

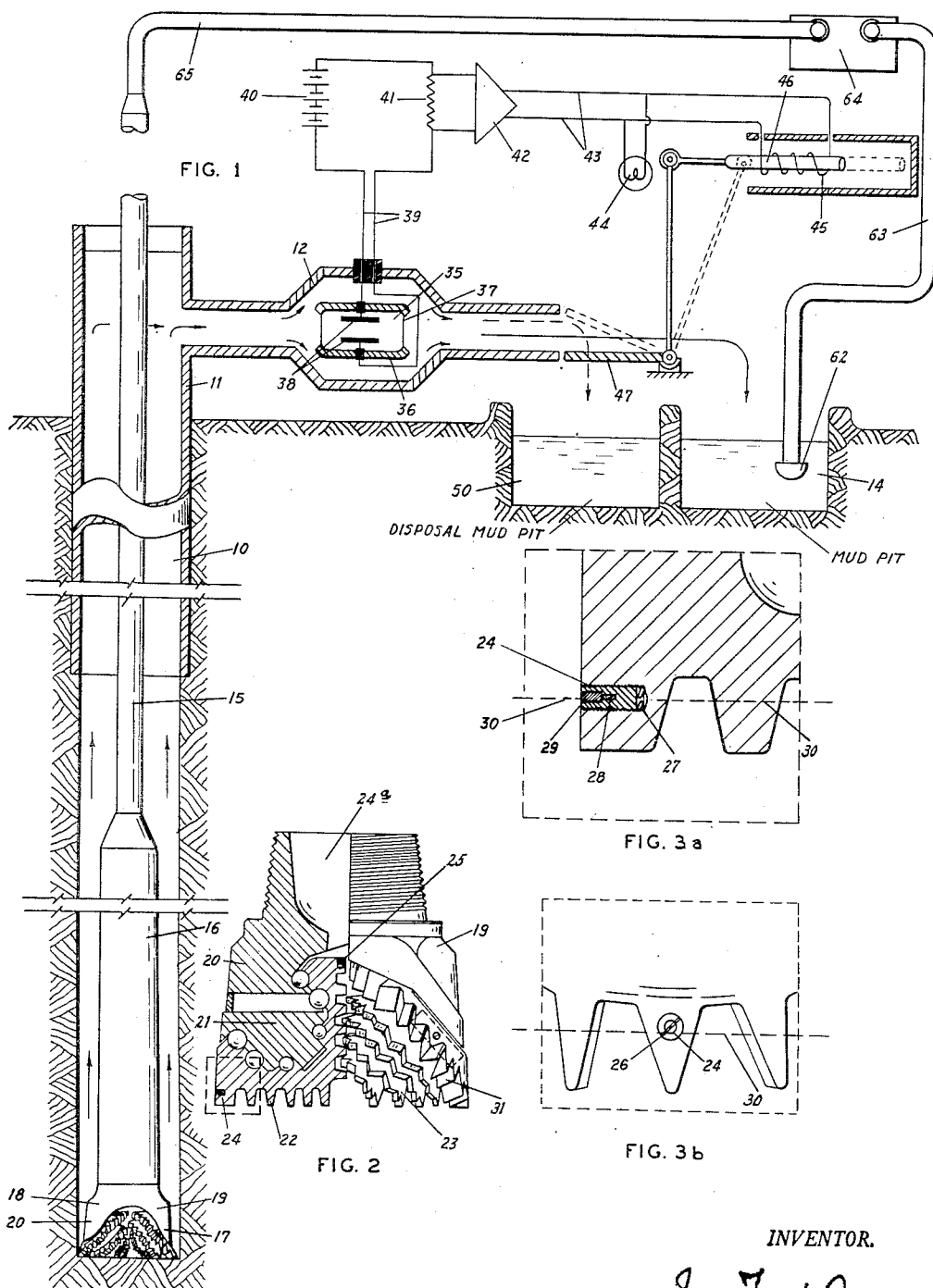
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J. J. ARPS

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WARNING SYSTEM FOR CONTROLLED ROTARY DRILLING

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INVENTOR.

Jan Jacob Arps

UNITED STATES PATENT OFFICE

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WARNING SYSTEM FOR CONTROLLED
ROTARY DRILLING

Jan Jacob Arps, Tulsa, Okla.

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5 Claims. (Cl. 255—1)

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This invention relates to an improvement in drilling and particularly to an arrangement for providing the driller with a warning signal whenever certain undesirable conditions occur such as excessive heating of the drill bit, or whenever the drill bit becomes worn to such a degree that its further use is uneconomical.

During the drilling operations as heretofore practiced, various instruments were used in conjunction with the drilling equipment, to provide the driller with suitable indications regarding the progress of drilling. These instruments such as weight indicator, pump stroke meter, etc. provided measurements on the portion of the drilling equipment that is located above the earth's surface but the driller was usually unaware of the conditions of subsurface equipment. As a result, many failures occurred. In some instances when the drilling progress slowed down the driller was unable to decide whether this was caused by the encountering of a hard formation or whether the bit had become worn to such an extent as to render its further use uneconomical. This resulted in expensive and often unnecessary withdrawals of the drilling string to bring the drill bit to the surface for visual inspection to determine whether or not the replacement of the drill bit was necessary.

In other instances where the drilling string was not withdrawn soon enough, the bearing in the drill bit was found to have stuck, thereby causing the cutting cones to stop turning. This resulted in a continuous and progressive wear on the exposed side only of the cutting edge, the wear reaching eventually the shaft of the cone, causing the breakage of the shaft and a subsequent expensive fishing job to remove the cutters from the drill hole. Whenever the cutters stick an excessive temperature is developed as a result of the friction of the bit against the formations.

Another cause of failure of subsurface equipment consisted in "wash-outs" or leaks in the drill pipe. Such wash-outs ultimately cause a break in the string and a serious fishing job for the drill pipe. These leaks divert or short circuit a part of the circulation of the drilling fluid (which may be an aqueous slurry conventionally referred to as drilling mud), thereby reducing the cooling action on the bit and allowing excessive heating of the bit.

It is, accordingly, the purpose of the present invention to obviate some of the aforementioned difficulties by providing the driller with information regarding the condition of subsurface equipment while performing drilling operations.

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It is another purpose of this invention to provide the driller with a warning signal whenever the bit becomes worn out and a replacement is necessary.

It is another purpose of this invention to provide a warning signal whenever an excessive temperature is developed at the bit as a result of wash-out or any other failure.

Further objects of this invention will become apparent from the following specification and drawings in which:

Fig. 1 shows diagrammatically the general drilling assembly comprising a drill bit modified in accordance with the present invention and means at the earth's surface for providing an indication of the condition of subsurface equipment.

Fig. 2 shows diagrammatically a drill bit provided with tracer capsules imbedded therein in accordance with the present invention.

Fig. 3a shows a cross section of a fragment of a cutter head illustrating the position of the tracer capsule.

Fig. 3b shows the front view of the arrangement of Fig. 3a.

The invention is arranged to provide a warning signal whenever certain undesirable conditions occur, such as, for instance, excessive wear on the bit, or excessive heating of the bit. This is accomplished by inserting capsules comprising a suitable tracer material in the teeth on the periphery of the cutter head of the bit. Under normal operating conditions the tracer is imbedded in the bit and is not in contact with the circulating drilling fluid. If, however, the bit becomes excessively worn and/or if its temperature rises due to some failure, such as a wash-out, the tracer becomes dissolved or suspended in the mud stream and is thereby brought to the earth's surface, thus providing the driller with a suitable warning signal.

The tracer should be easily detectable, i. e. it should be characterized by a physical property that would easily differentiate the tracer from the drilling fluid in which the tracer is suspended or dissolved. It is apparent that each tracer released from the capsule becomes eventually, after a number of cycles in the mud circulation, more or less uniformly distributed throughout the mud stream. This causes an increase of the general background concentration of the tracer in the circulating stream. Such condition is undesirable since it may eventually lead to a difficulty in distinguishing the warning signal caused by an additional release of a tracer

from the general background comprising the contribution of all the tracers that have been released in the past. For instance, if the tracer imbedded in the capsule consists of a commercial dye (such as, for instance, a substance commonly known as fuchsin) then the first failure in the drilling operation accompanied by the release of a suitable amount of dye will cause a bright coloring of the output mud and a mere visual inspection will inform the driller as to the conditions at the bottom of the drill hole. However, since the output mud is recirculated into the well the dye will remain slightly colored and if another failure occurs caused by an additional release of dye into the mud stream, the coloring of the output mud will become less distinguishable from the general background. Consequently each additional failure, accompanied by a release of dye, will increase the brightness of the drilling fluid uniformly throughout its length and eventually it may become extremely difficult to distinguish the warning signal caused by an additional release of a tracer from the general background comprising the contribution of all the tracers released in the past.

The above undesirable conditions will exist if we choose another tracer substance such as a fluorescent dye (fluorescein) or any other substance that will remain permanently in the mud stream and that eventually will distribute itself uniformly throughout its length.

In order to provide a practical and satisfactory signalling system utilizing tracers two arrangements are herewith proposed. The first arrangement consists in eliminating the tracer from the circulating stream of drilling fluid after it has been brought to the earth's surface and provided the driller with the warning signal. The tracer can be eliminated by means of a suitable mechanical device that shall be subsequently described. The second arrangement consists in selecting a particular tracer that gradually disappears after it has performed its purpose, i. e. after it has provided the driller with the warning signal. The only "disappearing" substances are radioactive substances since they spontaneously disintegrate with time. Therefore I am proposing to use as tracers radioactive substances having half lives that are not very large when compared with the period of drilling of a well. Such a radioactive tracer performs the role of a messenger that carries the warning signal to the top of the drill hole and gradually dies after it has outlived its usefulness. Because of its decay the radioactive tracer does not contaminate permanently the drilling fluid stream and leaves the general background of the circulating stream at a relatively low level.

It is apparent that the shorter is the life of the tracer the lower will be the general radioactivity of the background of the well. It would be generally desirable to use a tracer the half life of which is less or of the same order of magnitude as the total length of time during which the same stream of mud is used for circulation purposes. Roughly, this would correspond to the total length of time necessary for drilling an oil well.

An additional advantage in utilizing radioactive substances as tracers is based on the consideration regarding the size of capsule. It is apparent that the radioactive capsules are much smaller than the capsules containing other tracers such as dye, or fluorescein, because the radioactive tracer needs to override only the nat-

ural radioactivity of the mud which is only 0.1 μ curie per cubic foot. Strong radioactive tracers such as Iodine have a specific radioactivity of 0.3 to 2.0 curies per gram and assuming that the background must be overridden by a 100 to 1 ratio and that the capsule is released in 10 seconds (or 10 cubic feet), we need only 100 μ curies or 0.1 millicurie or less than $\frac{1}{2}$ milligram per capsule.

Referring now to Fig. 1, there is shown a portion of an apparatus for drilling a well bore 10 in accordance with conventional rotary drilling practice, i. e. by employment of a circulating drilling fluid. The upper portion of the well bore 10 is lined with a casing 11, generally termed the surface casing, which usually extends only a comparatively short distance into the well. At the upper end the casing 11 is provided with a side outlet 12 which discharges into a mud pit 14. Extending into the well through the casing 11 and the well bore 10 is a conventional hollow drill string designated by the numeral 15. The lower end of the drill string is provided with a drill collar 16 which is connected at its lower end to a drill bit 17.

The drill bit (shown more in detail in Fig. 2) is of a standard construction and comprises a head 18 having an upwardly tapered shank threadedly engaged to the lower extremity of the collar 16. The head has two downwardly diverging legs 19 and 20, said legs being spaced well apart at their lower ends. On the leg 20 is an inwardly and downwardly projecting shaft 21 upon which cutters 22 are rotatable. A similar shaft with cutters 23 is provided on the leg 19. The shank and head have a central passage 24a therein, through which the drilling fluid may be discharged upon the cutters. Each of the cutters 22 and 23 is constructed with a plurality of concentric and annular teeth 31. These teeth become gradually worn off with the progress of the drilling and eventually they become worn out to such a degree that they are no longer effective to disintegrate hard formations.

The cross sectional view of the cutters 22 in Fig. 2 shows two plugs 24 and 25 in the teeth of the cutters. Both plugs are mounted in their respective teeth at a depth of approximately $\frac{2}{3}$ of the length of the teeth. The portion of the cutters containing the plug 24 and comprised within the dotted rectangle is shown in an enlarged form in Fig. 3a. A frontal view of this portion is shown in Fig. 3b. As shown in detail in Figs. 3a, 3b, a shallow hole is drilled into the body of the tooth. The hole is provided with threads to accommodate a small cylindrical plug 24 provided with outside threads and a slot 26 on the top to facilitate its insertion by means of a screw driver. A conventional means is provided for preventing the screw from loosening, such means consisting, for instance, of a spring washer 27 pressing against the inside extremity of the plug. Within the plug 24 is imbedded a tracer containing capsule 28, which is covered from the outside by a suitable element 29 and thus is protected from any contact with the drilling fluid. The element 29 is made of an alloy having a relatively low melting point, i. e. arranged to melt slightly above the normal temperature of the bit. The tracer substance contained in the capsule is radioactive.

Under normal operating conditions the capsules are completely imbedded in the cutter head and separated from any contact with the drilling fluid by the material of the cutting edge. As the

drilling progresses, however, the cutting edge becomes progressively worn out, and the tracer substance becomes eventually exposed to the direct action of the drilling fluid. As a result of such an action the tracer becomes released and dissolved or suspended in the mud and is carried by the stream in the direction indicated by the arrows to the outlet pipe 12. It is thus apparent that the radioactive tracer contained in the capsule 28 becomes automatically released into the mud stream whenever the abrasive effect of drilling reaches "the wear level." The wear level designates a plane tangent to the capsule and perpendicular to the cross sectional plane in Fig. 3a. The wear level is designated in Fig. 3a and Fig. 3b by a dotted line 30.

The cross sectional view of Fig. 2 shows only two teeth provided with plugs, said plugs being designated by numerals 24, 25. I provide, however, a much larger number of teeth with plugs. On the average each annular row such as 31 comprises four teeth provided with plugs, said teeth being equally spaced on the periphery of said row.

The arrangement illustrated in Fig. 3a is also adapted to release automatically the radioactive tracer whenever an excessive temperature is developed at the bit. This may happen whenever bearings become stuck thereby causing the cutter cones to stop turning, or during the wash-outs when the mud circulation is diverted, thereby reducing the cooling action on the bit, or whenever the drilling is conducted with too much weight or speed. Under such conditions, whenever the bit becomes excessively heated the alloy top 29 of the capsule is arranged to melt and to release the tracer from the capsule 28 into the mud stream in the direction of the arrow to the outlet pipe 12. It is apparent that the alloy itself could contain a radioactive substance and when it gradually melts under the effect of temperature, it enters into the mud and is carried in the stream to the earth's surface. Under such conditions the alloy acts as a tracer.

The outlet pipe 12 is provided with a suitable ionization chamber 35 for providing a signal whenever radioactive tracer is present in the drilling fluid flowing through the outlet pipe 12. The ionization chamber may be of any type well known in the art which is adapted to respond to beta or gamma radiations, derived from the radioactive tracer present in the mud. It consists of an envelope 36 of convenient shape and material, such, for example, as glass, and provided with one or more apertures 37 covered with a material such as mica or aluminum, of sufficient mechanical strength to exclude the drilling fluid and at the same time allow beta particles emitted from the radioactive tracer within the drilling fluid to easily pass into the chamber. In case gamma radiations are to be detected the covered aperture can be dispensed with since gamma radiations pass through relatively thick metallic walls. Two electrodes 38 which may have various geometrical shapes and relative positions are introduced into the envelope and the whole is rendered tight by any suitable means. The interior is evacuated and a suitable quantity of gas such as argon is introduced at a suitable pressure. The electrodes 38 are connected by leads 39 to an electrical circuit consisting of a battery 40 in series with a resistor 41. The output terminals of the resistor 41 are connected through an amplifier 42 and the amplifier's output terminals 43 to a signalling lamp 44.

The ionization chamber is of low sensitivity, i. e. under normal operating conditions, the background radioactivity of the fluid is low and the voltage across the terminals of the resistor 41 is substantially zero. Consequently, no signal is provided by the lamp 44 and the operation of the subsurface equipment is assumed to be satisfactory. Whenever certain undesirable conditions take place, i. e. when the bit becomes worn out or whenever its temperature becomes excessive due to wash-out or other failure, the tracer normally contained in the capsule 28 becomes automatically released into the mud stream, by which it is then carried to the earth's surface and renders the ionization chamber 35 conductive. We obtain thus, a current supplied by the battery 40 and flowing through the resistor 41 and a suitable voltage thereby developed across the terminals of the resistor 41 is transmitted to the amplifier 42. The amplified voltage derived from the terminals 43 is applied to the lamp 44, which provides a luminous signal indicating to the driller either the worn out condition of the drill bit or an excessive temperature of the bit.

It is thus apparent that whenever the drilling mud flowing into the outlet pipe 12 is strongly radioactive, which is shown by the light signal given by lamp 44, a condition is reached that requires removal of the drilling string in order either to replace the worn out or defective bit by a new one or to replace the damaged pipe segment in case of a washout.

The output mud flowing out of the outlet pipe 12 over the butterfly valve 47 into the mud pit 14 is used for recirculation purposes. The recirculation is effected by means of a pump suction unit 62 leading through a suction pipe 63, pump 64, into a mud discharge conduit 65 which communicates with the drill pipe. The satisfactory performance of this arrangement is based to a large extent upon the use of a radioactive tracer having a limited half life. As explained above, the radioactive tracer is particularly applicable for our purpose since this is the only known tracer that gradually disintegrates with time, and, therefore, does not leave a permanent contamination in the mud stream. Consequently under normal operating conditions the general radioactivity background of the mud due to the contribution of all the tracers that have been released in the past is maintained at a low value and furthermore this value gradually decays as time goes on. The concentration of the radioactive substance in the drilling fluid is proportional to the half life of the substance, and to the frequency at which the tracer substance is released (frequency of occurrence of failure), and is inversely proportional to the volume of the drilling fluid used in the circulatory system. By properly selecting the radioactive tracer, there is no difficulty in distinguishing the warning signal caused by an additional release of a tracer from the general background.

In order to reduce the radioactivity level of the drilling fluid by an additional amount I may provide an arrangement for eliminating mechanically the tracer each time after it has served its purpose and provided the driller with a warning signal. Such a mechanical elimination is in case of radioactive tracers not essential, although it may improve the operation of the general arrangement. If such a provision is used, then only under normal conditions, i. e. when the drilling proceeds satisfactorily, the mud flows into the regular mud pit 14 and only then is used for re-

circulation purposes. When, however, the radioactive tracer carrying the warning signal appears in the output mud, a voltage suddenly appears across the output terminals 43. This voltage lights the warning lamp 44 and simultaneously energizes a solenoid 45 which in turn moves the rod 46 and the butterfly valve 47 into the position indicated by dotted lines thus by-passing the portion of the mud stream containing the radioactive tracer into the disposal pit 50.

It is thus apparent that whenever radioactive tracer appears in the outlet pipe 12, a warning signal provided by the lamp 44 is produced and simultaneously a voltage appearing across the output terminals 43 actuates a suitable mechanism causing the tracer material to be by-passed into the disposal pit 50, thus eliminating the tracer from recycling in the mud stream.

The arrangement as described above for automatically eliminating from the drilling fluid or drilling mud stream the tracer substance and collecting said substance in the disposal pit 50 may not always be necessary or desirable. In many cases the increase in the general radioactivity background of mud due to prior tracer releases is not very great and we need not to be concerned with it.

The tracer contained in the capsule should preferably be released into the drilling fluid instantaneously as soon as it comes into contact with it. By means of an instantaneous, almost explosive action as hereinafter described, the tracer may be made to produce a high local concentration in the drilling fluid. Such a local concentration when carried to the earth's surface, is easily detected and produces a satisfactory warning signal. The ordinary chemical tracers that slowly ooze out and do not produce high local concentration are less desirable in this particular application. Consequently, when an aqueous drilling fluid is used, the material comprised in the capsule should preferably react violently with water, be thermally stable, and not spontaneously inflammable.

Suitable reactants are the alkali metal borohydrides, alkaline earth metal borohydrides, other metal borohydrides, metal hydrides, metal silicides, and borohydrides and metal alloys which combine violently with water giving off gas and heat. I prefer to use such substances as LiBH_4 , $\text{Al}(\text{BH}_4)_3$, LiH , B_2H_6 , or other boron hydrides. Other substances may be used such as Na-K alloy, CaH_2 , $\text{Be}(\text{BH}_4)_2$, $\text{Mg}(\text{BH}_4)_2$, and NaBH_4 . These reactants may be non-radioactive and a thorough mixture may be prepared comprising either of these reactants and a suitable radioactive salt. We may choose as a radioactive salt one of the following substances: NaCl (formed with Na^{24} or Cl^{36}), CdI_2 (formed with Cd^{109} or Cd^{115} or Cl^{36}), or $\text{Cd}(\text{NO}_3)_2$ (formed with Cd^{109} or Cd^{115}). When such a mixture is brought in contact with water a violent reaction takes place between the non-radioactive reactant and water giving off heat and a large volume of gas. The radioactive salts present in the mixture do not participate in this reaction but are instantly thrown into the mud stream and subsequently carried to the earth's surface.

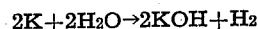
In the above arrangement the capsule contains a mixture of a non-radioactive reactant with a radioactive salt. The radioactive salt does not react chemically with water and it is merely thrown into the mud stream by the explosive force resulting from the contact between the reactant and water in the drilling mud. We may

use a different arrangement that would consist of a capsule comprising a reactant interacting violently with water and in which some of the elements are radioactive. Such a reactant may be one of the following substances:

(1) A metal borohydride comprising a radioactive metal; for instance, NaBH_4 (formed with Na^{24});

(2) A metal hydride comprising a radioactive metal; for instance CaH_2 (formed with Ca^{45}); or

(3) Radioactive isotopes of the base metals such as K^{42} , Na^{24} , Cs^{134} , Cs^{137} , which upon the contact with the water from the mud violently react according to the general equation:



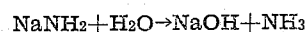
In some instances the violent reaction of the tracer substance with water may not be necessary. We can then dispense with the use of the reactants mentioned above and use capsules containing radioactive salts such as NaCl (formed with Na^{24} or Cl^{36}), Cl_2 (formed with Cd^{109} or Cd^{115} or Cl^{36}), or $\text{Cd}(\text{NO}_3)_2$ (formed with Cd^{109} or Cd^{115}). Either of these salts when brought in contact with water dissolves itself at a sufficiently fast rate to provide an adequate concentration of tracer in the drilling fluid.

In addition to the above, other radioactive substances may be used as tracers. Some of the examples are as follows:

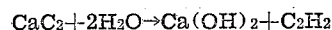
(1) A radioactive gas enclosed under pressure. A typical example is CO_2 with C^{14} as the tagged isotope. It could be inserted in the capsule as Dry Ice or solid CO_2 .

(2) A radioactive liquid immiscible with water and lighter than water. Typical example is carbon tetrachloride CCl_4 (with C^{14} or Cl^{36}).

(3) A compound which generates a radioactive gas upon contact with water. A typical example is NaNH_2 or sodium amide which reacts with water to produce ammonia gas NH_3 which will be released from the mud at the earth's surface when the PH of mud is above 7 which is usually the case. The reaction is



Either the nitrogen N^{13} or H^3 can be tagged. Another example is calcium carbide CaC_2 which reacts with water to form carbide gas C_2H_2 according to the equation



In this case carbon C^{14} is tagged. The gas will release itself from the mud upon arrival at the earth's surface.

It is thus apparent that I have provided a method and arrangement for providing the driller with information regarding the condition of subsurface equipment while performing drilling operations.

I claim:

1. An arrangement for determining an excessive rise in temperature at a predetermined inaccessible location in subsurface drilling equipment, said drilling equipment being used in conjunction with a drilling fluid circulating system, comprising: a solid tracer substance having a relatively low melting point and imbedded in said subsurface equipment at said inaccessible location, said tracer substance being in contact with said circulating system, whereby an excessive rise in temperature causes said substance to melt and allows said circulating system to carry said substance to the earth's surface; and means at the earth's surface to detect said tracer substance, the presence of said substance being

associated with said excessive rise in temperature.

2. An arrangement for determining an excessive rise in temperature at a predetermined inaccessible location in subsurface drilling equipment, said drilling equipment being used in conjunction with a drilling fluid circulating system, comprising: a radioactive solid tracer substance having a relatively low melting point and imbedded at said inaccessible location, said tracer substance being in contact with said circulating system, whereby an excessive rise in temperature causes said substance to melt and allows said circulating system to carry said substance to the earth's surface; and a radioactivity detector at the earth's surface to detect said tracer substance, the output of said detector being indicative of said excessive rise in temperature.

3. An arrangement for determining the occurrence of abnormal operating conditions at a predetermined inaccessible location in subsurface drilling equipment while drilling in conjunction with an aqueous drilling fluid circulating system, comprising: a radioactive tracer substance imbedded in a cavity in said subsurface equipment at said inaccessible location, said radioactive tracer substance comprising a radioactivity-containing substance which undergoes a rapid chemical reaction with water; a shielding element normally protecting said tracer substance from contact with drilling fluid, said element being adapted to be removed upon the occurrence of said abnormal operating condition, thereby exposing said tracer substance to contact with aqueous circulating fluid in said circulating system, to thereby produce a concentration of radioactivity in said fluid in said circulating system; and means at the earth's surface to detect the arrival there of said concentration of radioactivity in the fluid in said circulating system.

4. Apparatus for determining the occurrence of an abnormal rise in the operating temperature of a subsurface drilling tool during drilling in conjunction with a drilling fluid circulating system, comprising: a tracer substance imbedded

in said drilling tool; and a shielding element of a material other than that of the drilling tool secured to said drilling tool and normally covering said tracer substance to prevent contact of drilling fluid with said tracer substance, said shielding element having a melting temperature substantially lower than the melting temperature of the drilling tool and melting upon an abnormal rise in the temperature of the drilling tool to thereupon uncover and release said tracer substance into the drilling fluid as an indication of such abnormal rise in temperature.

5. Apparatus for determining the occurrence of an abnormal rise in the operating temperature of a subsurface drilling tool during drilling in conjunction with an aqueous drilling fluid circulating system, comprising: a tracer substance imbedded in a cavity in said drilling tool; a material associated with said tracer substance in said cavity, which material undergoes a rapid chemical reaction with water; and a shielding element secured to said drilling tool and normally covering said tracer substance and said material to prevent contact of drilling fluid with said tracer substance and said material, said shielding element having a melting temperature substantially lower than the melting temperature of the drilling tool and melting upon an abnormal rise in the temperature of the drilling tool to thereupon uncover said tracer substance and said material to expose said material to the aqueous drilling fluid and to expel said tracer substance into the drilling fluid as an indication of such abnormal rise in temperature.

JAN JACOB ARPS.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,663,677	Byerly	Mar. 27, 1928
1,790,995	McErlane	Feb. 3, 1931
2,338,174	Garrison	Jan. 4, 1944
2,462,241	Wallhausen et al.	Feb. 22, 1949
2,468,905	Warren	May 3, 1949
2,554,476	Werner	May 22, 1951
2,555,314	Buckley et al.	June 5, 1951