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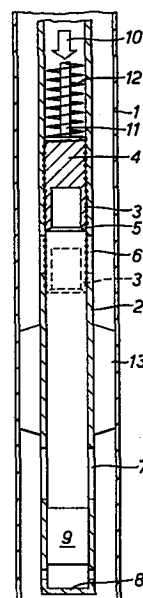
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54 **Well testing apparatus and method.**

57 Well testing of either exploration or production wells is carried out by locating a hollow member, which contains test instruments, in the well bore or within the internal bore of a drill string run, in such a manner that fluid flow up the bore is caused to take place along the path, at least a portion of which includes testing through the region within the hollow member where fluid is in direct communication with the test instruments and performing the well tests while permitting such flow through the member to occur or while preventing fluid escape from the member.

In the method of the invention well testing apparatus may be used for down-hole shut-in purposes even on production wells not provided with built-in shut-in facilities.



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Well Testing Method

This invention relates to the testing of oil or gas exploration wells and to apparatus for use in such testing.

In the evaluation of an oil or gas exploration well one of the principal parts of the data acquisition is the drill stem test (DST). The DST is the production of the reservoir fluid under carefully controlled conditions to provide information on the possible future performance of a production well at the exploration site. In the DST, the column of the drill pipe is used as the temporary production tubing.

During the drilling of any well formation fluids are prevented from entering the well, under their own pressure by the weight of the column of drilling mud in the well. To enable test production of fluids from a selected formation through the drill pipe in a safe manner the column of mud must remain intact around the drill pipe.

An inflatable packer run, as part of the drill pipe column, provides sealing between the drill pipe and the side wall of the well which may be bare rock or steel casing. To enable production the drill pipe must contain a fluid which is both of lower density than the mud and gives hydrostatic head pressure which is less than the formation pressure.

The most useful data available from the DST are pressures relating to the flowing well, and most importantly, measurements of the build-up of reservoir pressure when the well is closed in and the reservoir is stabilising. The latter data gives the most direct information on the permeability of the reservoir rock and the degree of damage to permeability in the immediate vicinity of the well.

In order to provide a basis for sound interpretation the pressure measurements must be of great accuracy and the well must be able to be shut-in down hole to prevent production of fluids into the well bore or settling out of fluids after a surface shut in. The movement of fluids in the long vertical well bore after shut-in will cause a pressure transient that would obscure the reservoir effects that are of interest.

Hitherto conventional drill stem testing uses a packer run which is placed in a point fairly near to the bottom of the drill string. A downhole shut-in valve is placed near to but above this. Clockwork driven recorders on Bourdon Tube type gauges are placed in protected holders below the shut-in valve to 'see' the reservoir flowing and shut-in pressures. A similar clockwork driven recording thermometer provides temperature data. This was the state of the art about four years ago.

This system had the following problems:-

- a) Inaccurate and insensitive gauges meant that long tests were required to provide data that could be interpreted with any reliability.
- 5 b) The engineer conducting the test had no knowledge of the situation down hole or whether the gauges were even working.
- c) The gauges were run in the DST down hole equipment being subjected to very rough handling during the run-in of drill pipe.
- 10 With the advent of electrically operated pressure gauges the possibility of very much improved accuracy was offered. However, there was one very major drawback the gauge had to be run on a conductor wire-line and therefore could not pass through the down hole shut-in valve which would obviously
15 cut the wire. One alternative, recently available, is an electrical gauge with a self contained recording device. This is designed such that it can be run in a conventional gauge holder.

20 This system has the serious disadvantage of not providing the engineer with information as the test proceeds requiring the engineer to act blindly not knowing exactly what is happening down hole.

On production wells where down-hole shut-ins are not normally possible, wire-line electrically operated gauges are run routinely. This requires the careful monitoring of after flow well bore effects so that this data can be ignored and only reservoir effects considered. This has major time disadvantages in low productivity gas wells and oil wells where after flow effects are very prolonged and tests have to be extended.

The most recent development which makes electrical gauges a practical tool in DST's is the 'SPRO' system developed by Flopetrol/Dowell Schlumberger. This system uses a gauge built into the down hole shut-in valve. The gauge is so arranged as to give pressure measurements beneath the valve by providing a pressure communication to the gauge mounted above the shut-in device.

The gauge and shut-in assembly is run in as part of the drill pipe column and the wireline electrical connection is made after the gauge and valve assembly is in position. This has the following disadvantages:-

- a) An elaborate shut-in valve assembly run as part of the drill pipe column requiring the presence at the test of a specialist downhole engineer. This together with the tool itself can prove very expensive.

b) The gauge electrical connection has to be made in the presence of well bore fluids and is not altogether reliable.

c) The flow through the valve is restricted by a rather narrow path approximately 2.00cm diameter.

5 The present invention proposes well testing apparatus which seeks to avoid the disadvantages associated with both wireline apparatus and specially adapted pipe runs and a method, employing such apparatus, for testing wells.

10 According to the present invention there is provided a method for performing one or more designated tests upon a well in which the well fluid pressure is less than the associated reversoir pressure so that well fluid can flow up the well towards the surface, the method comprising locating a hollow member, containing instruments for measuring and
15 data aquisition from said tests, in the well bore in such a manner that the fluid flowing up the bore is caused to take a path which includes passage through at least a portion of the hollow member in which said fluid is in direct communication with said instruments and performing said
20 designated tests while permitting such flow through said member to ocur or while preventing fluid escape from the member.

Apparatus for use in the method of testing of wells

according to the present invention may be in the form of an assembly adapted to be received within the bore of a drill string and arranged to carry instruments for data acquisition, the assembly comprising a hollow member
5 provided with longitudinally spaced inlet and outlet ports to allow passage of fluids from the well upwardly through the inlet ports into the lower end of the member and a closure device which is movable relative to the upper part of the member to close the outlet ports, means for actuating
10 the device to close the outlet ports and means for sealing the annular space between the lower end of the member and the wall of the pipe run in the region between the inlet and outlet ports, said instruments being located within the member and being in direct communication with fluid in the
15 region between the inlet and outlet ports.

The invention will be described with reference to the accompanying drawings in which

Figure 1 is a diagrammatic sectional elevation of one form of the apparatus and

20 Figure 2 is a diagrammatic sectional elevation of another form of the apparatus.

Referring to Figure 1, the assembly located within the bore of a drill pipe 1 comprises a hollow member 2 and an internal closure device 3 which forms a sliding seal within

the hollow member 2. The device 3 comprises an uppermost cylindrical plug body portion 4 leading to a lowermost cylindrically hollow portion 5.

The hollow member 2 is provided with longitudinally spaced ports 6,7, which may be in the form of elongate slots in the wall thereof. The lowermost ports 7 form inlets 8 for the well fluids while the uppermost ports 6 form outlets for the fluid.

The hollow member 2 is closed at its lowermost end 8 and its provided therein with instrument packages 9 for monitoring well fluids. The instruments may comprise pressure measuring devices, thermometers and flow meters.

The closure device 3 is actuated by actuating means 10 (shown schematically) including a hydraulic/pneumatic, hydraulic or electromechanical driven ram 11 located within the hollow member 2 above the device 3 and secured thereto. The drive device for the piston may be remotely operated via a cable (not shown) from the surface.

Cables (not shown) from the instruments 9 run to the surface through a conduit (not shown) which is hermetically sealed. The conduit may be disposed in a longitudinal recess in the inner or outer wall of the member 2 or it may extend upwardly through the bore of the member 2 through the closure device 3 and the ram 11 in a manner similar to that

shown in Figure 2.

In use, the ram 11 is actuated to move the closure device 3 downwardly under the action of a return spring 12 located above the device 3 and circumventing the ram 11. Movement of the device 3 downwards causes the hollow portion 5 thereof to cover the outlet ports 6 to seal off the lower part of the hollow member 2. The closed position of the device 3 is shown in outline in Figure 1. Upon release of the actuating means the ram 11 is moved upwardly under the action of the return spring 12 to move the closure device 3 back to its original position thereby uncovering and reopening the outlet ports 7. In any case should the control signals to the actuating means fail, the upward release of the closure device 3 occurs automatically.

In order to seal the annular space between the hollow member 2 and the wall of the pipe 1, an inflatable packer 13 is provided in the region between the ports 6 and 7. The packer 13 may be inflated hydraulically by remote control from the surface.

The closure device 3 may comprise a form which is a variant of that shown in Figure 1. For instance the device 3 may merely comprise a hollow cylinder. Alternatively it may comprise a hollow cylinder which has a portion containing ports corresponding to those outlet ports 6 in

the hollow member 2. In this case, the outlet ports 6 are open when in one longitudinal position they are aligned with the ports in the cylinder whereas in another longitudinal position displaced from the first, the outlet ports 6 are closed by an integral wall portion of the cylindrical device.

As a further variant, the device may comprise a hollow cylinder with circumferentially spaced ports which, in one position, are alignable with the outlet ports 6 to open them. In another position to which the cylinder is moved by a limited angular rotation thereof the outlet ports 6 are closed by the wall of the cylinder. In this case of course the actuating means must be adapted to effect an axial angular rotation of the cylinder rather than a longitudinally directed sliding movement thereof.

Referring to Figure 2, like parts bear the same reference numerals as in Figure 1. The closure device 14 comprises an outer sleeve which is sealingly slidable over the hollow member 2. Upward movement of the sleeve 14 is limited by its engagement of a shoulder 15 on the hollow member 2 formed between a lower portion 16 and upper portion 17 of greater diameter than the lower portion. A septum 18 divides the member 2 into upper and lower chambers 19 and 20 respectively, the lower chamber 20 including the ports 6 and 7.

The sleeve 14 is connected to the piston 21 of a ram 22 for moving the sleeve 14 slidably over the hollow inner member 2. The piston 21 has radially directed portions 23 extending through elongate longitudinal slots in the wall of the hollow member 2, which portions are connected to the sleeve 14 to permit movement thereof by the piston 21 moving relative to the slots. The ram 22 is actuated by fluid introduced under pressure into the upper part 24 of the chamber 19. A fluid reservoir and fluid control valves (not shown) are provided in the upper part 24 of the chamber 19.

Extending from the surface through the hollow member 2 by way of a central bore in the ram 22, piston 21 and the septum 18 is a hermetically sealed conduit 25. The conduit 25 carries cables (not shown) for remote control of the fluid reservoir and control valves and of the instruments 9.

Movement of the piston downwards from the position shown in Figure 2 causes the sleeve 14 to move to cover the outlet ports 6 and upon release of the actuating fluid pressure in the chamber 19, the ram 22, piston 21 and sleeve 14 are urged upwardly under the action of the return spring 12 which is mounted for compression between the piston 21 and the septum 18.

The actuation may be achieved either hydraulic/pneumatically, hydraulically or

electromechanically.

The DST tool in accordance with the invention may be run into the well bore by one of an alternative sequence of operations. Firstly a conventional down hole shut in valve, 5 in the shut mode, may be run in as part of the drill string and, subsequently the DST tool is lowered into the hole down the hollow drill stem. Upon opening of the lower down hole shut-in valve, flow control is regulated by the valve assembly of the tool. An alternative method of locating the 10 tool is to run in a drill string and to run in an open ended drill string down the hole. The column of mud in the drill stem is replaced with a less dense fluid such as sea water, diesel oil or nitrogen and thence the DST tool is sunk through the less dense fluid. After setting the tool the 15 fluid control is again regulated by the valve assembly of the tool.

The use of the testing tool in accordance with the invention has many technical advantages. An example is the selective perforation of intervals between tests to evaluate 20 the performance of short intervals of the reservoir thickness and their aggregate. Down-hole flowmeters can be run to measure the flow from each group of perforations.

The present invention may be used with advantage for testing producing wells. Whilst this may not be so 25 important for high rate oil and gas wells, in poorer wells

particularly with two phase flow, redistribution of the well bore contents after shut-in and after-flow into a large capacity well can obscure valuable data. In order to provide this facility with existing equipment it was previously necessary to provide a special nipple which is an integral part of the tubing string and must be run in when the well is completed. Thus existing wells which do not have a modified tubing string cannot be tested with the existing equipment. In contrast no modifications to the production tubing are required for use of the present invention and it may be used on pre-existing wells.

Since in accordance with the invention, the testing instruments are not usually run in with the drill string, there is little risk of damage, as would be in the case of known DST tools since they are subject to jarring as the drill string is run in.

Furthermore since the measuring instruments are in direct communication with the well fluids under test, anomalies such as temperature changes and slow pressure changes on shut-in are eliminated. Thus results are available both quickly and accurately, saving in both time and costs.

CLAIMS

1. A method for performing one or more designated tests upon a well in which the well fluid pressure is less than the associated reservoir pressure so that well fluid can flow up the well towards the surface, the method comprising
5 locating a hollow member, containing instruments for measuring and data acquisition from said tests, in the well bore in such a manner that the fluid flowing up the bore is caused to take a path which includes passage through at least a portion of the hollow member in which said fluid is
10 in direct communication with said instruments and performing said designated tests while permitting such flow through said member to occur or while preventing fluid escape from the member.
2. A method as claimed in Claim 1 in which the well bore
15 is a region defined by the internal bore of a pipe string run.
3. A method as claimed in Claim 1 or Claim 2 in which said hollow member is included in an assembly wherein said member is provided with longitudinally spaced inlet and
20 outlet ports to allow passage of the well fluids upwardly through the inlet ports into the lower end of the member, and wherein said assembly further includes a closure device which is moveable relative to the upper part of the member

to close the outlet ports, means for actuating the device to close the outlet ports and means for sealing the annular space between the lower end of the member and the wall of the well bore in the region between the inlet and outlet
5 ports.

4. Apparatus for the testing of wells, in the form of an assembly adapted to be received within the bore of a drill string and arranged to carry instruments for data acquisition, the assembly comprising a hollow member
10 provided with longitudinally spaced inlet and outlet ports to allow passage of fluids from the well upwardly through the inlet ports into the lower end of the member and a closure device which is movable relative to the upper part of the member to close the outlet ports, means for actuating
15 the device to close the outlet ports and means for sealing the annular space between the lower end of the member and the wall of the pipe run in the region between the inlet and outlet ports, said instruments being located within the member and being in direct communication with fluid in the
20 region between the inlet and outlet ports.

5. Apparatus as claimed in Claim 4 in which the closure device is received within the hollow member for movement within the member to close the outlet ports.

6. Apparatus as claimed in Claim 5 in which the closure
25 device is longitudinally/slidable within the hollow member

and the actuating means is adapted to cause the device to slide longitudinally.

7. Apparatus as claimed in Claim 4 in which the closure device comprises a sleeve for the hollow member, the sleeve
5 being longitudinally slidable over the upper part of the hollow member to close the outlet ports and the actuating means being adapted to cause the sleeve to slide longitudinally.

8. Apparatus as claimed in any of Claims 4 to 7 in which
10 said sealing means is an inflatable packer.

9. Apparatus as claimed in any of Claims 4 to 8 in which the actuating means is pneumatically, hydraulic/pneumatically, hydraulically or electro-mechanically operated.

15 10. Oil and gas well incorporating the equipment as claimed in Claim 4.

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FIG.1.

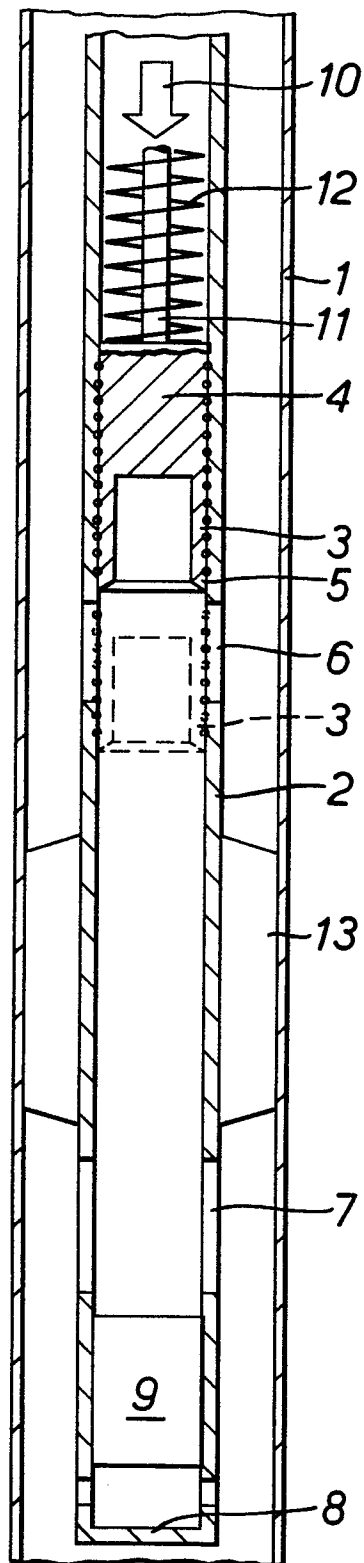


FIG.2.

