March 19, 1957 C. M. HAYES 2,785,875

JET REAMER

Filed Dec. 20, 1954

FIG.1.

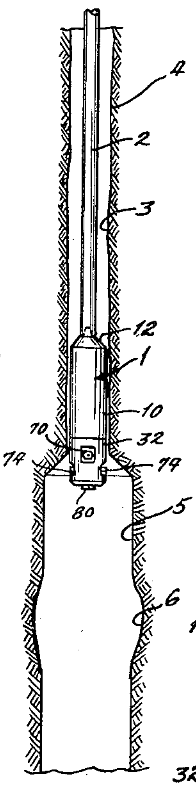


FIG.3.

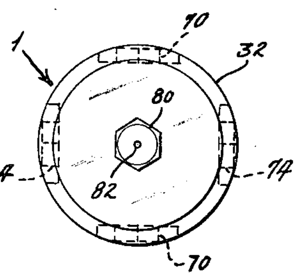


FIG.2.

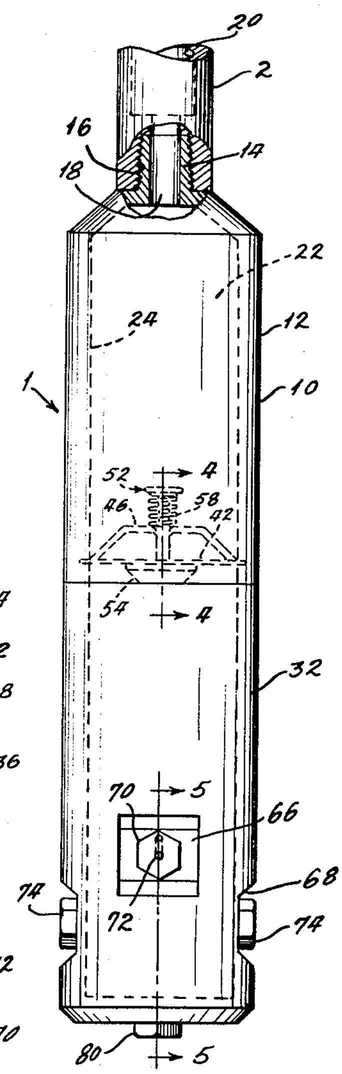


FIG.4.

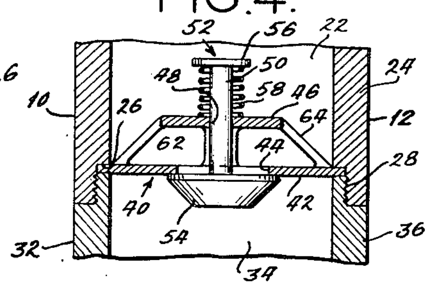
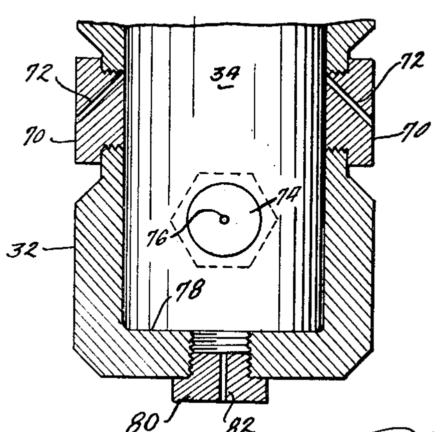


FIG.5.



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JET REAMER

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2 Claims. (Cl. 255—1.8)

This invention relates to a method of and apparatus for drilling wells.

It is frequently desirable in bringing in a well to enlarge the bore of the well through a selected vertical space. It is also common practice to pack the enlarged cavity with gravel or the like. In wells drilled with a rotary rig, it is presently customary to use what is known as a hydraulic rotary wall scraper in order to enlarge the bore. This consists of hinged blades which fold back into a cylindrical body so as to permit the scraper's being inserted in a bore hole. The blades are so arranged that they may be forced radially outwardly to scrape the wall of the bore hole.

Such a device has a number of marked disadvantages. First, it is a relatively expensive tool both in its initial cost and in its upkeep, since the blades and the body must be kept in repair, and the retracting and extending mechanism is necessarily made accurately and sturdily to ensure proper operation in a bore hole.

Secondly, such a scraper requires a great deal of power to operate. It can, as a practical matter, be used for only a limited enlargement and in only a limitedly large bore hole, because the turning torque increases with the radial reach of the blades.

Thirdly, the shape of the blades is such and the action of the blades in opening is such that in an enlargement of any substantial size, the "roof" of the enlargement is substantially perpendicular to the axis of the bore hole.

While for relatively small enlargements, this poses no great problem in gravel packing, in a wide enlargement, the roof of the enlarged chamber does not correspond with the angle of repose of the gravel, so that an unsupported void is left between the roof and the gravel which is introduced into the enlargement.

Fourthly, the scraping action of a conventional hydraulic scraper tends to force mud into porous formations in much the manner in which potatoes are forced into the perforations in a ricer. This is the very antithesis of what is desired, since the object of the enlarging and the scraping is to provide free and unobstructed passage of fluid from porous strata.

In bringing in a well, it is not only desirable to enlarge the bore hole in the producing zone, but it is essential that the enlargement be in the proper zone. It is frequently very difficult to determine where the zone of greatest porosity lies. This is particularly true in drilling through dirty sand and the like where the difference in the drilling rate through zones of different porosity is so small as to be practically undetectable.

One of the objects of this invention is to provide a method of accurately and easily determining the location of a producing zone in a well.

Another object is to provide apparatus for enlarging a bore hole, which apparatus is simple, cheap to manufacture, use and maintain, which requires little power to operate, which is capable of extensive enlargement of a bore hole without substantial increase in power, which

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is capable of being used to enlarge a bore hole of large original size, also with no substantial increase in the power required, which is capable of producing an enlargement with a roof sloping downwardly at the angle of repose of gravel, or at any desired small or large angle, and which removes mud or other material which would tend to plug a porous formation without squeezing it into the interstices of the formation.

Other objects will become apparent to those skilled in the art in the light of the following disclosure and accompanying drawing.

In accordance with this invention, generally stated, a device is provided which utilizes jets of liquid under pressure to enlarge a bore hole. A method of determining the producing zone or zones of a well is provided which includes the steps of subjecting the wall of the bore of a well to a substantially uniform jetting action and then measuring the enlargement along the wall. By determining where the enlargement is greatest, it is possible to determine accurately the zone of greatest porosity.

In the drawing,

Figure 1 is a view partly in section showing a device of this invention positioned within a bore hole;

Figure 2 is a view in front elevation partly broken away of a jet reamer constructed in accordance with one embodiment of this invention;

Figure 3 is a bottom plan view of the device shown in Figure 2;

Figure 4 is a sectional view taken along the line 4—4 of Figure 2; and

Figure 5 is a sectional view taken along the line 5—5 of Figure 2.

Referring now to the drawing, reference numeral **1** indicates a jet reamer constructed in accordance with an illustrative embodiment of this invention. The jet reamer **1** is connected to a string of pipe **2** through which liquid, generally water, is pumped by means of a pump not here shown.

In Figure 1 the jet reamer **1**, hanging on the string of pipe **2**, is shown in the process of enlarging a bore **3** in earth **4** to form a cavity **5**. In the cavity **5** shown in Figure 1, there is an enlarged section **6**.

In the embodiment shown, the jet reamer **1** includes a hollow cylindrical bomb **10** which is made up in two parts. An upper part **12** of the bomb is provided with a threaded male tool joint connection **14** which takes into a complementary female connection **16** at the lower end of the string of pipe **2**. A passage **18** in the connection **14** communicates at its upper end with a passage **20** in the pipe **2** and at its lower end with a cavity **22** in the section **12**. The cavity **22** is defined by a heavy wall **24**. The inside surface of the wall **24** is cut away at its lower end to define an annular shoulder **26**. The cut away portion of the wall **24** below the shoulder **26** is internally threaded at **28**.

A lower part **32** of the bomb **10** is also hollow, an internal cavity **34** being defined by a heavy wall **36**. The outside surface of the wall **36** is cut away at its upper end and is externally threaded complementarily to the threaded section **28** of the upper part **12**. A spring-biased check valve **40** normally separates the cavity **22** from the cavity **34**.

The check valve **40** includes a circular web **42** with a port **44** in its center. The circular web **42** is seated between the upper end of the part **32** and the shoulder **26**. A spider **46** on the upper side of the web **42** is provided with a central hole **48** through which a stem **50** of a valve **52** extends. The valve **52** has a head **54** at its lower end which seats on the lower face of the web **42** to close the port **44**. A cap **56**, removably secured to the upper end of the stem **50**, serves to retain a helical spring 58. The spring 58, the lower end of which rests against the top of the spider 46 and the upper end of which bears against the underside of the cap 56, biases the head 54 into closed position. Openings 62 between legs 64 of the spider are large enough to permit an unrestricted flow of liquid through the port 44.

In the embodiment of this device shown, the outside surface of the wall 36 is recessed in four places to form two upper flats 66 and two lower flats 68. The upper flats 66 are diametrically opposite one another. The lower flats 68 are diametrically opposite one another and perpendicular to the upper flats 66. The wall 36 at the center of each of the flats 66 and 68 is drilled and tapped to take nozzle inserts. Nozzle inserts 70 in the upper flats 66 are provided with an outwardly downwardly directed passage 72. The passage 72 makes an angle of about 35° to 45° from the horizontal, corresponding to the angle of repose of the gravel with which the cavity made by the reamer is to be filled. Nozzle inserts 74 of the flats 68 are provided with axial passages 76. An otherwise closed end 78 of the lower part 32 is also drilled and tapped and provided with a nozzle insert 80, having an axial passage 82. Each of the nozzle inserts 70, 74 and 80 in the embodiment shown, is a tool steel cap screw.

In operation, water under pressure is pumped through the pipe string 2, through the passage 18 and into the cavity 22. The pressure of the spring 58 need be only on the order of five pounds. The pressure of water will be several hundred pounds so that the head 54 will be moved away from the port 44 against the bias of the spring to permit the water to enter the cavity 34 and jet from the nozzles 72, 76 and 82. Since the radially directed nozzle passages 76 are positioned below the downwardly directed passages 72, the uppermost end of a cavity will have a roof which slopes downwardly outwardly at an angle corresponding to the angle at which the passage 72 is set. The vertical distance between the passages 72 and 76 is goverened to some extent by the size of the cavity to be produced. It can be seen that for a given bomb, the larger the cavity, the greater must be the vertical spacing between the passages 72 and 76, to prevent the intersection of the planes of the streams of water from the two sets of nozzles, since beyond the point of intersection, the radially directed stream will be the higher. However, within reasonable limits, a fixed spacing will be satisfactory for any enlargement up to the size at which the planes intersect.

The provision of the check valve prevents clogging of the nozzle passages, because the bias of the spring ensures that the valve will close before equilibrium is reached. Thus the water through the nozzles will be under a positive internal pressure until the check valve closes.

When the nozzle inserts take the form of tool steel cap screws, they can easily be replaced. By increasing the pressure of water and substituting nozzle inserts having a passage of smaller diameter, a larger cavity may be made so long as a sufficient volume of water is provided to wash out the material in which the cavity is made. However, a cavity of large diameter can also be made by increasing the diameter of the bomb and using large nozzle insert passages, since, unlike mechanical wall scrapers, an increase in diameter of the jet reamer bomb does not appreciably increase its turning torque. Thus, to the limit of the size of the bore above the cavity, the bomb may be made as large as desired. If the bore is to be enlarged all the way to the top, for example, a bomb four feet or more in diameter would not be impractical. It can easily be seen that a blade-type reamer in which the blades extended even two feet to either side would impose an unbearable strain on a string of ordinary two inch pipe of any considerable length.

In operation, the jet reamer is self-cleaning, both with respect to its nozzle passages and with respect to the wall of the bore. Even when the wall is caked with drilling mud, the jet reamer of this invention washes it clean, instead of scraping the mud into the interstices of the formation.

In using the jet reamer of this invention with a rotary rig simply to enlarge a bore hole, which may have been made by any means, the connection 14 of the bomb is screwed into the connection 16 at the end of a string of pipe 2. The reamer 1 is then lowered on the end of the pipe to the uppermost point of the section to be enlarged, water is pumped under pressure through the pipe, through the aperture 44 against the bias of the spring 58 and through the passages 72, 76 and 82, and the pipe string and reamer are simultaneously rotated and lowered.

In dirty sand, using a bomb three inches in diameter on a string of two inch pipe, with quarter inch passages in the nozzle inserts, with the water at a pressure of 300 pounds per square inch, with a bias of five pounds on the valve head 54, and with the pipe rotated at four to ten revolutions per minute, the jet reamer may be lowered at the rate of one-half a foot per minute to produce a cavity approximately two and one-half feet in diameter, in a bore which was originally four inches in diameter.

In using the jet reamer of this invention to determine the location of a producing zone in a well, the reamer is supplied with water under uniform pressure and is rotated and lowered (or raised) at as uniform a rate in a bore hole as ordinary care will permit in the usual rotary rig.

The reamer is then removed and a bore hole diameter gauge is introduced into the bore. Such gauges are well known in the art. The various diameters of the bore hole and their locations are logged. It will be found that the varying diameter of the bore hole provides a sensitive measure of the porosity of the formation through which the reamer has traveled. The more porous the strata, the greater the diameter of the hole. Since the well should be brought in at the location of the most porous stratum, it is only necessary to note the depth of the greatest enlargement, and to take what steps are necessary to bring in a well at that level. In bringing in a water well, the porous area is usually further enlarged, and the cavity packed with gravel.

This system is much cheaper and simpler than any method known heretofore, and is at the same time more exact. In actual practice, water wells have been brought in by using this method in marginal areas where other methods have repeatedly failed.

Numerous variations, within the scope of the appended claims, in the construction of the device of the invention and in the method of determining producing zones will occur to those skilled in the art in the light of the foregoing disclosure. For example, a greater number of passages may be provided in the bomb wall, and the passages may be made to direct jets of liquid in vertically or horizontally overlying bands. The shape, size and location of the passages may be varied. For example, larger or smaller passages may be provided for the downwardly sloping passages than for the radially directed ones, or one or the other kind may be eliminated. The bottom jet may be omitted, although it serves to keep the bore clear. The bomb may be made in one piece. The check valve may be put in the pipe line adjacent the bomb. The jet passages may be made in the bomb itself, but in any of these variations some of the advantages of the preferred embodiment are lost.

In order to produce a cavity of large diameter at a substantial distance below the mouth of a relatively small well hole, various devices for moving the jet nozzles outwardly from the bomb, so as to place them closely adjacent the wall of the hole even as the cavity is enlarged, will occur to those skilled in the art. For example, high pressure flexible hoses can be secured to the bomb, each provided with a nozzle insert in its outer end. The droop of the hoses will permit the bomb's being inserted, with the outer ends of the hoses hanging down, in a relatively small bore hole. As the water pressure within the bomb is increased, the hoses will tend to stand straight out in the direction in which they are secured to the bomb. Thus, by securing hoses at an angle, their nozzles can be directed at the appropriate downward angle even when the hoses are under pressure. Another way to accomplish this "expansion" is to mount the nozzles on the ends of sections of rigid tubing slideably or telescopically mounted in the walls of the bomb and spring biased to a retracted position. Thus, when pressure is applied, the tube sections will move against the bias of the spring to an extended position at which the nozzles will closely approach the wall of the cavity. Still another way is to hinge hollow rigid arms to the body of the reamer in such a way that water may be pumped through the arms, hence through nozzles at the outer ends of the arms. The erection of the arms can be controlled by a piston moved by water pressure and serving as a sliding valve to admit water to the arms only when the arms are properly extended. The piston can be spring biased or the weight of the arms may be such as to restore them to their downfolded position against the weight of the piston when the pressure of water is removed. The term "passages" as applied to the bomb includes extensible passages of the general character described.

Having thus described the invention, what is claimed and desired to be secured by Letters Patent is:

1. A jet reamer for use in enlarging a bore hole in the ground to form a cavity to be packed, comprising a hollow cylindrical bomb having an upper, inverted cup-shape part and a lower cup-shape part, said upper and lower parts being threadedly connected and divided internally by a normally closed downwardly opening upwardly spring-biased check valve, said upper part being provided at its upper end with a threaded connection complementary to a connection on the lower end of a pipe, and said lower part being provided with upper and lower sets of removable nozzle inserts having passages therein, the passages of the upper set of nozzle inserts being directed outwardly downwardly at an angle no less than the angle of repose of material with which the cavity is to be packed, the passages of the lower set of nozzle inserts being radially directed and spaced a distance below the passages of said upper set of nozzle inserts sufficient that the surfaces generated by the projected axes of the passages as the reamer is rotated intersect beyond the desired radius of the enlarged bore hole, all of said passages communicating with the interior of the bomb.

2. In the art of producing a well, the method comprising drilling in the earth a hole defined by a substantially straight side wall, projecting liquid against the said side wall at a substantially uniform pressure along a selected axial section thereof to enlarge the said hole, thereafter measuring the diameter of the hole along the said section to determine the zone of greatest enlargement, and subsequently further enlarging the zone of greatest enlargement.

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