

Sept. 2, 1969

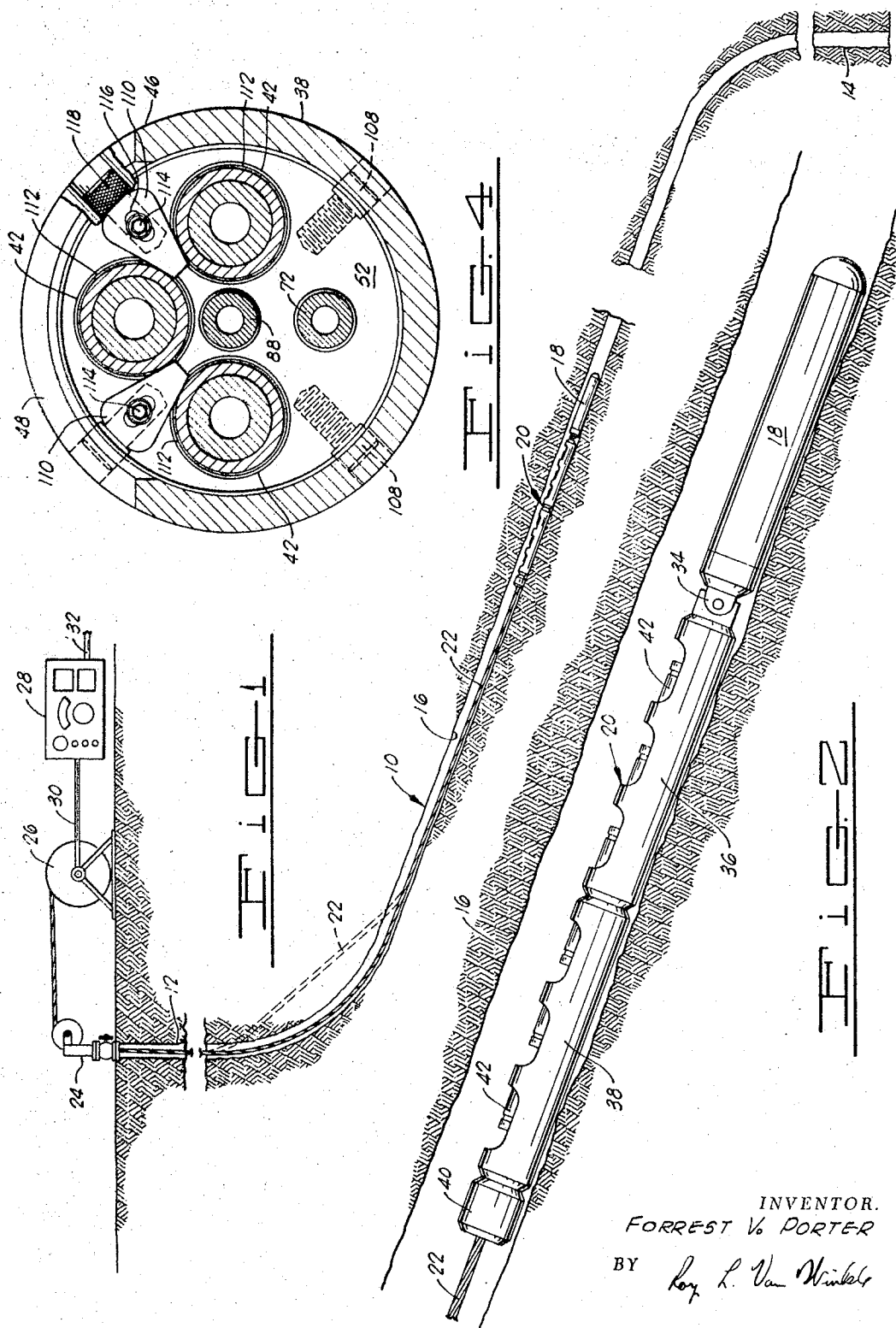
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3,465,356

APPARATUS AND METHODS FOR USE IN WELL BORES

Filed Jan. 22, 1968

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

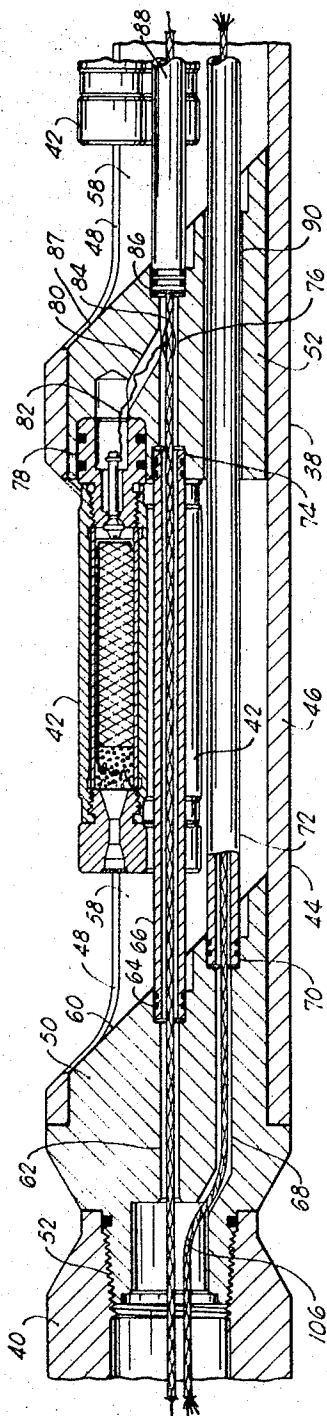


FIG. 3A

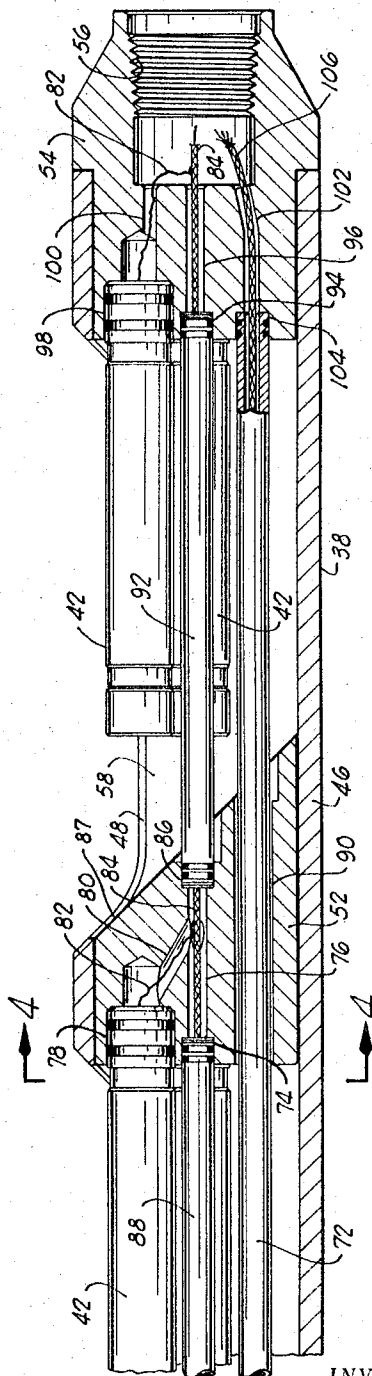


FIG. 3B

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4 Sheets-Sheet 3

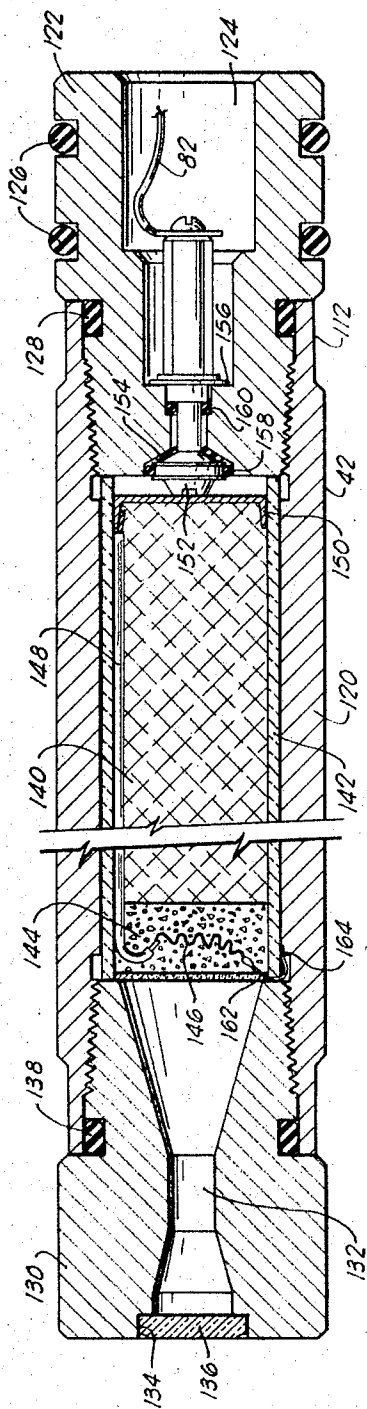


FIG. 3

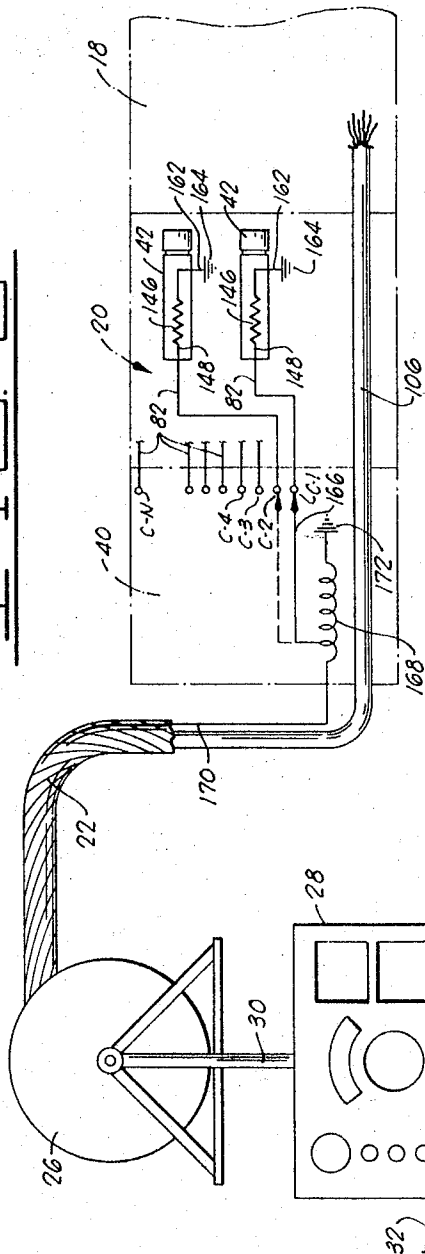


FIG. 4

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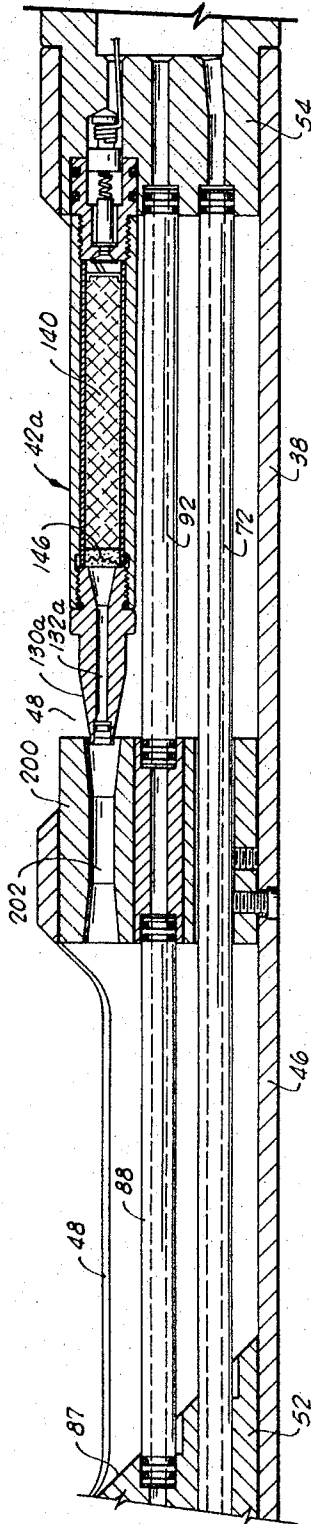


Fig. 7

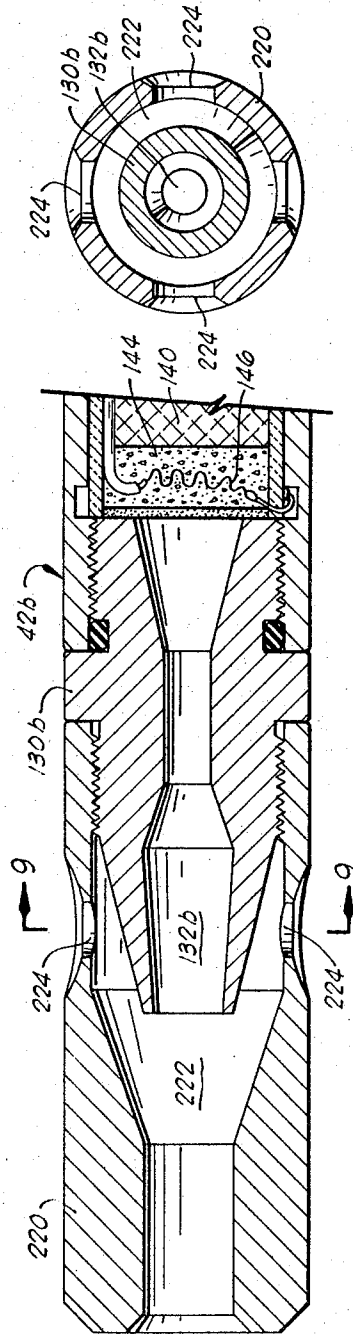


Fig. 9

Fig. 9

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APPARATUS AND METHODS FOR USE IN WELL BORES

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Continuation-in-part of abandoned application Ser. No. 583,900, Oct. 3, 1966. This application Jan. 22, 1968, Ser. No. 699,721

Int. Cl. E21b 47/00

U.S. Cl. 166—301

6 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus useful in assisting the movement of wire-line operated well tools through well bores having portions disposed at an angle deviating from the vertical. The apparatus includes one or more propellant charges arranged, when ignited, to exert a thrust on the well tool, thereby moving the tool along the well bore.

This application is a continuation-in-part of my co-pending application Ser. No. 583,900 filed Oct. 3, 1966 and now abandoned.

BACKGROUND OF THE INVENTION

This invention relates generally to improved methods and apparatus for moving well tools through a well bore having a deviated portion. More particularly, but not by way of limitation, this invention relates to an improved method and apparatus for exerting a moving force on wire-line operated tools whereby such tools can be effectively utilized in a well bore having a deviated or angularly disposed portion.

Within recent years, it has become more and more common in the search for oil and gas to drill wells that deviate from the normal vertical orientation. Particularly in the case of drilling in a municipal area or in offshore drilling from a platform, the initial or vertical portions of a plurality of well bores are located in a relatively small area and, as the drilling progresses, devices known as "whipstocks" are set at intervals to change the direction of such wells so that they radiate outwardly for several thousand feet from the relatively small initial surface area. Frequently, the wells are then again "whipstocked" to return the wells to the vertical orientation. Sometimes, the deviated portions of the well bore may extend essentially horizontally or at angles not more than 18° to 20° from the horizontal.

As is well known, many well tools utilized in performing exploratory or service operations in well bores are arranged to be run on and operated by wire-lines or cables. In the usual vertical orientation of well bores it has been possible to utilize the force of gravity to lower such tools into the bore and to utilize a reel or other hoisting apparatus to raise the tools therefrom.

However, in the well bores having extreme deviations, that is, in those having deviated portions approaching a horizontal orientation, the force of gravity is not sufficient to overcome the frictional engagement between the well tools and the well bore. Thus, the wire-line operated tools can be lowered only to the deviated portion severely curtailing the usefulness of such tools in deviated well bores. It is sometimes possible, if the angle of the deviated portion is not too great, to lower the tools into the deviated bores but when attempting to raise such tools it has been found that the cable may engage the wall of the well on the upper side of the entrance to the deviated portion and form what is known in the art as a key seat. When this occurs, the tool becomes stuck when the tool encounters the lower end of the key seat as it is being withdrawn.

SUMMARY OF THE INVENTION

This invention provides improved apparatus for moving a wire-line operated tool through the deviated portion of a well bore. The apparatus is arranged for connection with the wire-line and for engagement with the well tool whereupon the ignition of a propellant charge contained within the apparatus exerts thrust on the tool to move the tool through the deviated portion of the bore.

In another aspect, this invention contemplates an improved method of moving a wire-line operated tool through a substantially horizontal bore including the steps of positioning the tool and thrusting means including the ignitable propellant charge on the wire-line in the bore; and, imparting a thrust to the tool by igniting the propellant charge to move the tool along the bore.

One object of the invention is to provide improved apparatus for moving wire-line operated tools through the deviated portion of a well bore.

Another object of the invention is to provide an improved method wherein wire-line operated tools may be moved through the deviated portion of a well bore.

A further object of the invention is to provide an improved apparatus including an ignitable propellant charge that can be used in the deviated portion of a well bore to move the wire-line operated tool therethrough upon ignition of the charge.

Still another object of the invention is to provide an improved apparatus for moving wire-line operated well tools through the deviated portion of a bore wherein the apparatus is subjected to the heat and pressure prevalent in such well bores.

The foregoing and additional objects and advantages of the invention will become more apparent as the following detailed description is read in conjunction with the accompanying drawings wherein like reference characters denote like parts in all views.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a vertical cross-sectional view illustrating a well bore having a deviated portion and illustrating, schematically, apparatus constructed in accordance with the invention disposed therein.

FIGURE 2 is an enlarged view of a segment of the deviated portion illustrating in more detail thrusting apparatus constructed in accordance with the invention disposed therein.

FIGURES 3A and 3B comprise an enlarged cross-sectional view taken through the thrusting apparatus illustrated in elevation in FIGURE 1 and 2.

FIGURE 4 is an enlarged, transverse cross-sectional view of the apparatus of FIGURES 3A and 3B taken substantially along the line 4—4 of FIGURE 3B.

FIGURE 5 is an enlarged cross-sectional view of a propellant charge assembly utilized in the thrusting apparatus of FIGURES 3A and 3B.

FIGURE 6 is a schematic diagram illustrating electrical wiring utilized in the thrusting apparatus.

FIGURE 7 is a view similar to FIGURES 3A and 3B, but illustrating another embodiment of thrusting apparatus also constructed in accordance with the invention.

FIGURE 8 is an enlarged cross-sectional view showing a modification of the thrusting apparatus of FIGURE 7.

FIGURE 9 is a transverse cross-sectional view taken along line 9—9 of FIGURE 8.

DESCRIPTION OF THE EMBODIMENT OF FIGURES 1—6

Referring to the drawings and to FIGURE 1 in particular, shown therein is a well bore 10 having an upper

vertical portion 12, a lower vertical portion 14, and a deviated portion 16 interconnecting the upper and lower portions 12 and 14. As illustrated, the deviated portion 16 extends at an angle of approximately 20° to the horizontal and it will be understood that the precise angle of deviation will vary from well to well. In any event, it is to be assumed that the logging tool 18 shown disposed in the deviated portion 16 will not move through the well bore 10 by gravitational force due to the angle of inclination thereof and the frictional engagement between the wall of the well bore 10 and logging tool 18.

The logging tool 18 is operably connected with thrusting apparatus generally designated by the reference character 20 and with a wire-line or cable 22 that extends to the surface. It will be understood that the wire-line 22 includes the necessary structural members to support the logging tool 18 and thrusting apparatus 20 in the well bore 10 and the necessary electrical conductors for actuating the logging tool 18 and apparatus 20 as will be described more fully hereinafter.

The wire-line 22 extends upwardly through the well bore 10 projecting from the upper end of the well bore 10 through conventional well head apparatus 24. The wire-line extends from the well head apparatus 24 to a cable drum or reel 26 located on the surface adjacent the well bore 10. Control and recording equipment 28 is connected with the reel 26 by a conductor 30 and the usual collector ring (not shown) is utilized to transmit electrical current from the wire-line 22 through the rotating reel 26 to the device 28. A conductor 32 connects the control and recording equipment 28 with a source of electrical potential (not shown). Manifestly, the equipment 28 contains the necessary switch gear and recording apparatus corresponding to the type of well tool to be operated.

As illustrated more clearly in FIGURE 2, the logging tool 18 is connected by a swivel 34 with the lower end of the thruster assembly 20. The swivel 34 permits the assembled tool 18 and apparatus 20 to more easily traverse the changes in direction of the well bore 10. The swivel 34 may be eliminated when the assembled apparatus is not long enough to interfere with its movement through the well bore 10.

The thrusting apparatus 20 includes an up thruster 36 having its lower end connected with the swivel 34 and its upper end connected with a down thruster 38. The upper end of the down thruster 38 is connected with an ignition control device 40. One type of suitable ignition control device 40 is described in more detail in U.S. Patent No. 3,221,655, issued to Alexis A. Venghiattis on Dec. 7, 1965.

The pertinent portion of the electrical circuits involved in the control 40, thruster assembly 20 and well logging tool 18 and their relationship to the wire-line 22 will be described more fully in connection with FIGURE 6.

It will be noted in FIGURE 2 that the down thruster 38 and the up thruster 36 are identical in construction though oppositely disposed in the thruster assembly 20. Identical charge assemblies 42 contained in the thrusters 38 and 36 are oriented in appropriate directions to exert thrust forces on the logging tool 18 in a downwardly direction and upwardly direction, respectively. Thus, it is possible and as will be described more fully hereinafter, to move the well logging tool 18 either downwardly or upwardly through the deviated portion 16 of the well bore 10 as desired.

FIGURES 3A and 3B illustrate in more detail the structure of the down thruster 38. It will be remembered that the up thruster 36 is identically constructed though oppositely disposed when located in the assembly 20. An appropriate connector (not shown) is utilized to connect the thrusters 36 and 38 to form the thrusting apparatus 20.

The down thruster 38 includes a body 44 including a tubular member 46 having openings 48 formed in one

side thereof; a top sub 50 threaded at 51 for connection with the ignition controller 40 and sized to extend into the tubular member 46; a pair of mounting and deflection blocks 52 located at spaced intervals in the tubular member 46 between the openings 48; and, a bottom sub 54 suitably arranged at 56 for connection with the connector (not shown), the up thruster 36, or the swivel 34, and is arranged for insertion into the opposite end of the tubular member 46. As clearly illustrated in FIGURES 3A and 3B, the openings 48 in the tubular member 46 and the spacing of the top sub 50, the mounting and deflection blocks 52 and the bottom sub 54 cooperate to form a plurality of cavities 58 in the body 44 for receiving the charge assemblies 42.

In addition to the threads 52, the top sub 50 includes a deflection surface 60 adjacent the cavity 58, a wiring passageway 62 having a counterbore 64 formed in the deflection surface 60 for receiving one end of a wiring tube 66. The top sub 50 also includes a wiring passageway 68 and a counterbore 70 formed in a passageway 68 adjacent the deflection face 60 for receiving one end of a wiring tube 72.

The wiring tube 66 extends into a counterbore 74 that forms a portion of a wiring passageway 76 extending through the mounting and deflection block 52 located adjacent the top sub 50. The mounting and deflection block 52 also includes a plurality of counterbores 78 sized to receive one end of each of the propellant charge assemblies 42. Connecting passageways 80 (only one is shown) extend from each of the counterbores 78 to the wiring passageway 76 to accommodate ignition wires 82 that form a portion of an ignition cable 84.

The opposite end of the wiring passageway 76 in the block 52 is counterbored as illustrated at 86 in a deflection surface 87 to receive one end of a wiring tube 88. An opening 90 extends through the mounting and deflection member 52 and the wiring tube 72 is extended there-through.

As can be seen in FIGURES 3A and 3B, the mounting and deflection blocks 52 are identical in construction. The counterbore 86 in the mounting and deflection block 52 shown in FIGURE 3B receives one end of a wiring tube 92 that has its opposite end disposed in a counterbore 94 formed in the bottom sub 54. The counterbore 94 forms a portion of a wiring passageway 96 that extends through the bottom sub 54 to accommodate the ignition cable 84.

The bottom sub 54 is also provided with a plurality of counterbores 98 that are sized to receive one end of a plurality of the propellant charge assemblies 42. Ignition passageways 100 (only one is shown) extend from the counterbores 98 into communication with the ignition passageway 96 to accommodate ignition wires 82 that are connected with the propellant charge assemblies 42.

An ignition passageway 102 extends through the bottom sub 54 in spaced relation to the ignition passageway 96 and includes a counterbore 104 that is sized to receive the opposite end of the wiring tube 72.

As clearly shown in the drawings, the wiring tubes 66, 88, 92, and 72 are each provided with appropriate seals to prevent the entrance of well fluids into the various wiring passageways. It will also be noted that the wiring tube 72 extends entirely through the down thruster 38 and thus provides a continuous conduit for a logging cable 106 that forms a portion of the wire-line 22 when the apparatus is used with the logging tool 18. Manifestly, other electrical conductors may be extended through the wiring tube 72 in lieu of the cable 106 when the thrusters 36 and 38 are used in conjunction with other types of wire-line operated well tools such as a perforator, caliper, or the like.

As illustrated in FIGURE 4, the mounting and deflection blocks 52 are retained in the tubular member 46 by a plurality of set screws 108. If desired, the blocks 52 can be retained therein by welding or in any other suitable manner. It should also be pointed out that the top sub 50

and the bottom sub 54 may also be retained in assembled relationship with the tubular member 46 by a plurality of the threaded fasteners 108 or in any suitable manner.

FIGURE 4 also illustrates the geometric arrangement and the method of retaining the propellant charge assemblies 42 in the down thruster 38. As shown therein, a wedge shaped holding member 110 extends between adjacent propellant charge assemblies 42 and into annular recesses 112 (see also FIG. 5) formed in the exterior thereof.

A threaded fastener 114 extends through a slot 116 formed in each of the wedge shaped members 110 to hold the wedge shaped members 110 assembled on the blocks 52 and to permit their movement into and out of the recesses 112. A threaded fastener 118 is provided to hold each of the wedge shaped members 110 in the annular grooves 112 thus retaining the propellant charge assemblies 42 in their respective cavities 58. It should also be pointed out that an identical structural arrangement (not shown) is utilized to retain the propellant charge assemblies 42 in the bottom sub 54.

FIGURE 5 illustrates in detail the structure of each propellant charge assembly 42. As shown therein, each charge assembly 42 includes a tubular case 120 having the annular recess 112 encircling one end thereof. Threadedly connected with the end of the case 120 adjacent the recess 112 is a head 122 having a passageway 124 of varying diameters extending therethrough.

The head 122 has an outside diameter sized to fit within the counterbores 78 and 98 in the mounting and deflection blocks 52 and the bottom sub 54, respectively, as illustrated in FIGURES 3A and 3B. O-ring seals 126 are carried by the head 122 to prevent well fluids from entering the various passageways in the thrusters 36 and 38. An O-ring seal 128 is disposed in sealing engagement with the head 122 and the case 120 to prevent the entrance of well fluids into the interior of the case 120.

Threadedly connected with the opposite end of the case 120 is a nozzle 130 having a venturi-like passageway 132 extending therethrough. A counterbore 134 is formed in the outer end of the passageway 132 and is arranged to receive a nozzle seal 136 that functions to prevent the entrance of well fluids into the charge assembly 42 and also to permit a pressure rise in the charge assembly 42 after ignition. An O-ring seal 138 is carried by the nozzle 130 and is disposed in sealing engagement with the nozzle 130 and with the case 120 to prevent the flow of well fluids by the threaded connection between the nozzle 130 and case 120.

An ignitable propellant charge 140 is located within the case 120 between the nozzle 130 and the head 122. The charge 140 is encased in a sleeve 142 and includes a booster or ignition charge 144 located adjacent the nozzle 130 that functions in conjunction with a resistance wire 146 to ignite the propellant charge 140.

The ignitable propellant charges 140 must be operable under the heat and pressure conditions existing in the well bore 10, that is, they must function to produce thrust even though the well bore 10 is filled or partially filled with water, oil, or drilling mud. The ignition charge 144 may suitably consist of the same composition more loosely packed so that it can be more easily ignited. A suitable charge composition consists of the following:

Parts by weight	
Methyl methacrylate	10.0
Ammonium perchlorate	12.5
Nitroglycerine	3.42
Nitrocellulose	5.16
Castor oil	11.0

A conductor 148 extends from the resistance wire 146 to a conductor cap 150. The cap 150 is in engagement with an electrical contact 152 that extends partially through the passageway 124 in the head 122. Washers 154 and 156 and O-rings 158 and 160 insulate the contact 152

from the head 122 and also serve as a pressure seal to prevent the propellant gasses from escaping through the passageway 124.

It will be noted in FIGURE 5 that the ignition wire 82 is attached to the opposite end of the contact 152. The opposite end of the resistance wire 146 is electrically connected by a short conductor 162 as illustrated at 164 so that the resistance element 146 is grounded to the case 120.

The schematic diagram of FIGURE 6 illustrates more clearly the electrical circuitry involved in the apparatus. As shown therein, the logging tool 18, thrusting apparatus 20 and ignition controller 40 are illustrated by dash lines in block form.

The controller 40 includes a plurality of contacts C-1, C-2, C-3, C-4 . . . C-N. The contacts are electrically interconnected with the various ignition wires 82 making up the ignition cable 84 (see FIGS. 3A and 3B). The contacts are arranged to be engaged selectively by a switch 166 located in the ignition controller 40. The switch is electrically interconnected with a solenoid coil 168 that positions the switch 166 to engage the desired contact C-1, C-2, etc. to provide electrical potential for ignition of the charges 140.

The coil 168 is connected with a conductor 170 that extends through the wire-line 22 and the conductor 30 to the control and recording equipment 28 wherein it is interconnected with appropriate control switches (not shown). The opposite end of the coil 168 is grounded through the conductor 172.

It can be seen in FIGURE 6 that the ignition wires 82 extend to the propellant charge assemblies 42 wherein they are connected with the conductors 148 and the resistance elements 146 which are in turn grounded to the charge assemblies 42 by the short conductors 162. Thus, the circuit through any given resistance element 146 will be completed when the switch 166 is in engagement with the contact interconnected with the respective resistance element 146.

OPERATION

To utilize the thrusting apparatus 20, the ignition control device 40 is connected with the wire-line 22 and with the down thruster 38. The up thruster 36 is connected to the down thruster 38 and with the swivel 34. The swivel 34 is, in turn, connected with the logging tool 18, as illustrated in FIGURE 2. Appropriate electrical interconnections are made as previously described in connection with FIGURES 3A, 3B and FIG. 6.

After the logging tool 18, thrusting apparatus 20, and the ignition control device 40 are connected to the wire-line 22, they are positioned in the vertical upper portion 12 of the well bore 10 by passing them through the well head apparatus 24. The assembled apparatus is then lowered through the vertical upper portion 12 of the well bore 10 until the downward movement thereof is arrested by frictional engagement between the apparatus and the wall of the deviated portion 16.

When this occurs, the ignition control device 40 is actuated through appropriate switches (not shown) located in the control and recording device 28 to bring the switch 166 (see FIG. 6) into engagement with a selected contact C₁, C₂ . . . or C_N therein. The engagement of the switch 166 with one of the contacts heats the resistance wire 146 in a respective charge assembly 42, igniting the ignition charge 144 and, ultimately, the propellant charge 140 therein.

The ignition of the propellant charge 140 creates gas in the propellant charge assembly 42. The gas pressure increases until it is of sufficient magnitude to blow the seal 136 out of the nozzle 130. When this occurs, the gases are expelled through the venturi-like passageway 132 in the nozzle 130, creating a thrust on the down thruster 38 and exerting a force on the logging tool 18, thereby moving the logging tool 18 along the deviated portion 16 of the well bore 10. Manifestly, if the thrust developed by a single propellant charge assembly 42 is not sufficient to move the

logging tool 18, additional charge assemblies 42 are ignited to provide additional thrust whereby the logging tool 18 is moved.

As the logging tool 18 traverses the well bore 10, it may be actuated through the control and recording device 28 to log any desired portion of the well bore 10. The well bore 10 may be logged simultaneously with the firing of the charge assemblies 42 in the down thruster 38 if desired.

After the logging tool 18 and thrusting apparatus 20 have traversed the deviated portion 16 of the well bore 10, gravitational forces may again be utilized to lower the logging tool 18 through the vertical lower portion 14 of the well bore 10 as desired.

When it is desired to remove the logging tool 18 from the well bore 10, the direction of rotation of the reel 26 is reversed so that an upward pull is exerted thereon through the wire-line 22. Upon reaching the deviated portion 16 of the well bore 10, it may again be necessary to exert additional thrust on the logging tool 18 so that it may be easily retrieved from the well bore 10. Generally, no upwardly directed thrust is necessary to move the logging tool 18 in the upward direction through the deviated portion 16 of the well bore 10.

However, the wire-line 22 may in some instances engage the wall of the well bore 10 at the junction between the upper vertical portion 12 and the deviated portion 16 and cut thereinto forming what is commonly referred to as a "key seat." When this occurs, and as the logging tool 18 is moved relatively upwardly in the deviated portion 16, the upper end of the ignition control device 40 may engage the wall of the well bore 10 at the lower end of the "key seat" portion and bind the apparatus therein preventing further upward movement.

When this occurs, the ignition control device 40 is actuated through the control and recording device 28 to ignite the appropriate charge assembly 42 located in the up thruster 36. Thus, a force is imposed on the logging tool 18 moving it along the deviated portion 16 of the well bore 10 relatively toward the upper portion 12 thereof.

As the logging tool 18 and thrusting apparatus 20 move along the deviated portion 16 of the well bore 10, the wire-line 22 moves relatively out of the "key seat" and back into the vertical portion 12 of the well bore 10. Manifestly, the apparatus is then free to be retrieved from the well bore 10 by rotation of the reel 26.

It can be appreciated from the foregoing detailed description of the thrusting apparatus 20 that the appropriate number of propellant charge assemblies 42 can be fired in a very fast sequence to provide the necessary thrust to move the logging tool 18 through the deviated portion 16 of the well bore 10. Also, it can be appreciated that the expendable propellant charge assemblies 42 can be quickly and easily removed and replaced in the thrusters 36 and 38 after the apparatus has been retrieved from the well bore 10.

DESCRIPTION OF THE EMBODIMENT OF FIGURE 7

The partial sectional view of FIGURE 7 illustrates a modified form of the down thruster 38. All parts of the thruster 38 will be designated by the same reference characters previously used unless the part has been modified.

As shown in FIGURE 7, one of the deflection blocks 52 located between charge assemblies 42a has been replaced by an eductor 200. The eductor 200 is mounted in the body 44 of the thruster 38, as was the deflection block 52. Also, the wiring tubes 88, 92, and 72 are received in the eductor 200 as they were in the block 52.

The eductor 200 is provided with a plurality of venturi-like passageways 202. Each passageway 202 is aligned with one of the charge assemblies 42a carried by the thruster 38.

The end of the eductor 200 nearest the charge assemblies 42a is positioned with each passageway 202 in en-

circling relationship to the end of a respective nozzle 130a with the venturi-like passageway 132a in the nozzle 130a in alignment with the passageway 202. The precise spacing between the nozzle 130a and eductor 200 is dependent on the type of fluid in the well bore, that is, variations in the viscosity and density of the fluid will affect the thrust producing efficiency of the nozzle-eductor arrangement and, thus, the spacing.

In operation, the charge 140 is ignited as previously described. The gas produced by the burning charge passes through the passageway 132a in the nozzle 130a and through the passageway 202 in the eductor 200. Well fluid is induced into the high velocity gas stream through the space between the eductor 200 and the nozzle 130a, mixing with the gas and creating an increased reaction thrust on the thruster 38. The thrust increase is believed to be the result of the increase of the mass of the gas stream as the well fluids and gas mix in the eductor passageway 202.

In addition to the thrust increase, the additional distance (as compared to FIGURE 3A) between the nozzle 130a and the deflection surface 87 on the next adjacent block 52 results in a decrease in the vector component of the thrust tending to force the thrusting apparatus 20 into engagement with the wall of the well bore. It would be necessary to increase the overall length of the thrusting apparatus 20 to provide the same number of charge assemblies 42a, but the additional length is more than justified by the gain in thrust and decrease in friction.

DESCRIPTION OF THE EMBODIMENT OF FIGURES 8 AND 9

The enlarged, partial cross-sectional view of FIGURES 8 and 9 illustrate still another modification of the thrusting apparatus. Again, the same reference characters will be used to designate the same and unmodified components that have been previously described.

As shown in FIGURES 8 and 9, a modified charge assembly 42b is threadedly connected with a nozzle 130b. The nozzle 130b has a venturi-like passageway 132b extending therethrough.

Threadedly connected with the nozzle 130b is an eductor 220. The eductor 220 has a passageway 222 of varying diameter extending therethrough in alignment with the passageway 132b in the nozzle 130b.

A plurality of ports 224 extend transversely through the eductor 220 into communication with the passageway 222. The ports 224 are located between the connection of the eductor 220 with the nozzle 130b and the end of the nozzle 130b.

It will be understood that the modified charge assemblies 42b can be utilized in the thruster 38 or 36 in lieu of the charge assemblies 42 and 42a. However, alternate deflection blocks 52 will be omitted when the assemblies 42b replace charge assemblies 42 and the eductors 200 will be omitted when the assemblies 42b replace charge assemblies 42a.

In operation, ignition of the charge assemblies 42b produces a high velocity gas stream through passageways 132b and 222. As the gas flows therethrough, well fluid is induced through the ports 224 and mixing of the gas and well fluid occurs in the passageway 222. As previously mentioned, the increase in mass of the flowing stream causes an increase in reactive thrust on the thrusting apparatus 20. Since the charge assemblies 42b are spaced a considerable distance from the deflection blocks 52, the vector component of the thrust tending to force the apparatus into engagement with the wall of the well bore is also decreased.

Thus, the embodiment of FIGURES 8 and 9 will have the same operational advantages as the embodiment of FIGURE 7. Also, the embodiment of FIGURES 8 and 9 can be more easily manufactured and maintained due

to the unitary construction of the charge assembly-nozzle-educator arrangement.

Thus, there is provided improved apparatus capable of moving wire-line operated tools through a well bore having a deviated portion approaching the horizontal. Also, there is provided a method whereby wire-line operated tools, which normally depend upon gravitational forces for movement through the well bore, can be moved through a well bore having a substantially horizontal deviated portion.

It will be understood that the embodiments described in detail hereinbefore are presented by way of example only and that many changes and modifications can be made thereto without departing from the spirit of the invention or from the scope of the annexed claims.

The embodiment of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Apparatus for moving a wire-line operated well tool through a deviated portion of a well bore, said apparatus being connectable with the wire-line and engageable with the well tool and including:

a first ignitable propellant charge for exerting a thrust on said apparatus and well tool when ignited to move said tool in one direction through the deviated portion of the well bore;

a second ignitable propellant charge for exerting a thrust on said apparatus in well tool when ignited to move said tool in the relatively opposite direction through the deviated portion of the well bore;

a body member connectable with said wire-line and engageable with said well tool and having a cavity therein for receiving each of said charges;

mounting means holding said charges in said cavities and orienting said charges to produce thrust, when ignited, to move said tool along said well bore; and ignition control means operably connected with said wire-line and each of said charges, whereby said charges are selectively ignitable.

2. Apparatus for moving a wire-line operated well tool through a deviated portion of a well bore, said apparatus being connectable with the wire-line and engageable with the well tool and including:

an ignitable propellant charge for exerting a thrust on said apparatus and well tool when ignited to move said tool through the deviated portion of the well bore;

a body member connectable with said wire-line and engageable with said well tool and having a cavity therein for receiving said charge;

mounting means holding said charge in said cavity and orienting said charge to produce thrust, when ignited, to move said tool along said well bore; and

a case containing said propellant charge, said case having a first end retained by said mounting means and

an exit end having a venturi-like passageway extending therethrough.

3. The apparatus of claim 2 and also including educator means located adjacent an exit end of said case to increase the thrust produced upon ignition of said propellant charge.

4. The apparatus of claim 3 wherein said educator means includes a tubular member having one end connected with said case adjacent the exit end thereof, said tubular member having a passageway aligned with said venturi-like passageway and having at least one port extending transversely therethrough and located between the exit end of said case and the connection of said tubular member therewith.

5. The apparatus of claim 3 wherein said educator means includes an educator member mounted on said body, said educator member having a venturi-like passageway extending therethrough aligned with the venturi-like passageway in said case and having one end of said educator member disposed adjacent the exit end of said case.

6. A method of moving a wire-line operated well tool through a well bore having a deviated portion, the method including the steps of:

suspending the tool and thrusting means including an ignitable propellant charge on the wire-line in the well bore;

lowering the tool and thrusting means on the wire-line by gravitational force until the tool encounters the deviated portion of the well bore terminating the downward movement thereof;

imparting a thrust on the tool by igniting the charge whereby said tool is moved along the deviated portion of the well bore relatively toward the lower end thereof;

raising the tool by means of the wire-line until the tool is disposed in the deviated portion of the well bore; imparting a moving force on the tool by igniting a second propellant charge in said thrusting means, whereby said tool is moved along the deviated portion of the well bore relatively toward the upper end thereof; and

raising the tool by means of the wire-line to the surface adjacent the well bore.

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