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DRILL STEM TESTING APPARATUS

Filed June 21, 1965

Fig. 2

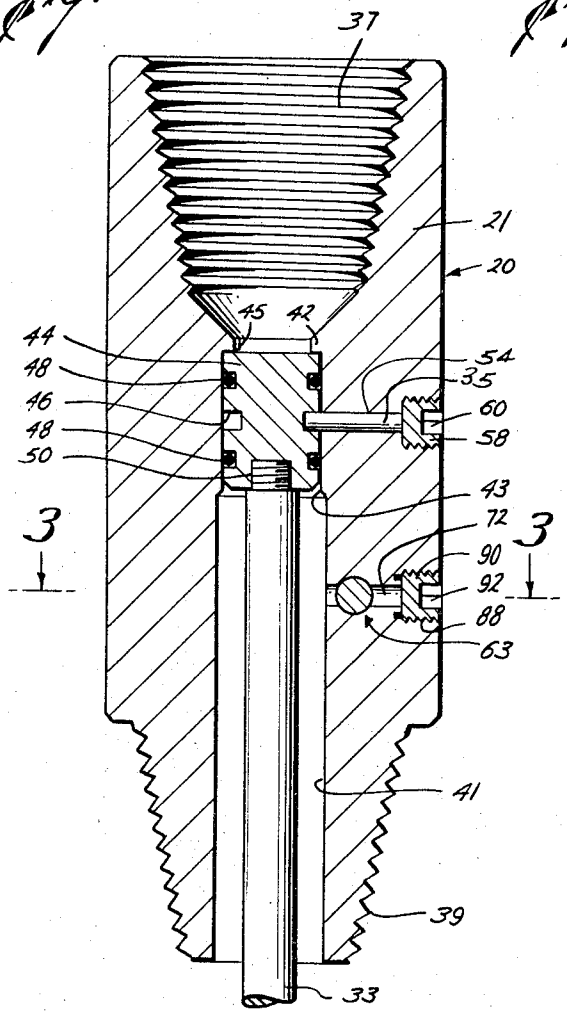


Fig. 1

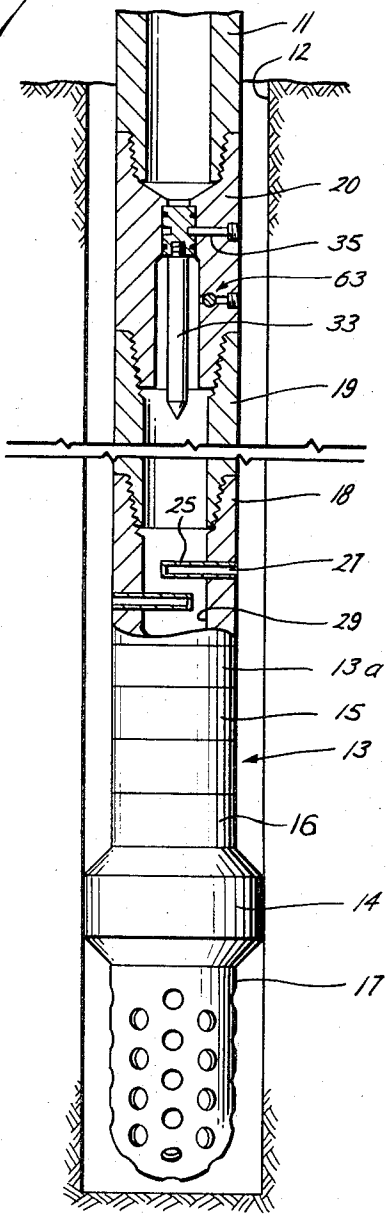
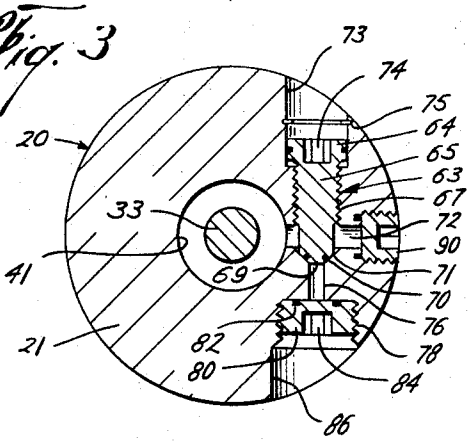


Fig. 3



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DRILL STEM TESTING APPARATUS

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ABSTRACT OF THE DISCLOSURE

The particular embodiment described herein as illustrative of one form of the invention utilizes, in a drill stem testing apparatus, a drill stem test valve for suspension in a well bore on a string of pipe. Sections of pipe above the test valve form a chamber which is closed at its upper end by a valved sub having an external control portion and positioned, during testing, below the upper end of the well bore. A reversing port is positioned in the lower end of the chamber above the test valve. A drop bar is held within the sub at the upper end of the chamber and is selectively releasable by means of an exterior control on the sub.

This invention relates to formation testing and, more particularly, to methods and apparatus for obtaining recovery of fluid samples from a well bore.

During the drilling of a well, the operator may at some time desire to test a section of the well for production potential. To do this, a testing tool having a normally closed tester valve and a packer means is inserted into the well at the lower end of a string of pipe or tubing. The packer means is disposed at a location just above the section to be tested and expanded to close off the bore of the well. Thus, the section for test is isolated from the drilling control fluid which is usually mud. The testing tool includes a pressure recorder which measures the initial pressure of the isolated section to obtain what is referred to as an initial shut-in pressure. The tester valve is then opened and formation fluids flow into the string of tubing. The flow may appear at the surface if the pressures are great enough. Pressure is recorded during the flow period. The tester valve is then closed and a final shut-in pressure recorded.

When the string of tubing is brought to the surface and sections of tubing and tools are removed from the string of tubing, the formation fluids in the tubing are exposed at the surface or floor of the drilling platform. Such exposure of formation fluids may be undesirable under certain circumstances for reasons of safety or secrecy.

Sometimes, during the testing operation, the tools become stuck in the well bore. A safety joint is normally provided in such tool strings to permit removal of the pipe above the stuck portion. However, it is often necessary to lower a free point indicator and then an explosive string shot through the bore of the pipe to loosen the threads in a drill collar, in event that the pipe is stuck above the safety joint, and thereby uncouple the string of tools at that point. In the event that the use of a free point indicator and string shot is warranted, the pipe and tools must have a bore therethrough to receive these devices which are lowered into the pipe by means of a cable.

Further, due to the extended periods of time sometimes required to operate a safety joint or loosen a drill collar, the drilling mud in the well bore must be circulated to prevent the drilling mud from setting up. such circulation also will prevent any gas which may be entering the well bore from aerating the column of mud. By continuously circulating the mud to the surface, the gas is permitted to escape from the mud and thereby maintain the mud density at a safe value. The circulation of mud in the well bore will also prevent further sticking of the pipe or tubing above the initial stuck point. Additionally, oil is sometimes spotted about the stuck point to free the pipe from the wall of the well bore.

It has often been undesirable heretofore to test wells at night since it is necessary to keep electrical equipment running in order to provide light. The presence of such electrical power at the well head may present a hazard if flammable formation fluids and gases are exposed at the surface during testing operations.

The present invention is directed to methods and control apparatus for use during the testing operation to prevent uncontrolled flow of formation fluids at the surface. The formation fluids are contained in the tool string to prevent uncontrolled escape at the earth's surface and may be transferred to closed containers or covered pits so that the results of the test are confidential. The apparatus is constructed to provide for the lowering of a free point indicator, string shot, or other device into the tools and to permit circulation of drilling mud in the well bore in the event the tools become stuck in the well bore.

Accordingly, it is an object of the present invention to provide new and improved methods and apparatus for conducting drill stem tests.

Another object of the present invention is to provide a new and improved method and apparatus for conducting drill stem tests wherein the results of the test are confined within a closed chamber and removed therefrom into convenient receptacles at the earth's surface.

Still another object of the present invention is to provide a new and improved method and apparatus for conducting a closed chamber drill stem test which permits the use of a free point indicator and string shot to loosen joints in the apparatus and also permits circulation of drilling mud in the well bore while the drill stem test apparatus is in the well bore.

Therefore, in accordance with the present invention, in a drill stem test, the fluid recovery is limited to a given portion of the drill pipe forming a closed chamber and is transferred into a closed system at the earth's surface. The fluid recovery enters the closed chamber through a test valve in the string of tools. Means are provided at the upper end of the chamber to contain the fluids therein. After sufficient fluid sample has been taken, the test valve is closed. Selectively operable means are provided for reversing the fluids out of the chamber into a convenient receptacle either before or after the string of tools is retrieved to the surface. The means for closing off the chamber is provided with a plug which may be selectively removed when the tool is in the well bore to provide an open bore through the string of tools for reception of apparatus lowered on a cable.

The novel features of the present invention are set forth with particularity in the appended claims. The pres-

ent invention, both as to its organization and manner of operation together with further objects and advantages thereof, may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a string of tools in a well bore for practicing the present invention;

FIG. 2 illustrates a view in cross section of apparatus embodying the present invention; and

FIG. 3 is a view taken along line 3—3 of FIG. 2.

FIGURE 1 illustrates apparatus embodying the invention where a drill or tubing string **11** is lowered from the surface of the earth into a well bore **12**. At the lower end of the drill string **11** is a conventional testing tool string **13** such as the type illustrated and described in U.S. Patent No. 2,901,001. The usual drill stem testing tool string **13** includes a tester tool **13***a* having a flow tube with a normally closed valve (not shown) and a packer element **14**. The packer element **14**, when actuated as shown, expands into sealing engagement with the borehole wall. After the tester valve is opened, fluid flows from below the packer **14** through its flow tube and into the tubing string. Pressure recorders (not shown) in the tool string **13** measure and record pressures. A bypass valve **15** is positioned in the tool string below the tester to permit well fluid to bypass the packer when the tool string is being lowered into the well bore. A safety joint **16** is positioned in the tool string above the packer to permit removal of the string of pipe above the packer should the packer or perforated anchor **17** become stuck in the well bore. As shown in FIG. 1, the perforated anchor **17** is positioned on the lower end of the string of tools for admitting well fluid to the flow tube and for engaging the bottom of the well bore to expand the packer in a conventional manner.

It will be appreciated that hook-wall packers (not shown), which can be set without a bottom hole anchor, could be employed rather than the type described.

In the present invention, a reversing sub **18** couples the lower end of a section of drill pipe **19** to the tester tool string **13**. An isolation sub **20** is coupled to the upper end of pipe section **19**. The portion of pipe **19** will normally be comprised of several sections of pipe to form a closed chamber of any desired length for receiving a formation fluid sample. It has been found that about 1000 feet of pipe provides a sufficient chamber for testing most wells.

The reverse circulation valve sub **18** is provided with hollow knock-out plugs **25** which seal off ports **27** in the outer wall of the sub. Plugs **25** are constructed so that a weighted member dropped thereon will break the plugs and open an interior bore **29** of the sub to fluid communication with the well bore through ports **27**.

The isolation sub **20** releasably supports a bar **33** by means of a retainer pin **35** which pin is operable from the exterior of the sub **20** to release the bar **33**. Release of the bar **33** permits the bar to drop to the lower end of the chamber **19** and into bore **29** in sub **18** to break the plugs **25** thus opening ports **27**. A bar stop (not shown) is provided below the knock-out plugs **25** to stop the falling bar **33**.

FIGURE 2 is a detailed view of the isolation sub **20**. This sub includes a housing **21** having threaded box and pin ends **37** and **39** for connection in a string of tubing. A bore **41** extending longitudinally through the sub forms a flow passage. An inwardly extending shoulder **42** is formed in the bore **41** at the upper end thereof to form a restriction in the bore. An intermediate shoulder portion **43** forms a lesser restriction in the bore below shoulder **42**.

A cylindrical knock-out plug **44** is positioned within the intermediate portion **43** of bore **41** with the upper surface **45** of the plug abutting the shoulder **42**. The plug **44** is sized for close fitting but sliding reception within the intermediate shoulder portion **43**. An annular recess **46** is

formed in the outer peripheral surface of the plug midway between its top and bottom. O-ring seals **48** are positioned in annular grooves above and below the recess **46**. The lower end of the plug has a threaded recessed portion **50** for receiving the upper threaded end of the weighted drop bar or dart **33**. A transverse bore **54** is formed through the wall of sub housing **21**. An enlarged portion is formed in the outer end of bore **54** and is threaded. The drop bar retainer pin **35** is positioned in the bore **54** with one end of the pin extending into the recess **46** in plug **44**. A threaded end portion **58** on the pin is received in the threaded portion of bore **54**. The end portion **58** is provided with a recess **60** to accommodate a wrench or tool to rotate the threaded pin for withdrawal from the recess **46** in plug **44**.

A valve assembly **63** in sub **20** is best shown by referring to FIG. 3. The valve **63**, shown in a closed position, has a body portion **65** threadedly received in a valve bore **67** and has a tapered end portion **69** provided with an O-ring **70**. When the valve body **65** is rotated in one direction, the tapered end portion **69** seats in a valve seat **71** to block or close off a transverse fluid passageway **72** which extends through the wall of housing **21**. The passageway **72** provides for fluid communication between exterior port **86** of the sub **20** and the flow passage **41**. Rotation of the valve body **65** is accomplished by means of a wrench or the like applied to a wrench access **74** in the body **65** through a bore **73** opening to the exterior of the housing. Thus, the valve has a control portion exposed to the exterior of the sub. An enlarged body portion **64** of the valve **63** is provided with an O-ring to form a fluid tight seal with the bore **73**. A snap ring **75** is received in a snap ring groove to maintain the valve body in the bore **73**.

A passageway **76** connects with the seat end **71** of the valve bore **67**. An enlarged threaded portion **78** is provided at the end of the passageway to receive a threaded access plug **80**. An O ring seal **82** is provided on the plug to seal the end of the passageway. A wrench access **84** is formed on one end of the plug to facilitate its removal from the threaded end portion of the passageway **76**. The wrench is inserted into the access through the port or bore **86** opening to the exterior of the sub housing **21**. When the access plug **80** is removed, the threaded portion **78** provide a means for connecting a flow line to the valved sub.

The passageway **72**, which opens to the flow passage **41**, is formed in the housing by boring from the outside of the housing **21**. A threaded end portion **88** of the passageway **72** opening to the exterior of the sub housing receives a threaded plug **90** with seal means to close off the passageway to the exterior of the sub. Wrench access means **92** are formed in the plug to provide for insertion and removal of the plug.

In operation, the test tool string **13** is lowered into the well bore at the end of a string of tubing or pipe **11**, the test valve **13***a* of the tool string being closed. Above the tool string **13** is pipe section **19** with isolation sub **20** secured to its upper end. Valve **63** in isolation sub **20** is positioned to close off passageway **72** and thereby isolate the upper end of chamber **19**.

At the level in the well bore where the test is desired, the packer is actuated into sealing engagement with the well bore and the test valve **13***a* of tool string **13** is opened permitting formation fluids from formations isolated below the packer to flow into the perforated anchor and thence into the pipe section or chamber **19**. It is readily seen that any amount of pipe may be included within this section defining chamber **19**, the amount depending upon the duration of the formation test. It may be desirable to take several shut-in tests on the formation with intermediate flow periods. At the end of the flow period, the test valve of the tool string **13** is closed, thus closing off the lower end of the pipe section **19** leaving a sample of fluid trapped in the section **19**.

When the test is completed, the packer **14** is disengaged from the well bore and the string of tools is retrieved to the surface. When sub **20** appears at the rotary table at the surface, the retrieval of the tool string from the well is temporarily halted. The plug **80** is removed from passageway **76** on the sub **20** and a gauge (not shown) is connected to the threaded end **78** of the passageway. The valve **63** is moved by rotation of valve body **65** to open the other end of passageway **76** into communication with flow passage **41** thereby placing the gauge in communication with the closed chamber **19**. After measuring the pressure of chamber **19**, the valve **63** is closed, the gauge removed, and a flow line is connected to the threaded end **78** of passageway **76**. The valve **63** is again opened to permit the pressure in chamber **19** to be bled off into a closed receptacle connected to the opposite end of the flow line.

The valve **63** is again closed and a transfer head or flow line (not shown) is connected to the upper box end of the sub **20**. The drop bar **33** is then released by rotating the retainer pin **35** which withdraws the end of the pin from the recess **46** in the plug **44**. The bar **33** drops through the fluid sample in chamber **19** and shears the plugs **25** to open ports **27** in the reversing sub **18**. Blowout preventers at the well head (not shown) are then closed and pump pressure is applied to the well fluid or drilling mud in the well bore annulus. This pumps the well fluid into ports **27** and thereby forces the formation fluid sample out of chamber **19** through the now open bore **41** in sub **20** into the flow line attached to the sub and from there into a closed receptacle or pit (not shown) which is disposed a safe distance from the upper end of the well. Pumping is continued until the fluid sample has been reversed out. Pumping is then ceased and the flow line disconnected. Upon further retrieval of the tools from the well bore, well fluid and any trace of formation fluid in the pipe will drain out through ports **27** into the annular space in the well.

In testing shallow wells, it may be desirable to use the full length of pipe above the test tools as the sample chamber. In this event, the upper end of the pipe is closed off by means of control valves, etc. at the surface. After the formation test, the test valve is closed. Pressure is bled from the pipe through the surface control valves into a closed receptacle connected to the control valves. A drop bar is then released from the surface to open the break valves in the reversing sub. Pressure is then applied to the well fluid to reverse the formation sample out of the pipe through the surface control valves and into the closed receptacle. The string of pipe and tools are retrieved to the surface and any well fluid or formation fluid in the pipe will drain back into the well bore through the reversing ports **27**.

During the above described operations, the formation fluid sample has remained in a closed system to prevent the disclosure of its contents and to prevent the exposure of flammable hydrocarbon fluids on the derrick floor.

In the event the tool string should become stuck in the well, and cannot be jarred loose, the safety joint **16** is backed off to permit retrieval of the tools positioned above the safety joint. The remaining part of the tool string is then fished or drilled out. A further safety feature is embodied in the tool should it be necessary to lower a free point indicator, string shot, or other apparatus into the pipe to loosen the threaded connection of a pipe collar and thereby free the tubing string above the collar.

In order to open the bore of sub **20** to permit a device to be lowered therethrough, the plug **44** is displaced from its position in bore **41**. This may be accomplished by dropping a bar from the surface. Alternatively, the drill stem or tubing above chamber **19** is filled with a fluid. The pressure of the fluid expels the plug **44** and attached dart from the intermediate bore **43** of the sub **20**. If the hydrostatic pressure of the fluid itself is insufficient to displace the plug, pressure may be applied to the fluid column to remove the plug. When sufficient pressure is applied to the top of plug **44** by whatever means, the retainer pin **35** is sheared to permit the plug to drop from the bore **41** in sub **20**. The bar **33** then drops through the fluid sample to break the plugs **25** and open ports **27** in reversing sub **18**. Pressure is then applied to the well fluid in the well bore annular space to pump the fluid into the ports **27** and thereby reverses the formation fluid sample out of chamber **19** while at the same time restoring circulation to the drilling fluid in the well bore. The opening left in the sub **20** by removal of the plug and drop bar is sufficient to pass the free point indicator and string shot.

It will be appreciated from the description above that drill stem testing by this method will minimize any hazard of fire when testing with electrical power equipment operating on the derrick floor such as is necessary at night. Furthermore, by controlling the exposure of formation fluids at the well site, it is possible to maintain the results of the test confidential.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. Drill stem testing apparatus for use in a well bore including a sample-receiving chamber formed by a string of pipe, a lower valve selectively operable in response to manipulation of the string of pipe in a well bore, an upper valve in said string of pipe below the upper end of the well bore, said upper valve being selectively operable in response to external control means, and an intermediate valve located just above said lower valve and selectively operable in response to means within said string of pipe.

2. Drill stem testing apparatus for use in a well bore including a sample-receiving chamber formed by a string of pipe, a lower valve selectively operable in response to manipulation of the string of pipe in a well bore, an upper valve selectively operable in response to external control means, an intermediate valve located just above said lower valve, said intermediate valve including a frangible closure sealingly received in a port in said string of pipe, and a weighted member in said string of pipe adapted upon release to open said port.

3. Drill stem testing apparatus comprising: tester means including a selectively operated tester valve and packer means for sealing off a section of a well bore, pipe means forming a chamber above said tester valve, selectively operable reversing port means positioned between said tester valve and said chamber, and a sub located intermediate said chamber and the top of the well bore, said sub including a selectively operable valve means for opening and closing the upper end of said chamber, said sub also including a selectively releasable drop bar for operating said reversing port.

4. Drill stem testing apparatus for use in a well bore including a selectively operable valve adapted for coupling to a string of pipe and packer means for sealing off a section of a well bore, means in said string of pipe defining a closed chamber in communication with said valve, break valve means positioned above said valve, and a sub at the upper end of said chamber including a selectively operable valve means for opening and closing the upper end of said chamber, said sub also including a selectively releasable drop bar for operating said break valve means.

5. Drill stem testing apparatus for use in a well bore including a selectively operable valve adapted for coupling to a string of pipe and packer means for sealing off

a section of a well bore, means in said string of pipe defining a closed chamber in communication with said valve, break valve means positioned above said valve, a sub at the upper end of said chamber including a selectively operable valve means for opening and closing the upper end of said chamber, said sub also including a selectively releasable drop bar for operating said break valve means, external control means for opening and closing said valve means and for releasing said drop bar, said sub defining a bore connecting said chamber with the string of pipe above said sub, and a plug releasably positioned in and closing off said bore.

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