reached. This technique relies on the assumption that the reference data were correct and that the previous bits were pulled
10 at the optimum point in their lives. In addition it relies on the assumption that all bits of a similar type last the same length of time under similar conditions. While this is generally true, occasionally a bit will leave the manufacturing facility in a sub-standard state. These bits will not last or perform as well as others of the same type.

Torque and the monitoring of vibrations can also be used to help determine when a bit
15 is worn out or failing. These indicators can be misinterpreted, as variations in them may just as easily be due to different formation types as well as bit failure. It is only when they become excessive that they can be relied upon by which time it is often too late.

There have been previous attempts to determine accurately when a bit has reached the end of its life. US Pat No 3,865,736 disclosed by B. A. Fries proposes that a
20 radioactive grease containing radioactive gaseous krypton 85 be implanted into the bearings of a drilling bit. It is proposed that when the bearings of the drilling bit fail, the krypton will be able to escape in gaseous form. It will then be liberated from the drilling fluids. A device for measuring radioactivity will then detect the krypton 85 as a peak in background radioactivity. This technique has a number of drawbacks. Apart from a
25 natural reluctance for people to work with radioactive materials, the technique relies

upon the bit manufacturers to comply with using a grease that has had a radioactive bubble of krypton 85 "kneaded" into it. The technique will only work if the manufacturers do this. However, due to the high technology of bit design and the materials used "kneading" a bubble of gas into the lubricating grease of a bit, the bit's life span may in fact be compromised to some extent, and it would be difficult to convince manufacturers to do this. The actual method of grease preparation is also quite complex. The radioactive gas is also prone to stay in the drilling fluids and come back to surface more than once. This feature is recognized by the inventor who maintains that distinguishing between the initial peak and relic peaks is easy. With just one initial peak this may be correct. However, when the situation arises where there are relic peaks with new peaks being superimposed upon these, from subsequent bit failures, and when some bits may have failed gradually, allowing the krypton gas out also gradually, it is envisaged that the distinction between new peaks and relic peaks will become difficult. As such, it is felt that there are a number of commercial and technical drawbacks to this technique.

US Pat No 4,298,572 discloses a technique for measuring hydrogen during drilling operations. This is mentioned in the abstract of the patent. However further reading suggests that hydrogen was typed by mistake and that the intention was to type hydrocarbon gas. The patent then discloses how to measure hydrocarbon gases while drilling.

US Pat No 4,635,735 discloses a technique for continuously measuring and analyzing the gases returned in the drilling fluid from a well as it is being drilled. It does mention the measurement of hydrogen but does not say why the hydrogen should be measured, or what conclusions should be drawn from such measurement.

US Pat No 4,030,558 discloses a technique for determining the amount and character of rotary drilling bit wear without interrupting the drilling operation. It discloses a technique for the collection and analysis of metal fragments and dust from the drilling fluid using a magnet. Looking at the quantity, size, shape and color of the fragments under an optical microscope can, it is said, aid in determining the condition of a rotary drilling bit. There are a number of drawbacks to this technique. Firstly when drilling a hole there are a number of sources for metal fragments. Metal may arrive on surface not only from the bit, but also from the outside and inside of the drill pipe and drill collars used in the process of drilling. A significant amount of metal arrives on surface from the casing strings that are periodically run and set in a hole. It is envisaged that it would be quite difficult to distinguish between the different sources of metal, especially given the fact that the bit represents such a small proportion of the total metal that would normally be expected to be in a hole when drilling normally. Secondly there is a time factor involved. Time must be given to allow the metal fragments to accumulate on the magnet. This time period will be in the order of hours. The technique is therefore not real-time. Thirdly the technique is only applicable to ferrous, magnetic metals. Many bits have components that are non magnetic, such as tungsten carbide. These would not be collected by the magnet and would therefore not be included in the analysis. Finally the disclosure recognizes the fact that broken teeth and buttons from a bit will generally not be seen on surface because, due to their size and density, they are likely to remain at the bottom of the hole. These are a major part of a bit, and a technique that cannot assess accurately whether or not the teeth of a bit have come out or are broken cannot assess the wear of a bit while it is still drilling.

SUMMARY OF THE INVENTION

A method for determining drilling bit condition during a drilling operation has been invented. The method provides an accurate, substantially real-time way of determining

the condition of the drilling bit without changing the structure of the bit and without pulling the drilling bit up to the surface for visual inspection. The method also provides a way to determine if there exists non-lithological debris down hole and to measure the success of fishing operations to remove non-lithological junk. The method can be used without the modification of standard drilling techniques.

Thus, in accordance with a broad aspect of the present invention, there is provided a method for determining drilling bit conditions during a drilling operation in a well, the method comprising: analyzing drilling fluid returning from the well to determine the hydrogen gas concentration of the fluid; observing fluctuations in the hydrogen gas concentration in such drilling fluid during the drilling operation; and, comparing the fluctuations to known hydrogen gas concentration fluctuations indicative of known drilling conditions.

The drilling fluid can be analyzed in any suitable way to determine the hydrogen gas concentration. In one embodiment, the drilling fluid is liquid and is treated to liberate gases entrained therein. Such gases are then examined to determine the concentration of hydrogen gas therein. The gases can be liberated from drilling fluids by, for example, application of positive physical action. Gas liberating apparatus, which apply positive physical action to the drilling fluid, are known from standard drilling operations and can be used to liberate the gases from the fluid. Gases liberated from the fluid can be drawn off by a gas sampling apparatus, for example a pump and conduit arrangement, to a gas analysis unit. It is to be understood that not all of the liberated gases need be collected, provided a constant volume of gas is collected for analysis at each time or distance period. However, preferably substantially all of the liberated gas is collected by providing that the chamber in which the positive physical action is applied to the fluid and the lines leading from the well to the chamber, are gas tight.

Where the drilling fluid is a gas, such as air, the drilling fluid itself can be passed to a gas analysis unit to determine the hydrogen gas concentration thereof.

The gaseous drilling fluid or the gases liberated from liquid drilling fluid are analyzed to determine the hydrogen gas concentration thereof. This analysis can be conducted in any suitable way. For example, where the gas to be analyzed is that liberated from liquid drilling fluid, the gas is preferably first dried and filtered and then passed to a hydrogen detection device such as, for example, a high speed chromatograph, a mass spectrometer or a solid state hydrogen detector. The hydrogen detection device must be sufficiently sensitive to detect levels of hydrogen gas which can be as low as 50 to 200ppm.

Fluctuations in the hydrogen gas concentration during the drilling operation are compared to the fluctuations known to be indicative of certain drilling conditions. To facilitate observation of fluctuations in the hydrogen gas concentration, it is preferred that the data concerning the concentrations be processed and plotted on a substantially real-time basis. The concentration data can be plotted against drilling time and/or drilling depth.

The method of the present invention is particularly useful for determining drilling conditions such as the determination of when a drilling bit requires replacement and the determination that a drilling bit is experiencing interference from non-lithological junk in the well. The hydrogen gas concentration should preferably be observed during the time periods when these determinations are relevant. For example, when the hydrogen gas concentration is being observed to determine when a bit requires replacement, the fluctuations in the hydrogen concentration should be observed during the life of the bit (i.e. from the start of drilling operations with the drilling bit of interest until a decision is made to pull the bit to surface).

Variations in the rate of flow of the drilling fluid causes the hydrogen gas concentration to fluctuate. This could lead to false indications of problematic drilling conditions. Thus, preferably, the rate of flow of the drilling fluid is measured and such measurements are processed with the concentration data to cancel out concentration fluctuations resulting from variations in the flow rate. Where the rate of flow of the drilling fluid is known to remain constant over the portion of the drilling operation being observed, the rate of flow of the drilling fluid need not be considered in the observation of the hydrogen gas concentration.

In any drilling operation, a background level of hydrogen gas can be detected in the drilling fluids. Background levels of hydrogen gas may vary between wells and between drilling bits, depending on the drilling fluid parameters, nature of the drilling bit, efficiency and positioning of gas liberating and sampling apparatus and accuracy of measuring devices. Thus, where fluctuations of hydrogen gas concentration relative to background levels are to be determined, it is preferred that the background level be established. The background level of hydrogen gas is that level which remains substantially steady over at least the time taken to drill about 8 m using a standard drilling bit for example a tri cone insert bit. There may be some fluctuations in the hydrogen gas concentrations immediately after start up with a new drilling bit. Baseline levels are usually achieved after the drilling bit has settled down to drilling, for example after the time taken for the drilling bit to penetrate between about 5 to 15m of new formation. This is generally the same period that is required to break in a new bit. It should be noted that the background levels of hydrogen gas can vary significantly for different bits. All that is required to establish the background baseline is a short period of steady drilling which in turn results in a period of observed steady hydrogen gas levels. The hydrogen gas concentration during this period is recorded as the baseline level against which fluctuations in the hydrogen gas concentration are measured.

The fluctuations in hydrogen gas concentration which are observed are compared to those fluctuations which are known to occur in certain conditions. Some conditions which can be identified by the fluctuations of hydrogen gas concentration are (a) drilling bit wear and wear requiring replacement of the bit, and (b) the presence of non-lithological junk in the well which is interfering with the operation of the drilling bit. During a drilling operation, where there is no non-lithological junk interfering with the drilling bit and where the drilling bit is in good condition, the hydrogen concentration will remain substantially steady over time. When the bit begins to wear, the concentration of hydrogen gas in the drilling fluid will increase relative to the already established background baseline level. The bit is in condition to be pulled when the hydrogen gas concentration in the drilling fluid begins to increase rapidly. In a plot, this is shown as a break away from the background level. In particular, preferably bit replacement is determined to be necessary when the hydrogen gas concentration increases to between about 40% to 120% over the background level. If the increase in hydrogen gas concentration becomes substantially exponential when measured at regular time and/or depth periods (i.e. at each half meter of drilling progression), it is highly likely that the bit has failed completely, for example, has lost many of its teeth and/or some of its cones.

Thus, in accordance with another broad aspect of the present invention there is provided, a method for determining the wear of a drilling bit during a drilling operation in a well, the method comprising: circulating drilling fluid through the well and past the drilling bit; analyzing drilling fluid returning from the well to determine the hydrogen gas concentration of the fluid; observing fluctuations in the hydrogen gas concentration in the drilling fluid during the drilling operation; and, comparing increases in the hydrogen gas concentration to known hydrogen gas concentration increases indicative of known conditions of drilling bit wear.

When the concentration of hydrogen gas trends steadily downward, it is an indication that there exists non-lithological junk, such as broken parts of drilling bits, in the well. In most cases it is known when there exists junk in the hole. As an example, if a bit returns to surface without any teeth then it is assumed that the teeth are at the bottom of the hole. Where junk is present in the well, the method can be used to measure the success of a fishing operation to remove the junk. The presence of junk will be indicated by a gradual decrease in the amount of hydrogen gas in the drilling fluid over drilling time. A rapid drop in the concentration of hydrogen gas, after a fishing operation to remove the junk, indicates that the fishing operation was, at least in part, successful. If after a fishing operation, the hydrogen concentration in the drilling fluid continues to trend downward, it can be determined that the fishing operation was not entirely successful and that the fishing operation should be repeated. The presence of junk in the well can also cause the drill to fail. Where, after a fishing operation when the bit is returned downhole and drilling is resumed, the concentration of hydrogen increases rapidly, it can be determined that the bit has failed.

Thus in accordance with a further broad aspect of the present invention, there is provided a method for determining the success of a well operation to remove non-lithological junk from a well, the method comprising: while drilling circulating drilling fluid through the well and past the drilling bit; analyzing drilling fluid returning from the well to determine the hydrogen gas concentration of the fluid; conducting an operation to remove non-lithological junk from the well; resuming drilling; while drilling circulating drilling fluid through the well and past the drilling bit; analyzing drilling fluid returning from the well to determine the hydrogen gas concentration of the fluid; observing fluctuations in the hydrogen gas concentration in the drilling fluid during the resumed drilling operation; and, comparing fluctuations in the hydrogen gas concentration to known hydrogen gas concentration fluctuations indicative of known conditions after an operation to remove non-lithological junk from a well.

BRIEF DESCRIPTION OF THE DRAWINGS

A further, detailed, description of the invention, briefly described above, will follow by reference to the following drawings of specific embodiments of the invention. These drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. In the drawings:

Figure 1 is a schematic representation of a drilling rig, showing an embodiment of a fluid analysis system according to the present invention;

Figure 2A is a flow diagram of a method according to the present invention;

Figure 2B is a schematic diagram illustrating an apparatus useful in the present invention;

Figure 3 is a plot of the hydrogen concentration in drilling fluid vs. time for a typical drilling operation; and,

Figure 4 is a graph of the hydrogen concentration in drilling fluid vs. time for a drilling operation where non-lithological junk is determined to be present in the well and is removed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 1, a typical drilling rig is shown which can be onshore or offshore. The drilling rig has a drilling bit 1 which is rotated with weight applied thereto in order for it to drill through a formation 2. At the same time, drilling fluid such as, for example, water-based liquids, oil-based liquids, foam, air, crude oil or a combination thereof, is

pumped from tanks 3 via pump 4 through line 5 to pass through a circuit to drill pipe 8. The fluid passes to the bottom hole assembly (BHA) 9 and finally to the drilling bit 1. The fluid acts to cool and lubricate the bit and to carry drilled fragments of formation back to the surface when it returns to the surface via the annulus 10. In addition to the fragments of lithology, any gases that may be present down hole are also transported to surface by the drilling fluid. Once on the surface, the fluid containing the gases and formation fragments passes from the annulus and through a flow line 12 to a shale shaker 13. In shale shaker 13, the lithology fragments are sieved out of, and agitation in the shakers causes the gases to be released from, the drilling fluid. The drilling fluid is then returned to tanks 3. This fluid flow circuit is continuous during drilling. This is an exemplary embodiment of a fluid circuit through a drill rig. It is to be understood that the method of the present invention can be used with other drilling fluid circuits.

Referring to Figure 2A, the method of the present invention is useful for determining drilling bit conditions during a drilling operation. In one preferred embodiment, the drilling fluid is a liquid and the fluid returning from the well is treated with positive physical action 16 to liberate the gases therein. The gases are then collected 17 and samples are analyzed 18 at regular intervals to determine the hydrogen gas concentration therein. The hydrogen gas concentration in the drilling fluid is observed 19 over at least a portion of the drilling operation (for example, over the life span of a drilling bit) to identify any fluctuations 20 in the concentration. If no fluctuations expected in the hydrogen gas concentration are observed, the observation continues. If a fluctuation, for example, an increase or a decrease in the concentration, is observed, the fluctuation is compared 21 with known fluctuation trends indicative of certain drilling bit conditions. From such comparison, conclusions can be drawn 22 as to the conditions which exist in the borehole.

An apparatus useful in the present invention is shown in Figure 2B. A gas sampling apparatus 36 is mounted in association with the header box 35 of shale shaker 13. Gas sampling apparatus 36 collects all gases liberated during the agitation process carried out by shakers 13. Gas sampling apparatus 36 can be any suitable device for collecting gases such as, for example an electric or air driven trap, an ultrasonic trap or, for air drilling, a suitable drop out chamber. The liberated gases are then drawn along a line 37 into a mudlogging unit 38 where gas analysis takes place. The gases can be drawn into mudlogging unit 38 by any suitable means such as pump 39. In mudlogging unit 38, the gases are dried and filtered by any suitable means. In the example shown, drying and filtering is done by passing the gas through, in series, a drop out jar 40 containing calcium chloride, a coarse filter 41, a fine filter 42, a gas-permeable membrane 43, a filter 44 containing magnesium perchlorate and at least one very fine air filter 45. It should be noted that the analysis of the gases can be made by equipment in any suitable location on the rig where the equipment can safely be set up e.g. next to the gas sampling apparatus. The mudlogging unit is, however, the preferred location.

After filtration and drying, the gas enters a hydrogen detector 46. The hydrogen detector measures the amount of hydrogen present in the dried gas mixture that has been liberated from the drilling fluid. Any detector capable of detecting low level of hydrogen gas can be used. For example, one useful detector is a gas chromatograph of the type manufactured by MTI or Chrompak using a chromatographic industry standard Molsieve 5A HR column. Examples of other useful detectors are mass spectrometers and solid state hydrogen detector.

Where the hydrogen concentration is to be determined using a high speed gas chromatograph, preferably the moisture is removed from the gases before analysis by,

for example, passing the gases through a filter 44 of fine bore tygon tubing of 5" in length and 1/8" internal diameter containing magnesium perchlorate.

After analysis, the sample is vented out of the mudlogging unit into the atmosphere or to another line, as desired. Preferably, the drilling fluid line 12 and shaker 13 are gas
5 tight except for an air inlet 35a provided to prevent a vacuum from forming in the shaker. Gas sampling apparatus 36, line 37 and the components of mudlogging unit 38 are preferably also gas tight.

Preferably, the gas is collected and analyzed on a continuous basis during a drilling operation. In one embodiment, the gas is collected and analyzed every thirty seconds
10 of drilling time or every 0.5m of drilling distance continuously during a drilling operation. The resultant concentration data are sent continuously to a computerized processing unit 48 which produces a plot 50 of the data. A preferred processing unit uses the mudlogging system developed by Datalog Technology Inc. and known as QLOG. Preferably, the hydrogen data are processed together with drilling time and depth data
15 from corresponding database. The time database should have a resolution of preferably less than or equal to one minute, 30 seconds is ideal. The depth database should have a resolution of, preferably, equal to or less than 50 cm. Preferably, the hydrogen data is plotted as it is gathered, on a substantially real-time basis as a curve against time.

20 Data analysis can be commenced as drilling fluid gas analysis is taking place. Figure 3, shows a plot of hydrogen gas concentration produced by continuously analyzing the gases liberated from drilling fluid returning from a well during the useful life span of a drilling bit. When drilling is commenced with a new drilling bit, indicated at X, a background level for the hydrogen is established. This background level is established
25 within the first 2 to 3 hours after commencing drilling with a new bit. Points X to Y show

that there is a background hydrogen level of A ppm. It should be noted that the background levels of hydrogen will vary from bit to bit and well to well due to variations in the drilling fluid parameters, the nature of the drilling bit, fluid flow rates, efficiency of gas sampling apparatus's, the positioning of the gas sampling apparatus in the header box and the accuracy of hydrogen gas measuring devices. Typically, the background level of hydrogen gas will remain constant while drilling until the bit begins to deteriorate. When deterioration begins, indicated at Z, the hydrogen concentration in the fluid begins to increase. This increase is slow initially, but rapidly increases with time as the bit develops a major failure. The bit is nearing the end of its life when the amount of hydrogen gas measured begins to increase rapidly over time to levels between 40% and 120% over the background. It is time to pull the bit when the trace for the hydrogen begins to display properties which can be expressed by the equation $y=x^2+c$, where y is the measured concentration of hydrogen gas, x is either time or depth, and c is the background level of hydrogen. If the trace increases exponentially against depth then it is too late and the bit has experienced major damage and may well have lost some of its cones. The known signature for hydrogen gas concentration fluctuation is an increase in the concentration which is between 40% and 120% over background levels and has a tendency to continue creeping up. While the hydrogen gas concentration in drilling fluid can be used alone to determine drilling bit failure, it is useful to use the concentration data in combination with other standard data, such as rate of drill penetration, to verify down hole conditions. For example, if a decrease in rate of penetration is seen in conjunction with an increase in hydrogen concentration then it is highly likely that the drop in rate of penetration is not due to a formation change but rather to the bit failing. Similarly, if the rate of penetration drops, but the hydrogen remains constant at or near background levels, this indicates that the bit is probably in good condition but that particular section of the formation is difficult to penetrate.

Events such as damage to the drilling bit can cause the hydrogen concentration to increase above background levels for short periods of time. When this happens, the increase in the hydrogen measured will be generally less than or equal to twice the background level and will not begin to increase rapidly. The exact size and nature of these variations will depend upon the nature of the damage the bit has experienced. If no further damage occurs to the bit, the level of hydrogen measured will return back to background levels. Increases in the hydrogen concentration of less than 30% of the background level over short periods of drilling time or drilling distance can be considered to be normal and not indicative of problems.

Figure 4 shows a typical concentration trace where non-lithological junk is present down hole during the drilling operation. Junk is present usually because a previous bit lost teeth or cones during its run. Observation of hydrogen gas concentration will show a baseline level, as shown between point X' and Y', which decreases slowly over time. If an unsuccessful attempt to remove the junk is made, the hydrogen concentration will be substantially unaffected, as shown at point B. However, as shown at point C, when an attempt to recover some of the junk is made which is at least in part successful, a rapid decrease in the concentration of hydrogen gas will be observed. As a result of the decrease a new lower hydrogen background level, M to N, will be established. Where, the background level between points M to N continues to decrease slightly over time, it can be determined that junk remains in the hole and that the new bit is slowly wearing it away or that the junk is being reduced in size to such an extent that it is small enough to be transported to surface with the rock cuttings by the drilling fluid. At point D, the junk removal operation is repeated and again junk is recovered. After a fishing operation which is completely successful, a new lower background level of hydrogen gas will then established, as shown after point P, which remains steady. In each case, the drilling bit was returned without replacement to resume drilling. It is to be understood that if the drilling bit was replaced, the hydrogen gas concentrations before

and after the fishing operation will not be indicative of the success of the fishing operation.

After point P, the hydrogen gas concentration can then be monitored as previously explained with reference to Figure 3, looking for an increase which is indicative of signs
5 of bit wear and failure.

It will be apparent that many other changes may be made to the illustrative embodiments, while falling within the scope of the invention and it is intended that all such changes be covered by the claims appended hereto.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for determining drilling bit conditions during a drilling operation in a well, the method comprising: analyzing drilling fluid returning from the well to determine hydrogen gas concentrations of the drilling fluid; observing fluctuations in the hydrogen gas concentrations of the drilling fluid during the drilling operation; and, comparing the fluctuations to known hydrogen gas concentration fluctuations indicative of known drilling conditions.
2. The method of claim 1 further comprising the step of determining a background level of hydrogen gas in the drilling fluid.
3. The method of claim 1 wherein the drilling fluid is a liquid and the drilling fluid is analyzed by liberating gases entrained in the drilling fluid and determining the hydrogen gas concentration in the gases.
4. The method of claim 3 wherein the gases are liberated by positive physical action.
5. The method of claim 1 wherein the drilling fluid is analyzed at regular intervals continuously over the drilling operation.
6. A method for determining the wear of a drilling bit during a drilling operation in a well, the method comprising: circulating drilling fluid through the well and past the drilling bit; analyzing the drilling fluid returning from the well to determine hydrogen gas concentrations of the drilling fluid at a plurality of times; observing any fluctuations in the hydrogen gas concentrations of the drilling fluid over the plurality of times during the drilling operation; and, comparing increases in the hydrogen gas concentrations of the drilling fluid to known hydrogen gas concentration increases indicative of known conditions of drilling bit wear.

7. The method of claim 6 further comprising the step of determining a background level of hydrogen gas in the drilling fluid and observing any fluctuations in the hydrogen gas concentrations of the drilling fluid over the plurality of times relative to the background level of hydrogen gas in the drilling fluid.
8. The method of claim 7 further comprising the step of determining that the drilling bit is in a condition to be pulled when the hydrogen gas concentration increases by between about 40% to 120% over the background level of hydrogen gas in the drilling fluid.
9. The method of claim 6 wherein the drilling fluid is a liquid and the drilling fluid is analyzed by liberating gases entrained in the drilling fluid and determining a hydrogen gas concentration in the gases.
10. The method of claim 9 wherein the gases are liberated by positive physical action.
11. The method of claim 6 wherein the drilling fluid is analyzed at regular intervals continuously over the drilling operation.
12. The method of claim 6 wherein the drilling fluid is analyzed by a hydrogen detection device capable of detecting hydrogen concentrations as low as about 50 ppm.
13. A method for monitoring a well operation to remove non-lithological junk from a well, the method comprising: drilling the well using a drilling bit; circulating drilling fluid through the well and past the drilling bit while drilling; conducting an operation to remove non-lithological junk from the well; resuming drilling and circulating drilling fluid through the well and past the drilling bit; analyzing the drilling fluid returning from the well to determine hydrogen gas concentrations of the drilling fluid; observing any fluctuations in the hydrogen gas concentrations of the drilling fluid over time during the resumed drilling operation; and,

comparing any fluctuations in the hydrogen gas concentrations of the drilling fluid to known hydrogen gas concentration fluctuations indicative of known conditions after an operation to remove non-lithological junk from a well.

- 5 14. The method of claim 13 wherein the drilling fluid is a liquid and the drilling fluid is analyzed by liberating gases entrained in the drilling fluid and determining the hydrogen gas concentration in the gases.
15. The method of claim 14 wherein the gases are liberated by positive physical action.
- 10 16. The method of claim 13 wherein the drilling fluid is analyzed at regular intervals continuously over the resumed drilling operation.
17. The method of claim 13 wherein the drilling fluid is analyzed by a hydrogen detection device capable of detecting hydrogen concentrations of as low as about 50 ppm.
- 15 18. The method of claim 13 further comprising: prior to the operation to remove non-lithological junk from the well, analyzing the drilling fluid returning from the well to determine a pre-removal operation hydrogen gas concentration of the drilling fluid; and comparing the pre-removal operation hydrogen gas concentration of the drilling fluid with at least
20 one of the hydrogen gas concentrations of the drilling fluid determined after the operation to remove non-lithological junk from the well.
19. The method of claim 18 wherein the step of comparing the pre-removal operation hydrogen gas concentration of the drilling fluid with at least one of the hydrogen gas concentrations of the drilling fluid is conducted
25 in order to determine if the at least one of the hydrogen gas concentrations of the drilling fluid determined after the operation to remove non-lithological junk from the well is decreased relative to the pre-removal operation hydrogen gas concentration of the drilling fluid.

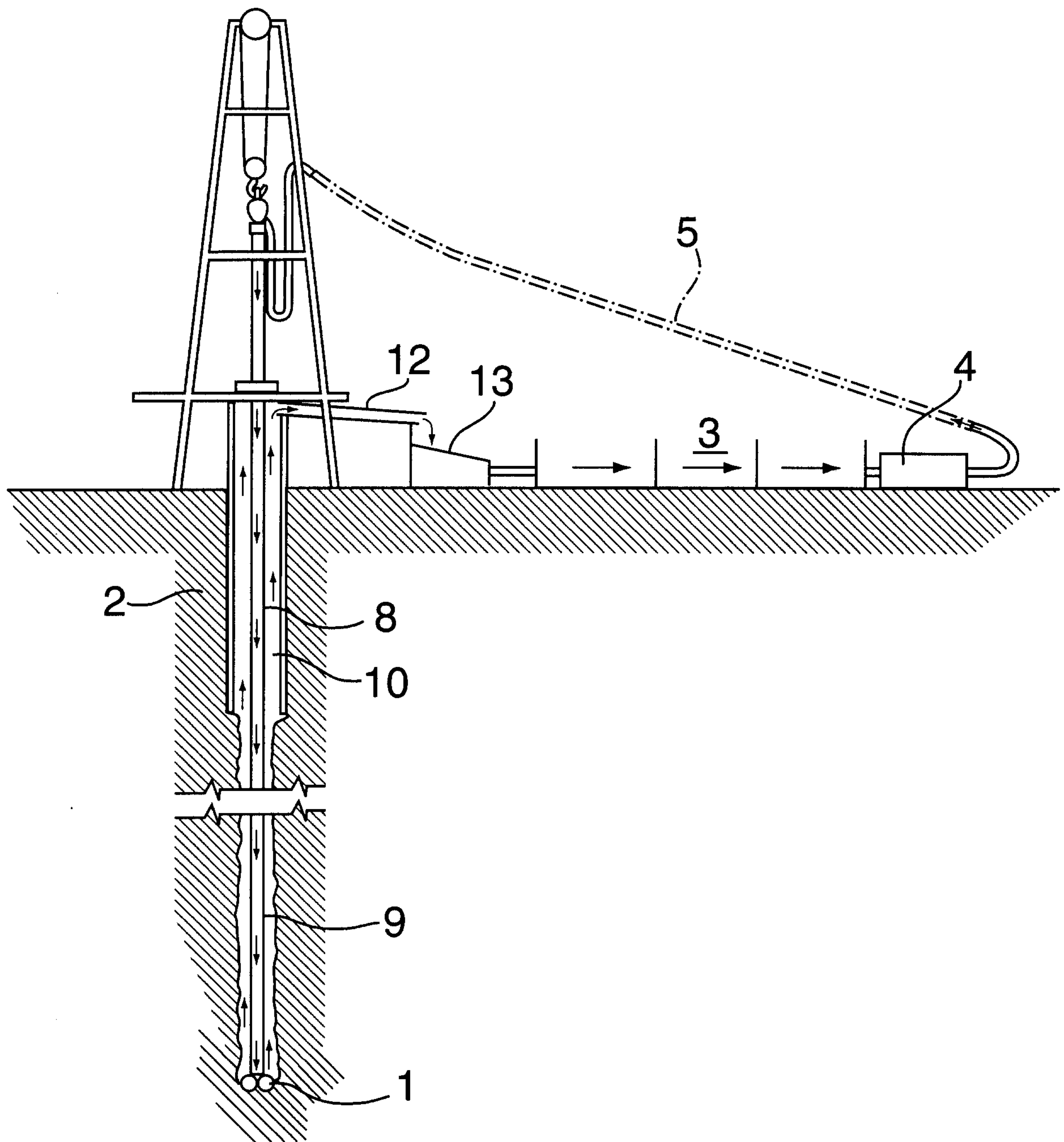
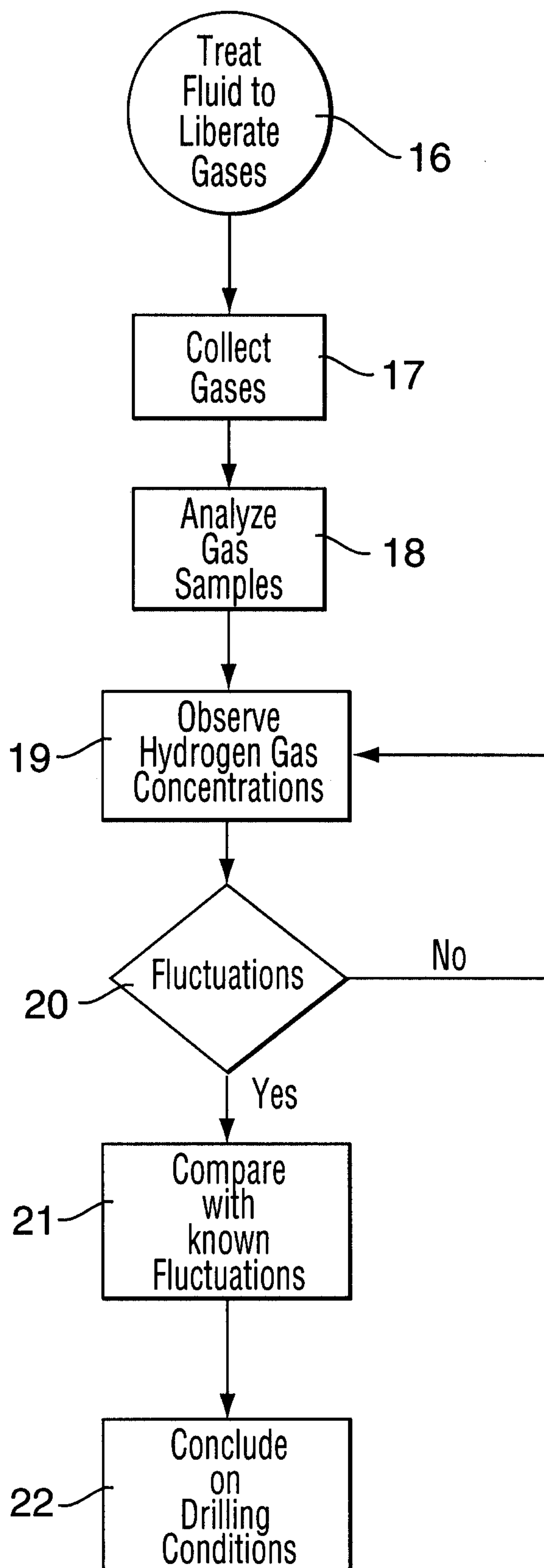


FIG. 1

**FIG. 2A**

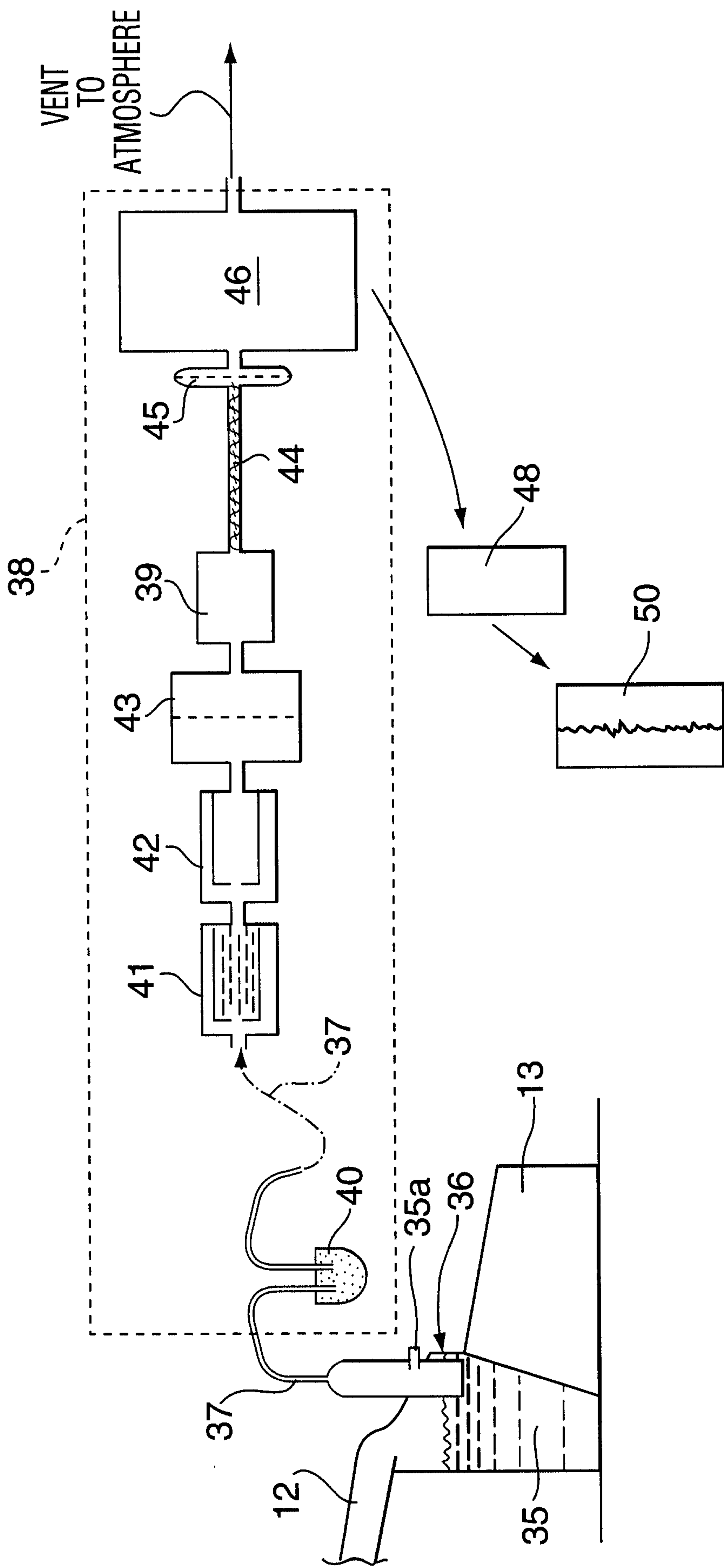
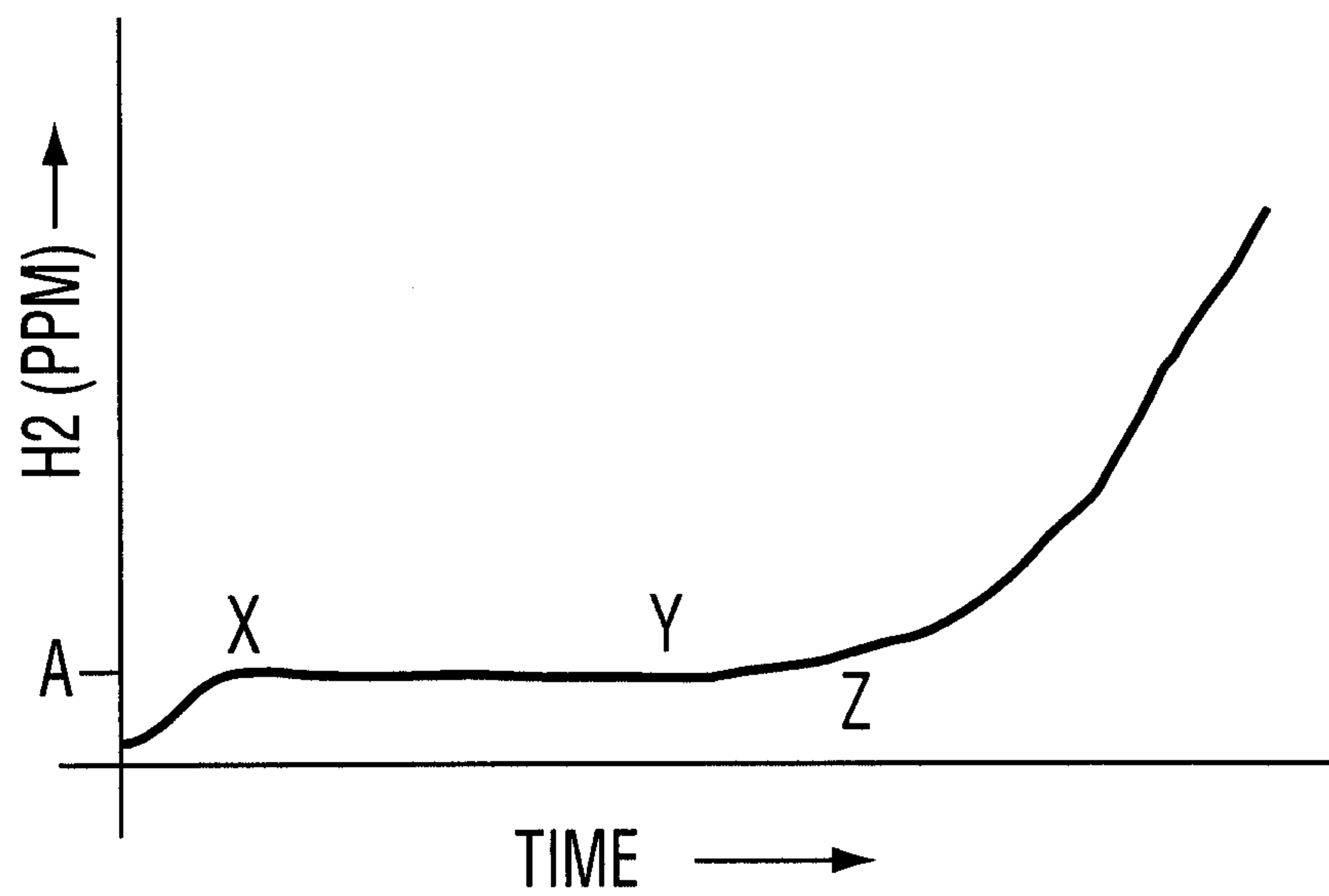
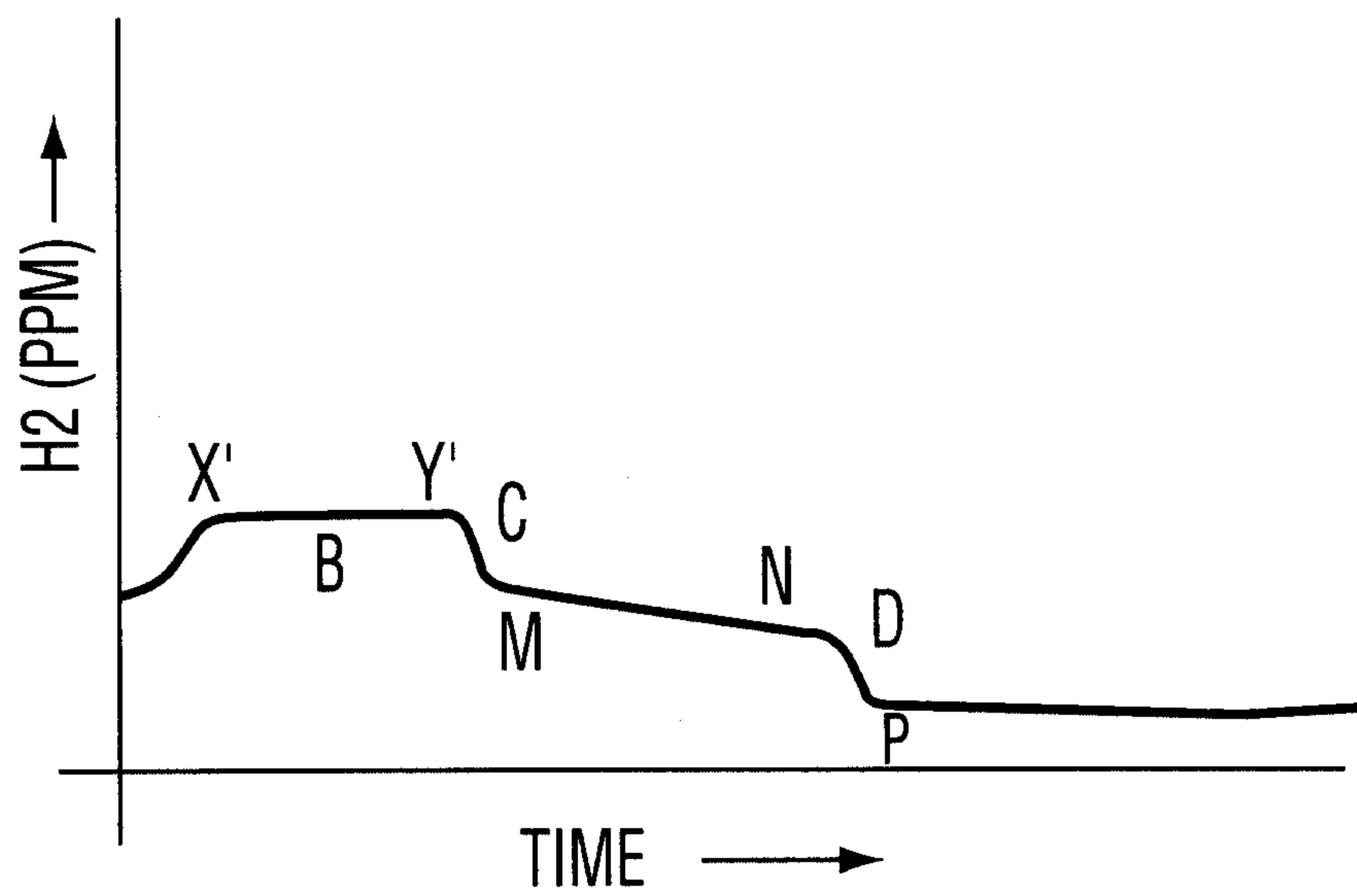


FIG. 2B

**FIG. 3****FIG. 4**

