Nov. 7, 1967 L. I. JENSEN 3,351,135

DRILL STEM TESTING APPARATUS

Filed June 21, 1965

Fig. 1

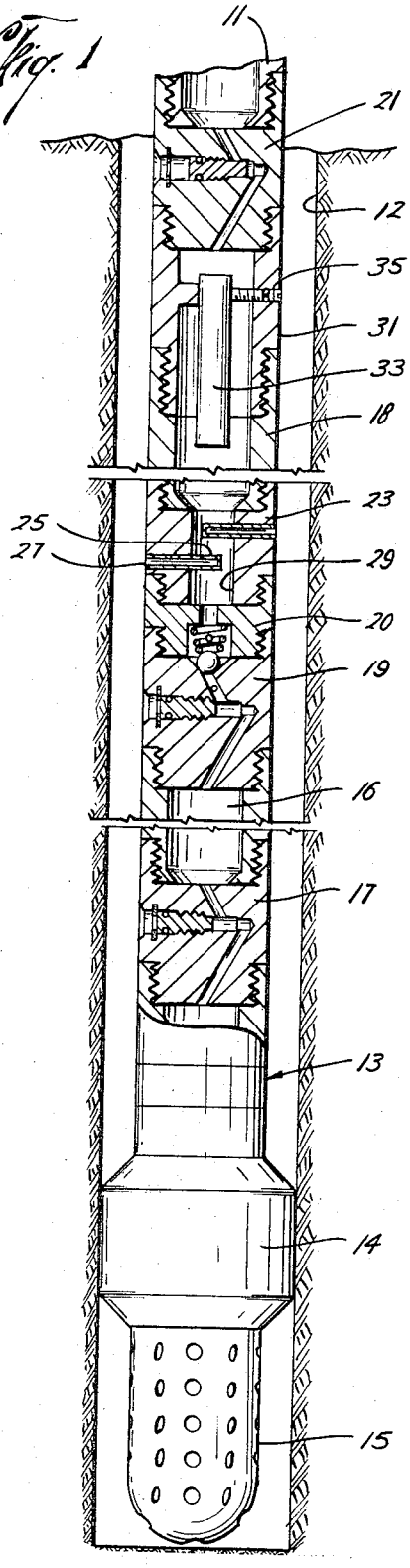


Fig. 2

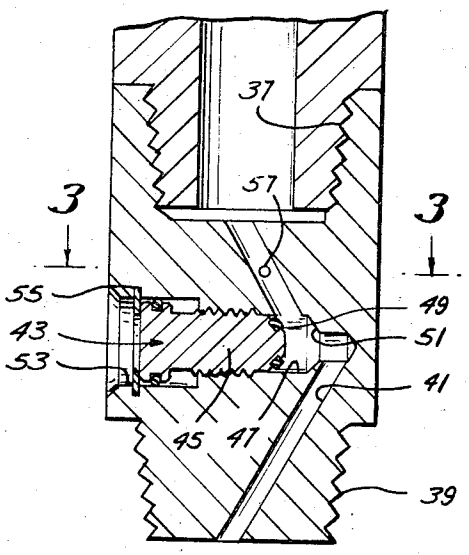
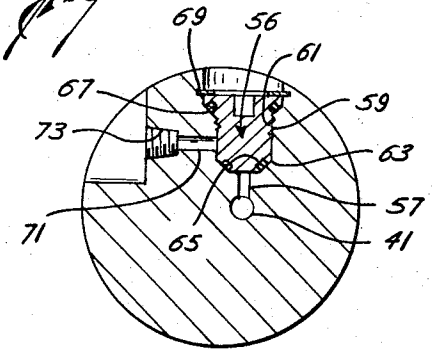


Fig. 3



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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 closed chamber testing technique, upper and lower sample receiving chambers separated by a one-way check valve for permitting the flow of formation fluids from a test valve upwardly through the lower sample chamber and check valve into the upper sample chamber while preventing flow in the opposite directions. Valves having external control means are positioned at the upper end of the upper chamber and the lower end of the lower chamber and are adapted to permit the removal of fluids therefrom into a closed receptacle. A reversing valve in the upper chamber is operated by a drop bar located within the upper chamber.

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 control fluid which is usually mud. The testing tool includes a pressure recorder which meaures 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.

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. At the same time, formation fluids are contained to prevent escape at the earth's surface and may be maintained in closed containers so that the results of the test are confidential.

Additionally, it is often undesirable 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.

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 between closed ends of drill pipe and drained therefrom at the surface into convenient receptacles.

Still another object of the present invention is to provide a new and improved method and apparatus for conducting drill stem tests which permits a formation to flow for a period sufficient to clean the formation of contamination and takes a sample of the last flowing fluids, all the recovered fluids being maintained in a closed system throughout the testing operation.

Therefore, in accordance with the present invention, in a drill stem test, the fluid recovery is limited to given sections of the drill pipe which are closed off prior to retrieving the sections at the earth's surface. The fluid recovery enters the sections of pipe through a first chamber and flows into a second chamber which, being comprised of sections of drill pipe, may be of any desired length. Means are provided between the chambers to prevent fluids from flowing back from the second chamber into the first chamber. After fluids have filled the two chambers, the test valve is closed and the string of tools is retrieved to the surface. Means are provided for reversing the fluids out of the upper chamber into a convenient receptacle. The lower chamber which contains an uncontaminated sample of the formation fluids may then be separated from the string of tools and removed from the well site for examination or the chamber may be drained into a receptacle at the well head.

The novel features of the present invention are set forth with particularity in the appended claims. The present 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 embodied in 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 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. As shown in FIG. 1, a perforated anchor **15**, for admitting well fluid to the flow tube is also used for engaging the bottom of the well bore for expanding 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, an isolation sub **17** couples the lower end of a first section of drill pipe **16** to the tester tool string **13** and a similar isolation sub **19** is coupled to the upper end of pipe **16**. Subs **17** and **19** have passage and valve means to permit fluid flow therethrough. The valve means of subs **17** and **19** when closed, as will hereinafter be more fully explained, serve to contain formation fluids within the chamber formed by the section of drill pipe **16**. Coupled to sub **19** are check valve sub **20** and a reverse circulation valve sub **23**. A second section of drill pipe **18** is coupled to valve sub **23** to form a second chamber. For reasons to be hereinafter described, the second section of pipe **18** is nor-

mally comprised of more than one joint of pipe. The check valve sub **20** permits a flow of fluid from sub **19** into the pipe **18** but prevents return flow. The reverse circulation valve sub **23** provided between the lower end of pipe **18** and check valve **20** has 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**.

A bar holder sub **31** is coupled to the upper end of pipe **18**. An isolation sub **21** similar to subs **17** and **19** couples sub **31** to the string of pipe **11**. The sub **31** releasably supports a bar **33** by means of a pin **35** which pin is operable from the exterior of the sub **31** to release the bar **33**. Release of the bar **33** permits the bar to drop to the lower end of the chamber and into bore **29** in sub **23** to break the plugs **25** thus opening ports **27**. The top of the sub **20** which houses the check valve also serves as a bar stop for the falling bar **33**.

FIGURE 2 is a detailed view of the isolation subs **17**, **19** and **21**. These subs include threaded box and pin ends **37** and **39** for connection in a string of tubing. Each sub has a flow passage **41** extending longitudinally through the sub and a valve **43** for opening and closing the passage **41**. Valve **43**, shown in FIG. 2 in its open position, has a body portion **45** threadedly received in a valve bore **47** and has a tapered valve portion **49** provided with O rings. When the valve body **45** is rotated in one direction, the valve portion **49** seats in a valve seat **51** to block or close off the fluid passageway **41**. Rotation of the valve body **45** is accomplished by means of a wrench or the like applied to the body **45** through a cylinder bore **53** opening to the exterior. Thus, the valve has a control portion exposed to the exterior of the sub. The body portion **45** of a valve **43** is provided with an O ring to seal within the cylinder bore **53**. A snap ring **55** received in a snap ring groove prevents the valve body from leaving the valve bore **53**.

The isolation subs are also provided with another valve **56** (FIG. 3) which controls fluid flow to a passageway **57** in fluid communication with and opening to the longitudinal passageway **41**. The valve **56** which is normally closed, includes a body **59** threadedly received in a bore **61** with a valve element **63** having O rings providing a seal with a valve seat **65** in the sub. The valve body **59** similarly is provided with an O ring **67** and snap ring retainer **69** and similarly is controlled from the exterior of the sub. Another transverse passage **71** opens midway of the valve body **59** and has a threaded end portion **73** exposed to the exterior of the sub. When the valve **56** is opened, as by unthreading of the valve body, the opening defined by portion **73** and the transverse bore **57** are placed in fluid communication.

In operation, the test tool string **13** is lowered into the well bore, at the end of a string of tubing or pipe, the test valve of the tool string **13** being closed. Above the tool string **13** are pipe sections **16** and **18** with isolation subs secured to the ends of the sections and one way check valve **20** positioned between the sections. Valves **43** in isolation subs **17** and **19** are open while the valve **43** in sub **21** is closed.

At the level where the test is desired, the packer is actuated into sealing engagement with the well bore and the test valve 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 **16** through the open valve **43** in sub **17**. After filling the pipe section **16**, the fluid flows through the open valve **43** in sub **19** and through the one way check valve **20** into pipe section **18**.

The uppermost isolation sub **21** is normally closed to prevent the fluid from filling the tubing above this point. However, it is readily seen that any amount of pipe may be included within the section defining pipe section **18**, 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 final flow period, the formation fluids flowing through the lower or first pipe section **16** will be the last fluids produced from the formation. Therefore, when the test valve of the tool string **13** is closed, thus closing off the lower end of the pipe section **16**, the sample of fluid trapped in the section **16** will represent the last fluid to flow from the formation. This provides a sample which should be least contaminated by drilling fluids and, therefore, a sample most representative of the formation fluid.

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 **21** reaches the surface, the retrieval of the tool string from the well is temporarily halted. One end of a flow line or transfer head (not shown) is connected to the opening **73** in the sub **21**. The other end of the flow line is placed within a closed receptacle or in a pit disposed a safe distance from the upper end of the well. The valves **43** and **56** in the sub **21** are then opened to place the opening **73** and flow line in communication with the longitudinal passage **41** through the sub. The opening of the valves in sub **21** permits gas pressure in pipe sections **16** and **18** to be bled off. This bleed off of gas may be measured by a positive displacement meter to determine the amount of gas in the formation fluid. The transfer head may alternatively be connected to the box end **37** of the sub in which event valve **43** would only be opened to place the transfer head in communication with the passage **41**. Next, the pin **35** is removed from the bar **33** to release the bar. Upon dropping to the lower end of the chamber **18**, the bar **33** is effective to shear the plugs **25** and open the ports **27** in the reversing tool **23**. 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 to pump the fluid into the ports **27** and thereby force the formation fluid out of section **18** through the now opened upper isolation sub **21** and flow line into the receptacle or pit. This pumping of the well fluid is continued until the fluid emerging from the flow line is free of formation fluid. Pumping is then ceased and the flow line is disconnected from the sub **21**. Thereafter, as the tool string is further retrieved from the well and the sections of pipe comprising the pipe section **18** are removed from the string, no flammable formation fluids will be exposed on the derrick floor to cause a fire hazard. Furthermore, as the pipe is raised, mud or well fluid in the pipe will drain out through the ports **27** into the annular space in the well.

When the reversing sub **23**, check valve **20**, and isolation sub **19** are brought to the surface, the retrieval of the tool string is once again halted. The valve **43** in sub **19** is closed to prevent fluid or gas in section **16** from escaping. Subs **23** and the check valve **20** are removed from the string of tools. A flow line or transfer head is connected to fitting **73** in the isolation sub **19**. The valves **43** and **56** in sub **19** are then opened to bleed off any pressure in the chamber **16**. Valves **43** and **56** are closed and the flow line is disconnected.

The tool string is then pulled up until isolation sub **17** is positioned at the surface. The valve **43** in sub **17** is then closed. The closed section **16** may then be removed from the tool string for transportation away from the well head for inspection or, if desirable, a transfer head or flow line may be attached to the fitting **73** in sub **17**, and upon opening of valves **43** and **56**, the contents of section **16** may be drained therefrom into a suitable receptacle.

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. In a string of tools for testing a well bore including a test valve for selectively permitting the flow of formation fluid into the interior of said string of tools, the combination of means for selectively maintaining such formation fluids enclosed in said string of tools, which means comprises: means forming a first chamber in the string of tools, including valve means at its upper end, the upper end of said first chamber and associated valve means being arranged to be positioned below the upper end of the well bore when the string of tools is in position for testing the well bore; means forming a second chamber in the string of tools, including valve means at its lower end; valve means positioned intermediate of said first and second chamber, each of said valve means having control portions exposed to the exterior of said string of tools; selectively operable reversing valve means in said first chamber, and means operable from the exterior of said string of tools for selectively operating said latter valve means.

2. In a string of tools for testing a well bore including a test valve for selectively permitting the flow of formation fluid into the interior of said string of tools, the combination of means for selectively maintaining such formation fluids enclosed in said string of tools, which means comprises: means forming a first chamber in the string of tools, including valve means at its upper end, the upper end of said first chamber and associated valve means being arranged to be positioned below the upper end of the well bore when the string of tools is in position for testing the well bore; means forming a second chamber in the string of tools, including valve means at its lower end; valve means positioned intermediate of said first and second chamber, each of said valve means having control portions exposed to the exterior of said string of tools; selectively operable break valve means in said first chamber, releasable bar means for operating said break valve means, and means operable from the exterior of said string of tools for releasing said bar means.

3. In a string of tools for testing a well bore, including a test valve for selectively permitting the flow of formation fluid into the interior of said string of tools, the combination of means for maintaining such formation fluids enclosed in said string of tools at the upper end of the well bore, which means comprises: means forming a first chamber in the string of tools, said first chamber having valve means at its upper end, which upper end and valve means of said first chamber are arranged to be positioned below the upper end of the well bore when the string of tools is in position for testing the well bore; means forming a second chamber positioned below said first chamber in the string of tools, said second chamber having a valve means at its lower end; intermediate valve means positioned between said first and second chambers; said upper and lower valve means having means thereon for connection with a flow line to permit removal of fluids from within said chambers into a receptacle means; each of said valve means having control portions exposed to the exterior of said string of tools; and a selectively operable reversing valve in said first chamber.

4. In a string of tools for testing a well bore, including a test valve for selectively permitting the flow of formation fluid into the interior of said string of tools, the combination of means for maintaining such formation fluids enclosed in said string of tools when the string of tools is removed from the upper end of the well bore, which means comprises: means forming a first chamber in the string of tools, said first chamber having valve means at its upper end; means forming a second chamber positioned below said first chamber in the string of tools, said second chamber having valve means at its lower end; intermediate valve means positioned between said first and second chambers; said intermediate valve means including one way check valve means preventing flow from said first chamber to said second chamber while permitting flow in the opposite direction; said upper and lower valve means including means for connection with a flow line to permit removal of formation fluids from within said chambers into a receptacle means; each of said valve means having control portions exposed to the exterior of said string of tools; and selectively operable reversing valve means in said first chamber.

5. In a string of tools for testing a well bore, including a test valve for selectively permitting the flow of formation fluid into the interior of said string of tools, the combination of means for maintaining such formation fluids enclosed in said string of tools when the string of tools is removed from the upper end of the well bore, which means comprises: means forming a first chamber in the string of tools, said first chamber having valve means at its upper end; means forming a second chamber positioned below said first chamber in the string of tools, said second chamber having a valve means at its lower end; an intermediate valve means positioned between said first and second chambers; said intermediate valve means including one way check valve means preventing flow from said first chamber to said second chamber; said upper and lower valve means being adapted for connection with a flow line to permit removal of formation fluids from within said chambers into a receptacle means; each of said valve means having control portions exposed to the exterior of said string of tools; and selectively operable reversing valve means in said first chamber, releasable bar means for operating said reversing valve means, means on the exterior of said string of tools for releasing said bar means.

6. 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, in serial connection to said tester means, a first valve sub, first sample-receiving means, a second valve sub, a third valve sub, a fourth valve sub, second sample-receiving means, and a fifth valve sub which is adapted for coupling to a string of pipe, said first, second and fifth valve subs including flow passages and valve means with external control elements for opening and closing said flow passages, said third valve sub including a flow passage and valve means operative to permit flow from said first chamber to said second chamber in one direction only, said fourth valve sub having a flow passage and valve means for selectively opening said flow passage to the exterior of said fourth valve sub.

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