

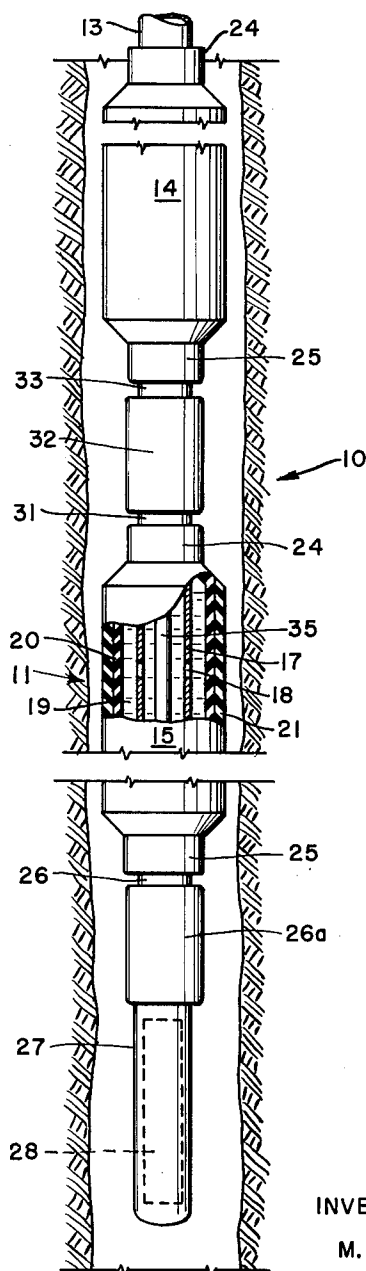
July 31, 1962

M. K. HUBBERT ET AL

3,046,601

CAVITY CONFIGURATION DETERMINATION

Filed Aug. 28, 1959



INVENTORS:

M. K. HUBBERT

W. C. SMITH

C. B. JOHNSON, JR.

BY:

James Podorovic
THEIR ATTORNEY

1

3,046,601

CAVITY CONFIGURATION DETERMINATION
Marion K. Hubbert, William C. Smith, and Chrest B. Johnson, Jr., Houston, Tex., assignors to Shell Oil Company, a corporation of Delaware
Filed Aug. 28, 1959, Ser. No. 837,320
8 Claims. (Cl. 18-6)

The present invention relates to exploration of well bores, and more particularly pertains to a method and apparatus for determining the configuration of surfaces, including bottom hole cavities, fissures, and the like, in the walls of well bores. In one of its more specific embodiments, the invention is directed to a system for forming replicas or impressions of the configuration of the internal surfaces or walls along a section of a well bore.

In the present-day practice in the petroleum industry, it is frequently desirable, if not necessary, that the operators have knowledge of the configuration of the internal surfaces or walls of the bore holes, and/or of the fissures, indentations or cavities encountered or formed during drilling or operating of the wells. Thus, it is known that subsurface formations usually exist under conditions of unequal stress and that the direction and nature of these stresses are related to the tectonic history of the area containing the particular subsurface formations. Unless otherwise prevented or controlled, fissures which are formed or which may be created, for instance, by the application of a high formation-fracturing fluid pressure will generally extend away from the point or area of such pressure application along planes which are normally perpendicular to the axis of the least principal stress within the formation. Determination of the directions and configurations of such fissures is of material value to geologists and petroleum engineers. This may be of particular importance to engineers involved in determining whether a particular underground oil-bearing formation could be effectively subjected to water-drive operations for secondary recovery of oil therefrom, and, if so, the type of operation to be used. Thus, generally it is advisable to use a series of wells parallel with the fissuring as water-input wells so that this water does not by-pass the oil in the formation but forces at at right angles to the fissures to other wells which are to be used as the recovery wells.

It is therefore a primary object of this invention to provide a process and apparatus for the effective, ready and economical determination of the configuration of underground cavities, including bottom hole cavities of well bores. It is another object to provide a process and apparatus for determining and permanently recording such underground cavity configurations to obtain imprints of fissures, and the like, occurring in these well bore cavities. Still another object is to provide method and means for geographically directionally orienting such underground cavity imprints.

It has now been discovered that the above and other objects may be attained by disposing an inflatable member, e.g. a tubular or sheath-like elastic inflatable member consisting of, comprising or including an uncured rubber member in the well bore in the substantial vicinity of the space, zone or cavity the configuration of which it is desired to obtain, inflating said elastic inflatable member so as to cause the uncured rubber to be forced against the walls and to conform to the configuration of the cavity, and curing said rubber in situ and while in the aforesaid contact with the cavity walls, whereby said rubber acquires a substantially permanent form or configuration corresponding to the space, e.g. that portion of the well bore or cavity in which it is expanded. The elastic inflatable member may then be deflated or collapsed so as to permit it (as well as the cured rubber sheath) to be collapsed to such a degree that it may be readily withdrawn from the bore

2

hole, the configuration of the cavity walls being now permanently imprinted or stamped on the surface of the rubber sheath. It has also been discovered that the above technique may be readily combined with any one of the well-known orienting techniques in order to geographically orient the cured rubber member and thus determine the geographic position of the various fissures and other irregularities in the cavity.

The invention may also be stated to reside in an apparatus for determining and obtaining the configuration of a cavity or portion of a well bore which traverses an earth formation, which apparatus includes an elongated tubular body member, means attached to said tubular body member for lowering said tubular member into a well bore and to a point opposite the place where the well bore configuration is to be taken, a cylindrical elastic permanently-deformable sheath, e.g. comprising or consisting of uncured rubber, carried on the outer surface of said body member, clamp means holding the upper and lower portions of said sheath against said body member, openings in the tubular body member at a point covered by the rubber sheath, means in communication with the interior of the tubular body member (and therefore with the interior of the elastic sheath) for expanding said sheath against the walls of the borehole, and means in communication with said elastic sheath while in said expanded state to cure said sheath to a permanently-set flexible form having the configuration of the borehole wall, against which it was impressed, imprinted thereon.

The apparatus of the present invention, as defined above, may also include orienting means which will record, for example, the geographic north of the assembly so that the imprint obtained on the rubber sheath, when brought up to the surface can be properly positioned or oriented to be able to determine not only the exact configuration of the cavity or the like at or near the bottom of the well bore, but also its position with respect to geographic direction, e.g. magnetic north, as well as inclination, if so desired. Any known means may be provided and used for the making of the record of the orienting means at the time the curing of the inflated rubber sheath is being effected. For example, and considering that a compass is the means being provided as the orienting means, photographic means may be used to make a print of the face of the compass and of some marker or indicating point which is fixedly correlated with respect to the rubber sheath. As an alternative, it is possible to use fluid pressure (including the same which is used for inflating the elastic sheath) to make an imprint of the compass needle on some known means, e.g. paper, or to otherwise immobilize the needle and maintain it in fixed relation with respect to the position of the sheath until the whole apparatus is brought to the surface and properly oriented there.

In order to provide means for expanding the elastic deformable sheath against the walls of the bore hole, the means for lowering the apparatus to the desired or necessary point in a well bore may consist of a string of pipe threaded or otherwise connected to the upper end of the aforementioned perforated elongated tubular member this pipe extending to the surface. Under these conditions, a fluid, whether gaseous or liquid (which latter is generally preferred), may be injected into and downwardly through said tubing and then through the ports or openings in the perforated elongated tubular member, to thereby force the flexible elastic sheath against the walls of the cavity the configuration of which it is desired to obtain. In the alternative, it is possible to provide two different agents or chemicals, which when brought together will react in a manner which causes the creation of large volumes of, for example, gases which latter (because they are in an enclosed space, the upper and lower ends of the aforementioned elongated tubular body member being

closed) will pass through the side openings in said tubular body member, and into the space behind the flexible member. This will force the latter against the cavity walls, an imprint of which is to be obtained.

There are a large number of pairs of compounds or compositions, both liquid and solid, which, when brought into intimate contact with each other, will react with the simultaneous formation of a gas of a considerably larger volume than that occupied by the reagents themselves. One such well known pair is calcium carbide and water. When calcium carbide is contacted with water a violent exothermic reaction occurs with the formation of acetylene. If the reaction is allowed to occur in a confined space, the gas thus formed will create a pressure which is sufficient to expand the flexible-deformable sheath, e.g. uncured rubber element, to force it against the walls of the cavity, the configuration of which it is desired to obtain. Other pairs of reagents which may perform in like manner are well known to those skilled in the art, thus eliminating the necessity of enumerating them here.

As indicated above, and as will be discussed more fully hereinbelow, the elastic sheath or bag, which is to be expanded to take the form and configuration of the cavity or well borehole, consists of, comprises or includes an uncured rubber member or the like, which after expansion as set forth above, must be cured in order that the rubber acquire a permanent form of that portion of the borehole in which it has been expanded. In the case of ordinary rubber, the curing or vulcanizing of the uncured rubber is effected in the well-known manner, i.e. by heating. This latter may be provided by the same reaction which generates the gas to expand the rubber sheath or bag, as for example the interaction of calcium carbide and water. In the latter case, the upper end of the aforementioned elongated tubular body member may be provided with a check valve; water is then introduced into said body member and then calcium carbide (e.g. present in a separated compartment therein) is then exposed to the reaction with said water. The pressure generated causes the uncured rubber to expand, while the heat generated will then vulcanize said rubber.

This in situ curing or vulcanization may also be accomplished by filling the interior of the elongated tubular body member with a liquid reactant, such as concentrated aqueous sodium hydroxide or aqueous hydrochloric acid, applying pressure to this liquid reactant to press the vulcanizable material against the borehole walls, and heating this vulcanizable material, e.g. rubber, in its expanded state, to a temperature at which the vulcanization occurs and proceeds at a rapid rate, e.g. by introducing a solid reactant, such as metallic aluminum or metallic magnesium into the body of the aforementioned liquid reactant. The curing or vulcanizing may also be effected by using an electric heating element lowered into place on an electric cable.

As the elastic sheath or bag member is expanded, the liquid in the borehole around it is displaced, some of it being forced back into the surrounding rock formation; this will occur in some cases at moderately low pressures particularly in formations or zones thereof which have been hydraulically fractured. After the curing or vulcanization has been completed, the cured rubber sheath or bag can be stripped free from the formation and shrunk by reducing the pressure within the body member, thus permitting the liquid in the surrounding rock formation to collapse the elastic vulcanized sheath to such a size that it can be removed from the well bore.

The invention will be more readily understood by reference to the following description as well as to the annexed drawing, the sole FIGURE of which is an elevation view, partly in cross-section of an embodiment of the apparatus of the present invention, which apparatus can be used to effect the described and claimed process.

Referring to the drawing, numeral 10 denotes a well bore the configuration of at least a portion thereof, e.g.

that indicated by numeral 11, it is desired to obtain, for instance to determine the position and direction of any fissures or fractures which may be existing thereat.

An apparatus of the present invention is shown as being disposed in said well bore, said apparatus being suspended on a string of pipe or tubing 13. Although one or more configuration-measuring units may be carried by pipe 13, two such units 14 and 15 are shown in the drawing. Each unit includes an elongated tubular body member 17 provided with one or more openings or perforations 18 which permit fluid communication between the interior space within said body member 17 and the annular space 19 surrounding it. Said annular space 19 is enclosed by a flexible inflatable sheath 20 around which is disposed the vulcanizable material, e.g. the layer of uncured rubber 21, this latter constituting a part of the cylindrical elastic sheath discussed above. The upper and lower ends of this sheath are held in position on body member 17 by means of clamping means 24 and 25, respectively.

The lower end of the lower unit 15 is attached via the clamping means 25 to a nipple 26 which, in turn, is threaded into a collar 26a the lower end of which is shown as carrying in a pipe 27 an orienting device 28 schematically indicated by means of a dotted rectangle. This may be a compass, or a clinometer, such as that described in U.S. Patent No. 2,045,342, which clinometer indicates not only well inclinations, but also geographic north.

At the upper end body member 15 is shown as being connected via nipple 31, collar 32, and nipple 33, to the lower end of another body member 14. The latter is optional since in most cases only one unit is employed to determine and record the configuration of the cavity or bore hole traversed.

In operation the apparatus described and illustrated in the attached drawing is lowered to the desired point in well bore 10 e.g. by means of a string of tubing 13. Thereupon pressure is exerted on the fluid within tubular body member 17 said fluid being forced through openings 18 into the annular space 19 to force the flexible sheath 20 and the vulcanizable material, i.e. the layer of uncured rubber 21 against the inner walls of the bore hole or cavity the configuration of which is to be made. While the uncured rubber 21 is thus pressed against the walls of the bore hole the rubber is cured or vulcanized, e.g. by heat. For this purpose and if the fluid used consists, for example, of a concentrated aqueous solution of sodium hydroxide, it is possible to drop metallic rods of magnesium which is represented in the drawing by numeral 35. The interaction between this magnesium and the liquid causes generation of heat which cures or vulcanizes the rubber. At the same time rod 35 may heat a piston (not shown) in the upper part of pipe 27 to make, in a well-known manner, a record of the relative orientation of the device, e.g. by imprinting the direction indicated by a compass needle on a sheet of paper or the like on the lower side of the piston disposed above the compass in the orienting device 28.

When the rubber sheath 21 has been vulcanized and thus acquired the form of the inner walls of the bore hole or cavity the pressure within body member 17 is reduced in any well-known manner, e.g. opening suitable valves at the top of the well. This will cause the collapse or deflation of inflatable member or sheath 20 which may then be withdrawn from the well bore 10. The surface of the rubber 21 which has now been cured has thereon the configuration of the well bore or cavity in which said rubber was cured.

If desired the outer surface of the rubber sheath 21 may be protected by a thin layer of a fluid type elastic material such as cured rubber, this in order to keep the raw rubber from becoming bonded to the wall surface against which it is pressed during the vulcanizing operation. At the same time the element 20 on the side of said rubber sheath 21 acts to prevent the fluid forced into

space 19 through perforations 18 from breaking through the uncured rubber. If so desired a thin elastic textile fabric layer may be disposed between sheath 20 and rubber element 21. This textile fabric can serve as a flexible retaining jacket which keeps the rubber sheath from rupturing particularly when a portion of said sheath or bag is expanded to a cavern which may be greater in size than possibly fillable by said sheath when in an expanded state.

It has been pointed out that the elastic deformable sheath 21 may consist or comprise rubber which may be natural or synthetic. Any of the known synthetic rubbers such as those comprising or consisting of isoprene polymers, butadiene polymers, neoprene polymer, thiocal polymer, polystyrene and inter- and copolymers of these may be used. These synthetic rubbers are described in greater detail in Chemistry and Technology of Rubber by Davis and Blake, issued in 1937, particular reference being made to chapter XX on pages 677-702 of said book which portion is incorporated by reference herein. Other types of rubbers are the so-called silicone rubbers manufactured and sold by Dow Corning Corporation under the trade name "Silastic."

These natural and synthetic rubbers are used in a raw state and then cured or vulcanized in situ as mentioned above. Obviously known vulcanizing additives such as sulfur and accelerators such as aldehyde-amine, thiuram, etc. may be employed as is well-known to those skilled in the art and as described for example on pages 264-267 of the aforementioned book by Davis and Blake. The raw rubber may be used in the form known as "camelback" which may be wrapped helically over the sheath 20 to form a uniform layer of desired thickness which may be as thin as $\frac{1}{16}$ " or as thick as from $\frac{1}{4}$ " to $\frac{1}{2}$ " or thicker, depending on the conditions of use, namely the size of the cavity the configuration of which it is desired to obtain.

From the foregoing, it is believed that the apparatus for practicing the invention described herein will be readily comprehended by persons skilled in the art. It is to be clearly understood however that various changes in the apparatus shown and described herein and in the method of practicing the invention outlined above may be resorted to without departing from the spirit of the invention as defined by the appended claims.

We claim as our invention:

1. In a method of forming an internal surface replica of a well bore, the steps of disposing a tubular member comprising uncured rubber in said well bore, expanding said rubber member to conform to the inner surface of the well bore, curing said rubber member in place against the well bore surface, thereby forming an impression of the well bore surface on said rubber member, at least partially collapsing said expanded and cured rubber member, and withdrawing it in the collapsed form from the well bore.

2. In a method of forming an internal surface replica of a well bore, the steps of disposing a tubular member provided with an uncured rubber member in said well bore, expanding said rubber member to conform to the inner surface of the well bore, curing said rubber member in place against the well bore surface, thereby forming an impression of the well bore surface on said rubber member, at least partially collapsing said expanded and cured rubber member, and withdrawing it in the collapsed form from the well bore.

3. In a method according to claim 2, wherein the geographic directional orientation of the rubber member is taken substantially at the same time as said rubber member is cured in its expanded state.

4. In a method for determining the configuration of an underground cavity which communicates with the surface of the ground through a bore hole, the steps of lowering through the bore hole and into the cavity zone an elastic inflatable member at least the outer surface of which comprises a layer of uncured rubber, inflating said inflatable member to cause the uncured rubber to be forced against the walls of the cavity, thereby causing said rubber to conform to the cavity configuration, curing said rubber in place and while in said contact with the cavity walls whereby said rubber acquires a permanent form of that portion of the bore hole in which it is expanded, at least partially deflating said inflatable member and withdrawing it from the bore hole with the configuration of the cavity walls impressed thereon.

5. In a method for determining the configuration of an underground cavity which communicates with the surface of the ground through a bore hole, the steps of lowering through the bore hole and into the cavity zone an elastic inflatable member provided on its outer surface with a layer of uncured rubber, inflating said inflatable member to cause the uncured rubber to be forced against the walls of the cavity, thereby causing said rubber to conform to the cavity configuration, curing said rubber in place and while in said contact with the cavity walls whereby said rubber acquires a permanent form of that portion of the bore hole in which it is expanded, at least partially deflating said inflatable member and withdrawing it from the bore hole with the configuration of the cavity walls impressed thereon.

6. In a process according to claim 5, wherein the geographic directional orientation of the elastic inflatable member is determined substantially at the time when the inflated uncured rubber is being cured.

7. Apparatus for obtaining a form which is equal in volume and configuration to a portion of a well bore hole traversing earth formations, said apparatus comprising an elongated tubular body member, a cylindrical elastic permanently-deformable sheath carried on the outer surface of said body member, said sheath including a layer of uncured rubber thereon, clamp means holding the upper and lower of said sheath against said body member, geographic directional orientation device carried by said body member, port means through the wall of said tubular body member at a point covered by said sheath, a string of pipe connected to the top of said body member and adapted to suspend said body member in a well bore hole with the top of the pipe extending to the surface, said pipe string forming fluid transmission means between said body member and the top of the well, means in communication with the bore of said tubular body member for expanding said sheath against the wall of the bore hole, and heating means adapted to be positioned in said tubular body member for curing the rubber to a permanently-set flexible form having the configuration of the adjacent bore hole.

8. Apparatus according to claim 7 wherein the uncured rubber employed is a synthetic rubber.

References Cited in the file of this patent

UNITED STATES PATENTS

2,016,904	Nathan et al.	Oct. 8, 1935
2,272,892	Taylor et al.	Feb. 10, 1942
2,405,245	Ushakoff	Aug. 6, 1946
2,416,441	Grant et al.	Feb. 25, 1947
2,618,014	Sawyer et al.	Nov. 18, 1952
2,653,474	Santiago	Sept. 29, 1953
2,665,187	Kinley et al.	Jan. 5, 1954
2,856,632	Rekettye	Oct. 21, 1958