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Baker

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[45] **Oct. 30, 1973**

[54] **FULL OPENING MULTIPLE STAGE CEMENTING TOOL AND METHODS OF USE**

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[73] Assignee: **Halliburton Company**, Duncan, Okla.

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[52] **U.S. Cl.** **166/289**, 166/224, 251/74

[51] **Int. Cl.** **E21b 33/13**, E21b 33/00

[58] **Field of Search** 166/289, 224; 251/74

[56] **References Cited**

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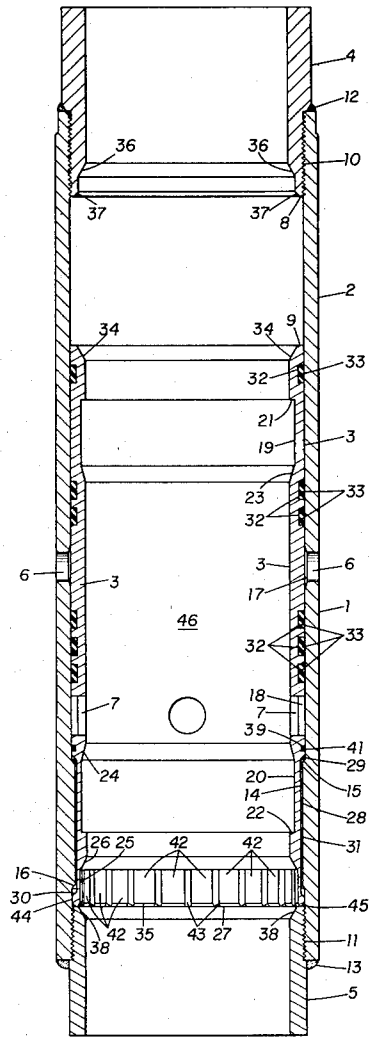
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Primary Examiner—James A. Leppink
Attorney—John A. Tregoning et al.

[57] **ABSTRACT**

A full opening cementing tool particularly suitable for cementing an oil well, and allowing the completion of as many cementing stages as desired, utilizes a cylindrical housing, a sliding valve sleeve within the housing, and an opening positioner and a closing positioner located on a pipe string within the casing for actuating the sliding valve sleeve at the appropriate times. Other tools such as isolation packers and circulating valves may be used advantageously in conjunction with one or more of the cementing tools.

23 Claims, 10 Drawing Figures



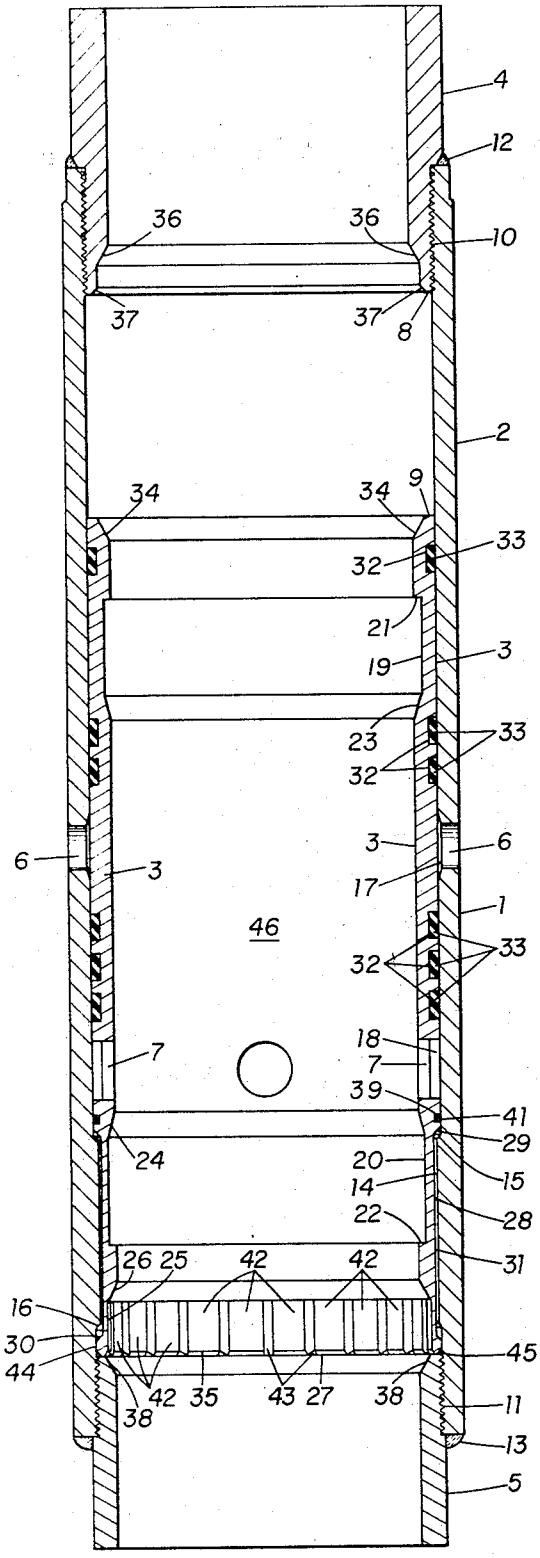

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FIG. 1

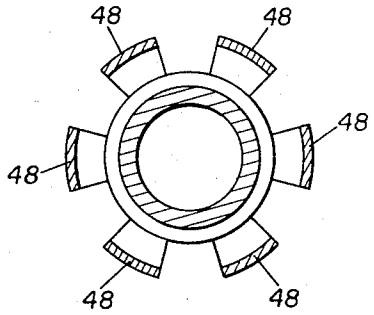

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FIG. 4

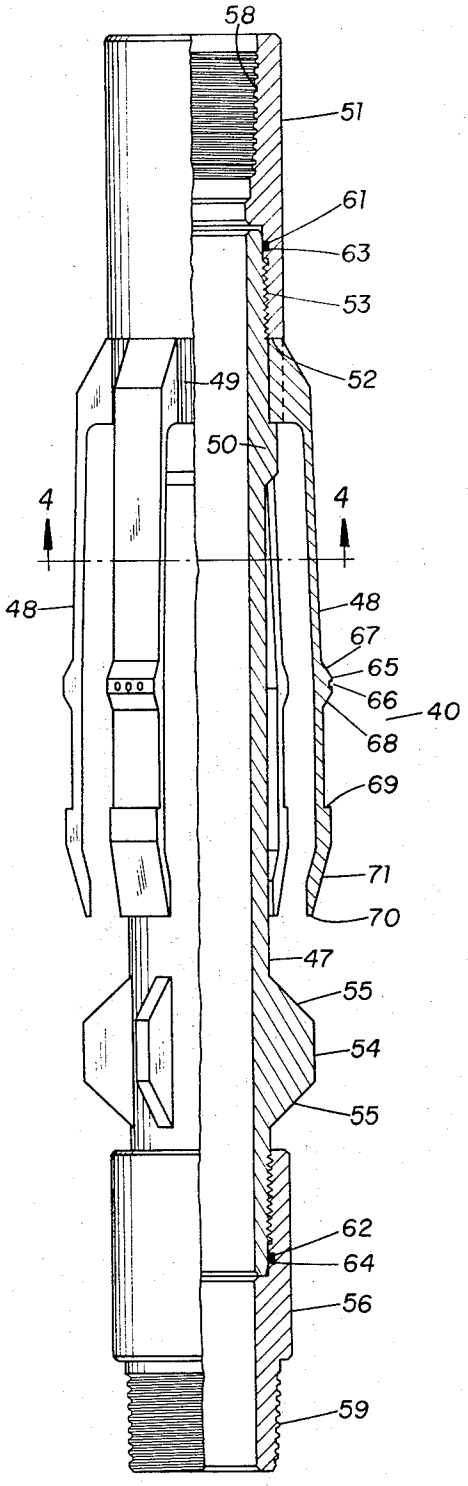

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FIG. 2

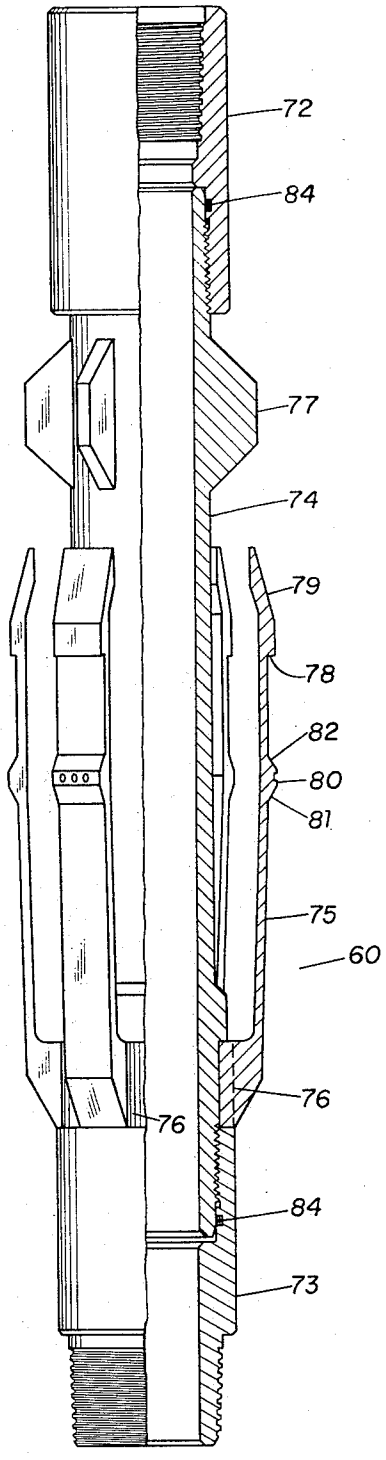

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FIG. 3

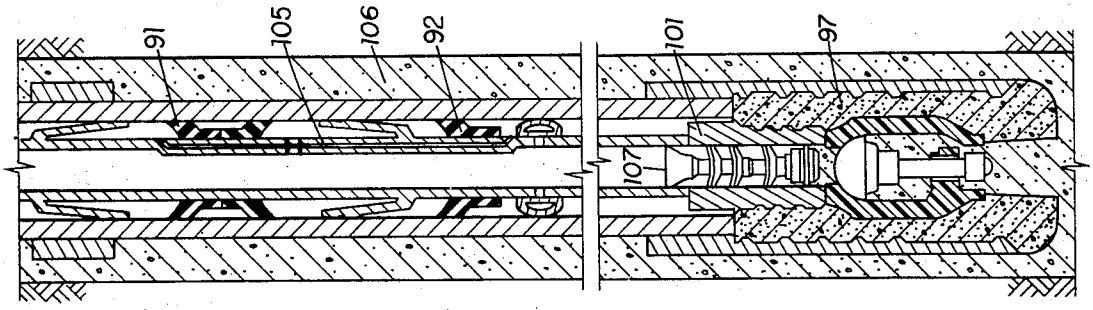


FIG. 10

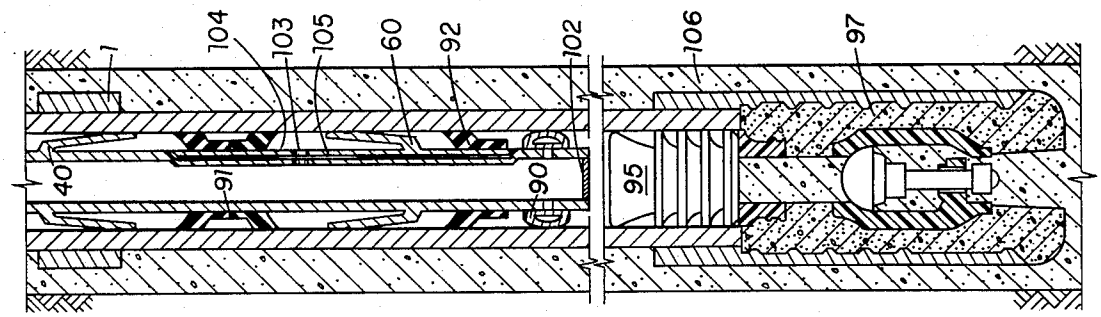


FIG. 9

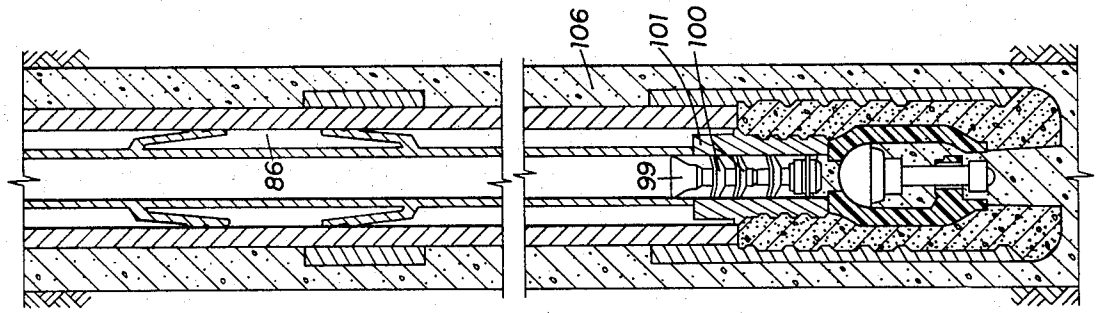


FIG. 8

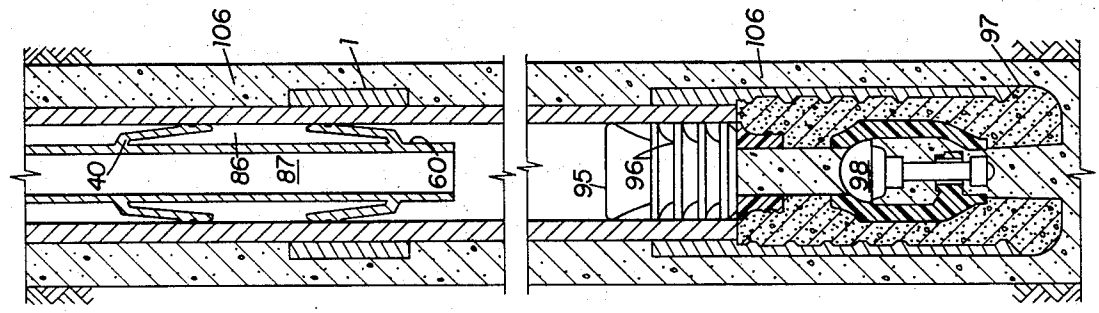


FIG. 7

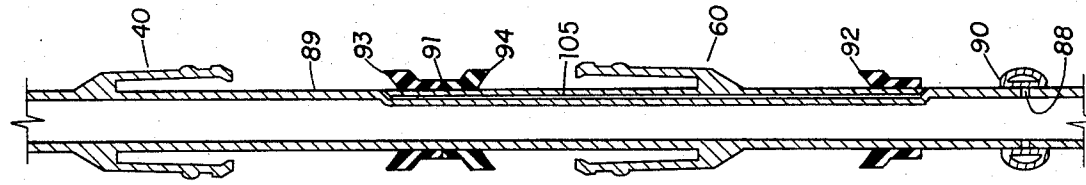


FIG. 6

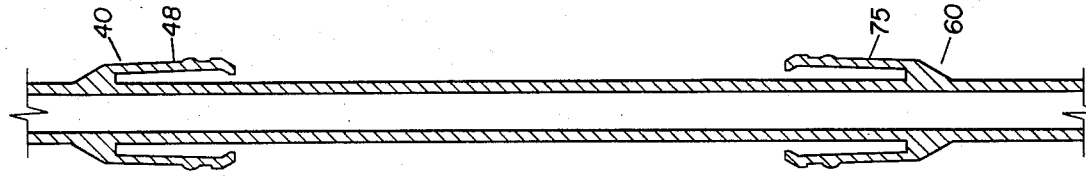


FIG. 5

FULL OPENING MULTIPLE STAGE CEMENTING TOOL AND METHODS OF USE

BACKGROUND OF THE INVENTION

In preparing oil well boreholes for oil and/or gas production a most important step involves the process of cementing.

Basically, oil well cementing is a process of mixing a cement-water slurry and pumping it down through steel casing to critical points located in the annulus around the casing, in the open hole below, or in fractured formations.

Cementing a well protects possible productive zones behind the casing against salt water flow and protects the casing against corrosion from subsurface mineral waters and electrolysis from the outside.

Cementing eliminates the danger of fresh drinking and recreational water supply strata from being contaminated by oil or salt water flow through the bore hole from those types of formations. It prevents oil well blowouts and fires caused by high pressure gas zones behind the casing and in addition prevents the collapsing of the casing from high external pressures building up underground.

A cementing operation for protection against the above described downhole conditions is called primary cementing. Secondary cementing includes the cementing processes used on a well during its productive life and includes remedial cementing and repairs to existing cemented areas.

The present invention is directed primarily to the first type of cementing operation, primary cementing.

In the early days of oil field production when wells were all relatively shallow, cementing was accomplished by flowing the wet cement slurry down the casing and back up the outside of the casing in the annulus between the casing and the borehole wall.

As wells were drilled deeper and deeper to locate petroleum products it became difficult to cement the entire well satisfactorily from the bottom of the casing and multiple stage cementing was developed to allow the annulus to be cemented in separate stages, beginning at the bottom of the well and working up.

This process was achieved by placing cementing valves in the casing or between joints of casing at one or more locations in the borehole, flowing through the bottom of the casing, up the annulus to the lowest valve in the wall, closing the bottom and then flowing through the valve to the next higher valve, then repeating until the cement reached the uppermost annulus region to be cemented.

There are prior art devices available today which can be used to perform a successful three-stage cementing operation. With modifications and under certain conditions, it is even possible to obtain a four-stage cementing operation with these types of cementing tools.

There are several types of devices known as "multiple stage cementing tools" which may be used for introducing cement slurry into the outer annular space from within the casing at any desired location along the casing. These tools, which are interposed in the string of casing at each such desired location, have covered ports which are exposed for discharging cement slurry into the annular space and then subsequently covered back up.

The exposing and covering steps are generally accomplished by dropping or pumping a pair of plugs, or other type devices down the well casing, the first of which engages a lower sleeve within the cementing tool and exposes the ports, and the second of which engages an upper sleeve which covers the ports. These plugs are retained within the cementing tool so that it is first necessary to drill them out before regaining access to the casing below each such tool.

What the prior art has needed has been a full-opening cementing tool capable of performing an unlimited number of cementing stages in a deep well. Such a tool is disclosed in the present invention and comprises one or more ported cylindrical housings interposed in the casing string, a valve sleeve telescopically located in a recessed area in each housing and capable of opening and closing the ports in the housing for cement flow, and an opening positioner and closing positioner to be used on a drill string in conjunction with the closing sleeves and the housings. In addition, the use of this invention can be advantageously coupled with one or more cementing plugs, isolation packers, and circulating valves.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional side view of the full opening cementing tool.

FIG. 2 is a partial cross-sectional side view of the opening positioner.

FIG. 3 is a partial cross-sectional side view of the closing positioner.

FIG. 4 is a cross-sectional axial view of the opening and closing positioners of FIGS. 2 and 3.

FIG. 5 shows a schematic view of a drill string setup containing the opening and closing positioners for use with the sleeve valve of the cementer.

FIG. 6 is a schematic view of a drill string containing the opening and closing positioners, isolation packers, and a circulating valve, all for use with the sleeve valve cementer.

FIGS. 7 through 10 are schematic views of the full opening multi-stage cementer of this invention in operation with several different types of associated apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

I. SLIDING SLEEVE VALVE

Referring to FIG. 1, the cementing tool 1 comprises an outer cylindrical housing 2, an inner valve sleeve 3 telescopically mounted within the housing 2, and upper body 4 and lower body 5. Housing 2 has one or more cementing ports 6 through the wall in the area where valve sleeve 3 is slidably located. Valve sleeve 3 has matching cementing ports 7 through the wall arranged so that the ports 7 will align with ports 6 when sleeve 3 is in its uppermost position within housing 2 which, in the drawing, would be in the left portion of housing 2 abutting shoulder 8 of upper body 4. In the open sleeve position of the uppermost position, shoulder 9 of sleeve 3 abuts shoulder 8.

Valve sleeve 3 and housing 2 have appropriate inner and outer diameters so that sleeve 3 fits just loosely enough within housing 2 to allow it to slide in housing 2 and sleeve 3 has substantially the same inner diameter as that of the standard casing being used, thus providing a full opening tool.

Housing 2 may be fixedly attached and fluidically sealed to upper and lower bodies 4 and 5 by threaded

connections 10 and 11 respectively, and welds 12 and 13 respectively.

Housing 2 also contains a wide flat inner annular ridge 14 having sloping shoulders 15 and 16 at its top and bottom respectively.

An inner annular recess 17 runs circumferentially around the interior wall of housing 2 intersecting ports 6 therein. A corresponding outer annular channel 18 runs circumferentially around the exterior of sleeve 3 in the area of and intersecting ports 7 therein. When the tool is assembled, ports 7 are placed in exact alignment with ports 6, but is is contemplated that rotation of sleeve 3 may occur within housing 2; and ports 6 and 7, while being in the same diametral plane, might still not allow cement to flow. Thus, recess 17 and channel 18 allow fluid communication through ports 6 and 7 should these ports not be exactly in line when sleeve 3 is moved to its open position abutting shoulder 8.

Sleeve 3 is provided with inner annular recesses 19 and 20 for engagement with the opening positioner 40 (see FIG. 2), and closing positioner 60 (see FIG. 3). Recess 19 has a perpendicular shoulder 21 and a sloping shoulder 23. Recess 20 has perpendicular shoulder 22 and sloping shoulder 24. Sleeve 3 also has an annular enlargement 25 at its lower end consisting of outwardly sloping shoulder 26 and skirt 27. In addition, sleeve 3 is provided with a broad, shallow external annular recess 28 in which annular ridge 14 may fit as shown in FIG. 1. Recess 28 is defined by sloping faces 29 and 30 and longitudinal face 31.

Recesses 32 can be provided in the outer face of sleeve 3 to contain seal rings 33 which sealingly contact housing 2 and prevent fluid communication between housing 2 and sleeve 3. Sleeve 3 also has beveled edges 34 and 35 at its upper and lower ends to facilitate movement of the opening and closing positioners 40 and 60 through it. Upper body 4 also has beveled edges 36 and 37 to provide easy movement therethrough and lower body 5 has a beveled edge 38 for easier passage of a tool string therethrough.

Recess 39 is cut in sleeve 3 to allow an O-ring seal 41 or other appropriate annular seal to be placed between housing 2 and sleeve 3 below ports 7 to prevent fluid flow between the housing 2 and sleeve 3.

Collet fingers 42 are formed around the bottom circumference of sleeve 3 by machining equi-spaced slots 43 longitudinally in skirt 27 of sleeve 3. This provides a spring clip effect on the skirt 27 through the spring ability of each finger 42.

Recess 31 in sleeve 3 extends partially along each finger 42 and defines at shoulder 30 a ridge-like ring 44 remaining on skirt 27 and on each finger 42. Sloping face 30 on ridge 44 abuts sloping face 16 on ridge 14 and prevents premature opening of cementing valve 1 which would occur by movement of sleeve 3 upward in housing 2.

The spring force holding sleeve 3 in the lowermost position in housing 2 can be adjusted by adjusting the spring tension of fingers 42. This can be done by machining larger or smaller slots 43 in skirt 27, or by making fingers 42 thicker or thinner by changing the machined size of enlargement 25. Thus, sleeve 3 can be prevented from sliding until a preset force is applied to the sleeve, which force will overcome spring tension in fingers 42. In this specific embodiment, opening tension is set at 20,000 pounds force.

Fingers 42 also have an external bevel at their exposed end which defines face 45 on each fingers 42. When the cementing tool 1 is in the fully opened position with sleeve 3 at its uppermost point, lining up ports 6 with ports 7, face 45 will be above shoulder 15 and in close relationship to it. The abutment of these two faces together prevents premature or unwanted closure of the cementing tool. The same force required to overcome collet finger 42 to move sleeve 3 upward from its closed position will be required to move it downward out of its open position.

II. THE OPENING AND CLOSING POSITIONERS

Referring now to FIG. 2, disclosed is a preferred embodiment of the opening positioner 40 for engaging and moving sleeve 3 from a closed position in housing 2 to an open position, whereby ports 6 are lined up with ports 7 and fluid communication can occur between the inner bore portion 46 of sleeve 3 to the exterior of housing 2.

Opening positioner 40 consists primarily of mandrel body 47 which contains a plurality of spring arms 48 fixedly attached to spring collar 49 which encircles mandrel body 47 and fits snugly against annular shoulder 50 on body 47.

Attached to mandrel body 47 by threaded connection 53 is upper adapter 51 which abuts spring collar 49 at shoulder 52 of adapter 51 and which serves to hold collar 49 firmly and snugly against shoulder 50.

Below arms 48 on body 47 are located a plurality of drag lugs 54 projecting outward from body 47 and having sloping faces 55, and aligned longitudinally one with each arm 48.

At the lower end of body 47 is lower adapter 56 which is an internally and externally threaded collar-like adapter attached to body 47 by matching threads 57. Adapters 51 and 56 are inserted in a standard tubing or drill string and connected to the tubing ends by threads 58 and 59 respectively. Circular seals 61 and 62 are positioned in recesses 63 and 64 respectively, to provide a fluid tight seal between the body 47 and the upper and lower adapters 51 and 56 respectively.

Located on each spring arm 48 is a shoulder 65 in which is imbedded one or more carbide buttons 66.

Shoulder 65 has sloped surfaces 67 and 68 which act as wedges to drive arm 48 down when contacting projections in sleeve 3. Shoulders 65 act as centralizers for the positioner 40 and keep it centered in the casing. Buttons 66 reduce friction wear on the positioner.

Arms 48 also have a perpendicular shoulder 69 which engages a corresponding perpendicular shoulder 21 in sleeve 3 and allows sleeve 3 to be pulled up into the open position by lifting up on the drill string containing the opening positioner 40.

Tips 70 located at the free end of arms 48 project inwardly towards the axis of the opening positioner 40 and are located on a smaller radius than the outer surface of drag lugs 54. Thus drag lugs 54 provide a centering and shielding function for arms 48 as the positioner 40 enters the sleeve 3. Sloping face 71 of the lower end of arm 48 provides a wedging action which pushes down on arm 48 when an inner projection in sleeve 3 is encountered, allowing the positioner to travel downward through sleeve 3 relatively unimpeded.

Arms 48 are thus arranged so that, on downward movement through the sleeve 3, no part of the arm will

engage the sleeve sufficiently enough to move the sleeve downward and overcome the spring tension of collet fingers **42** on flat annular ridge **14.** Thus, downward movement of opening positioner **40** has no effect on cementing valve **1,** and positioner **40** can pass downward entirely through sleeve **3** without changing its porting orientation.

Shoulder **65** on arm **48** also serves the function of a releasing cam when arm **48** is engaged in sleeve **3** and has moved sleeve **3** to the uppermost position in housing **2,** thereby opening ports **6** and **7.** In order that the opening positioner **40** may be pulled out of sleeve **3** after the sleeve has been opened, shoulder **65** is located on arm **48** so that when sleeve **3** is at the top of its travel, shoulder **65** abuts beveled edges **37** and **36** which drives shoulder **65** and arm **48** inward, disengaging shoulder **69** of arm **48** from shoulder **21** of valve sleeve **3.**

Referring now to FIG. **3,** the closing positioner **60** is illustrated. The closing positioner contains the identical parts of the opening positioner but with a differnt orientation.

The closing positioner has upper adapter **72,** lower adapter **73,** mandrel body **74,** spring arms **75,** spring collar **76,** and drag lugs **77.** The only difference between the closing positioner **60** and the opening positioner **40** is that the mandrel body, containing the spring arm and spring collar assembly, has been removed from the upper and lower adapters, rotated end for end 180°, and reconnected to the adapters. The spring arms **75** of closing positioner **60** point upward whereas the arms **48** of opening positioner **40** point downward. Spring arms **75** have an actuating shoulder **78** near the tips **79** of the arms. This perpendicular shoulder **78** is arranged to engage shoulder **22** of sleeve **3** as the closing positioner moves downward through the opening cementing tool **1.** The abutment of shoulder **78** against shoulder **22** in the sleeve **3** allows the sleeve to be pushed down into its closed position from the open position. When the sleeve reaches the closed position, shoulder **80** with sloping surfaces **81** and **82,** engages beveled surface **38** of lower body **5** which provides a wedging action forcing spring arms **75** inward, toward mandrel **74,** and out of engagement with sleeve **3** at shoulder **22.**

Shoulder **80** also has friction buttons **83** on its outer surface to prevent drag and unnecessary wear on the spring arms. Drag lugs **77** also shield arms **75** as do lugs **54** for spring arms **48** on opening positioner **40.** Seals **84** prevent fluid communication between the joined parts.

Referring now to FIG. **5,** opening positioner **40** is adapted to be placed in a drill string by threading it between two standard joints of tubing. The closing positioner **60** is placed in the drill string also, below the opening positioner and can be any desired distance below the opening positioner depending upon the length of tubing placed between them.

III. ASSOCIATED APPARATUS

Apparatus which is advantageously utilized with the cementing tool of this invention, as illustrated in FIG. **6,** and FIGS. **7** through **10,** includes a circulating valve **90** located on the exterior of a drill string or tubing string **89** and slidably movable on the drill string to open and close ports **88** which pass through the wall of the drill string **89** and provide fluid communication between the interior bore **87** of the drill string and the annulus **86** between the casing **85** and the drill string **89.** Circulating valve **90** can be any one of the commercially available valves suitable for such use and which can be actuated from the surface when desired.

Also particularly useful with this tool under certain cricumstances are isolation packers **91** and **92.** Packer **91** is the upper packer and comprises sealing cups **93** and **94** which are circular cups made of an elastomeric material which is capable of sealingly engaging the interior of casing **85.** Cup **93** on packer **91** is facing upwards and is capable of sealing flow of fluids in a downward direction, which downward flow presses into cup **93** and spreads it out into sealing contact with the casing **85.** Cup **94** is concave downward and suitable for sealing against upward flow in the same manner as cup **93** seals against downward flow.

Packer **92** primarily comprises only one elastomeric cup which is arranged concave upward for preventing downward flow thereby. Packer **92** does not prevent upward flow past it through the annulus **86.**

FIGS. **7** through **10** illustrate other equipment which is used with the multi-stage cementing tool **1,** including a standard cementing plug **95** with a plurality of circumferential elastomeric wiper cups **96** located on the plug. Also utilized is a standard commercially available cementing shoe **97** having a common check valve arrangement **98** in the passage therethrough. Cementing shoe **97** is fixedly attached to the casing **85** at its lowermost edge. Cementing plug **95** is designed to pass snugly within casing **85** and is used to separate two different types of fluids, drilling fluid and cement, and also wipes the interior of the casing clean as it passes down the casing.

Another system, as shown in FIG. **8,** uses a different type latch-down plug **99.** This plug is designed to pass down the drill string rather than the casing and is therefore necessarily of smaller diameter. The latch-down plug **99** contains elastomeric wiper collars **100** just as does plug **95.**

Sealing adapter **101** is located on the lower end of the tubing **89** and serves to retain latch-down plug **99** within tubing **89** and fluidically seal off the bottom end of the tubing.

The corresponding apparatus to seal off the tubing when cementing plug **95** and packers **91** and **92** are used in the casing is bull plug **102** which sealingly plugs the bottom end of tubing **89** and is passed down the drill string or tubing at the desired instant and seats at the bottom of the drill string thereby sealing it off.

IV. METHODS OF OPERATION

Referring now to FIG. **7,** a simple method of operating the present invention is to cement the first or lower stage through the casing with the drill string out of the hole. One or more of the cementing tools **1** will have been placed in the casing string in their closed state at the desired cementing points for the different stages, before the casing was placed in the well. A cementing shoe **97** was placed on the lowermost section of casing.

The lower stage of the annulus is then cemented by flowing a precalculated amount of cement slurry down the casing, through the shoe **97** and up the annulus **106.** A plug **95** is placed in the casing at the end of cement flow and then working fluid is flowed into the casing behind plug **95,** forcing all cement in the casing ot flow through the shoe and into the annulus. When plug **95**

seats in sh'e 97 and seals off the passage therethrough, valve 98 prevents backflow of cement through the shoe. Immediately after plug 95 seats, pressure in casing 85 starts to rise sharply, indicating to the operator at the surface that the first stage of cementing is completed, and the second stage is ready to begin.

The drill string or tubing 89 containing the opening positioner 40 and the closing positioner 60 is then placed into the casing and lowered until the closing positioner 60 and the opening positioner 40 have passed through the lowermost cementing tool 1. During the running in of the drill string 89 the inner bore 87 of the drill string remains open to allow fluid to flow upward into the drill string as it goes into the casing, thereby facilitating placement of the drill string in the casing.

After the opening positioner 40 has passed downward through the closed cementing tool 1, the drill string is then picked up just enough to pull the opening positioner 40 through the valve sleeve 3. As it passes upward through the valve sleeve, the opening positioner engages the valve sleeve by abutment of positioner shoulder 69 against sleeve shoulder 21 which allows the required lifting force to be applied to valve sleeve 3 overcoming spring tension in collet fingers 42 and moving the valve sleeve upward until ports 7 are in alignment with ports 6. At this moment shoulders 65 on spring arms 48 engage beveled edges 37 and 36 pushing the spring arms down, and disengaging shoulder 69 from shoulder 21.

The sleeve valve 3 is then held snugly in the open position by collet fingers 42 abutting shoulder 15. The drill string and closing positioner 60 can then be withdrawn from the sleeve until the lower end of the drill string is approximately even with ports 7 and 6. Cement is pumped down the drill string and through ports 7 and 6 into the annulus area 106 to be cemented during this second stage.

The working fluid, which for instance could be drilling fluid, remaining in the casing from below the drill string down to the top of cementing plug 95, acts as a fluid cushion which directs the cement slurry through the ports 7 and 6 instead of down the casing. Only a negligible amount of the cement slurry will mix with or enter the working fluid and this will settle harmlessly to the bottom.

After the second stage of cementing is completed, the drill string is set down enough to pass closing positioner 60 through the sleeve 3 without allowing opening positioner 40 to also pass through. In order to facilitate this, when the frill string was assembled at the surface, a sufficient length of drill pipe was placed between the opening positioner 40 and the closing positioner 60. For instance, a 30-foot section would normally be sufficient.

As the closing positioner 60 passes downwardly through the valve sheet 3, the actuating shoulder 78 engages shoulder 22 in the sleeve which allows a sufficient amount of force to be applied to sleeve 3 to overcome the tension in collet fingers 42 and move sleeve 3 to a closed position. This closing movement is felt at the surface as a sharp jerk as the collet fingers release and allow the sleeve to drop a short distance and then stop abruptly. The drill string can then be lifted to the third cementing stage, if any, or removed from the well if desired. Thus it is obvious that as many stages of cementing as desired can be accomplished with this method, merely by inserting the desired number of cementing tools 1 in the casing string and appropriately maneuvering the drill string or tubing containing the opening and closing positioners.

It should be noted that it may be advantageous to temperarily attach sleeve 3 to housing 2 by shear means to prevent premature opening of the sleeve when going into the hole or when performing operations other than cementing. When it is desired to open the tool, the shear means can then be sheared by applying sufficient additional lifting force over that required to contract collet fingers 42, to shear the means and allow sleeve 3 to move upward.

It is also emphasized that with the valve sleeve 3 in a closed position, closing positioner 60 can pass downward through the sleeve relatively unhindered due to the fact that beveled edge 38 of the lower body 5 engages shoulders 80 on spring arms 75, pushing the arms down and preventing engagement of shoulder 78 with shoulder 22 in sleeve 3.

FIG. 8 involves a modification of the method of cementing shown in FIG. 7. In this method all cementing, including the first stage, is performed through the drill string and the cement slurry never comes in contact with the inside of the casing.

In FIG. 8 a drill string is lowered into the casing to be cemented. The drill string contains a sealing adapter 101 at its lower end for contacting and fluidically sealing the drill string to the cementing shoe 97. After the drill string is lowered into sealing contact with the cementing shoe 97, a predetermined amount of cement slurry is pumped down the drill string, out shoe 97, and into the annulus 106 around the casing 85. A latch-down plug 99 is placed behind the cement slurry and working fluid is pumped in behind the plug to insure that the entire charge of cement is delivered to the desired annulus area. Latch-down plug 99 has wiper collars 100 made of elastomeric material and designed to clean the drill string inner surface of cement slurry.

After the first stage of cement has flowed through shoe 97, latch-down plug 99 engages and latches to shoe 97 and seals its passageway off. This indicates to the surface by the rapidly increasing drill string pressure that the first stage is cemented and then the following stages can be completed as described in the method above in conjunction with FIG. 7.

Referring now to FIG. 9, another method of using the cementing tool of this invention for multi-stage cementing is illustrated. This method is advantageous for cementing when the annulus around the casing does not contain fluid all the way to the surface. Under those circumstances the fluid in the annulus outside of the casing becomes balanced with the fluid between the casing and the drill string by flowing out of the inner annulus 86 in the casing and into the outer annulus 106. Thus when a cement slurry is flowed out of the drill string and into the casing it will pass up the inside of the casing as well as passing through the cementing tool and into the outer annulus.

This will result in as much cement in the inner annulus 86 between the drill string and casing as there is in the outer annulus 106 exterior of the casing. Normally the inner annulus is full of fluid which prevents cement from passing up the inner annulus and forces it into the outer annulus, and the outer annulus is full of working fluid also.

Under some conditions, such as encountering a lost circulation formation, the outer annulus fluid may have

flowed into a cavity or porous permeable formation, leaving the outer annulus partially or completely empty.

Use of the cementing tool of this invention in conjunction with the bull plug, isolation packer and circulating valve as disclosed in FIG. **9**, allows a multistage cementing operation to be performed when the outer annulus can not be filled with working fluid.

In operation, the first stage of cementing is accomplished through the casing without having the drill string in the hole. A premeasured quantity of cement slurry is pumped into the casing followed by a cement plug **95** which separates the cement from the working fluid and also wipes the interior casing wall clean of cement. Working fluid is pumped into the casing behind plug **95** until all of the cement is forced out through cementing shoe **97** and up the outer annulus. At this point, plug **95** seats in shoe **97**, sealing off the passage therethrough and indicating to the operator at the surface that the second stage is ready to begin.

Then the drill string is run in the casing to begin the subsequent cementing stages. Circulating valve **90** is in the closed position when running in the hole. A by-pass **105** is provided in the isolation packer to allow fluid to flow around the sealing cups of packers **91** and **92**, and through by-pass channel **105** as the drill pipe string is lowered or raised in the hole. Fluid can enter the drill pipe string since it is free to flow past the lower sealing cup **92** and into the drill pipe through the port hole **103** connecting the interior of the drill pipe to the outside of the isolation packer between the two sets of sealing cups of packers **91** and **92.** This will allow the drill pipe to fill as it enters the hole thereby cancelling the natural tendency of the pipe to be buoyant in the heavy working fluid. Fluid could not otherwise enter the drill string because of bull plug **102** sealing the bottom end of the drill string.

The drill string is lowered in the casing far enough to pass through the cementing tool **1** at the next stage to be cemented. The lower packer **92**, closing positioner **60**, upper packet **91**, circulating valve **90**, and opening positioner **40** all pass downward through the cementing tool **1**, which is initially in the closed position. The drill string is then lifted sufficiently to bring the opening positioner **40** into engagement with valve sleeve **3** thereby opening it and aligning ports **6** and **7.** Closing positioner **60** is also drawn up through the cementer **1** but the lower packer **92** is not. Circulating valve **90** is then closed and cementing of the second stage is achieved by flowing cement slurry down the drill string and out one or more ports **103** in packer mandrel **104** of upper packer **91** The cement slurry is prevented from traveling up the inner annulus **86** by packer **91** and from traveling down the inner annulus by packer **92.**

After the predetermined amount of cement has been pumped into the annulus **106** in the second stage, the drill string is set down enough to pass the closing positioner **60** through the cementing tool **1**, thereby engaging sleeve **3** and moving it downward into the closed position. Excess cement remaining in the drill string and in the section of inner annulus between the packers is then reversed out by pumping working fluid down the inner annulus **86**, through bypass channel **105** in the isolation packer mandrel **104**, into the inner annulus below lower packer **92**, up past packer **92** forcing the excess cement back through ports **103**, and into the drill string bore **87** where it is carried by the working fluid to the surface and out of the string.

FIG. **10** illustrates a method of cementing all stages including the first stage through the drill string **89** when the outer annulus is not filled with fluid as was the case in FIG. **9.** In this operation the drill string is run in the casing until it seats on the cementing shoe **97** and is fluidically sealed by sealing adapter **101** which may be initially attached to either the drill string or the cementing shoe. The drill string contains the same elements as did the drill string of FIG. **9** except for bull plug **102** which is not needed in this operation.

Cement is then pumped through the drill string in a predetermined amount and out through shoe **97** into the outer annulus **106.** When the desired amount of cement has been pumped into the drill string, two latch plugs **107** and **108** are placed in the drill string behind the cement and working fluid is pumped in behind the first latch plug **107.**

As the two latch down plugs **107** and **108** are pumped down the drill pipe string, the first plug **107** latches into the top of the float collar or float shoe to provide a second back pressure valve in addition to the float shoe or collar. If the fluid level in the hole is low, this latch down plug will also prevent the overbalance of fluid inside the drill pipe from flowing downward through the float shoe forcing the cement up the casing annular area beyond the casing shoe area where it is imperative that you have uncontaminated, durable cement. This plug also signals the surface by rising drill string pressure that the first stage of cement is completed and the second stage is ready to begin. The second latch down plug **108** can be entered in the drill pipe string immediately behind the first plug or after the first plug has landed in the float shoe or collar. The drill pipe will be raised to break the seal with the float collar; thereby, allowing the second plug to be pumped to a shut off in the end of the drill pipe string sealing off the passage of fluid therethrough. The inside diameter of the latch down seat in the end of the drill pipe is necessarily larger than the inside diameter of the latch down seat provided in the top of the float collar or shoe.

The drill string is then lifted up through the cementing tool **1** at the next stage to be cemented and the method is continued identical to the second stage cementing of the method of FIG. **9.** Latch plug **108** remains in the drill string **89** and serves the same purpose as bull plug **102** in FIG. **9.** The process is repeated for each additional cementing stage until the cementing is entirely completed.

Thus by the use of the methods and apparatus of this invention, a smooth, uniform, homogeneous sheath of cement can be applied to the outer annulus in a casing lined well bore thereby overcoming the difficulties of the prior art.

Although a specific preferred embodiment of the present invention has been described in the detailed description above, the description is not intended to limit the invention to the particular forms or embodiments disclosed herein, since they are to be recognized as illustrative rather than restrictive and it will be obvious to those skilled in the art that the invention is not so limited. For example, hollow cementing plugs could be used in the above described invention rather than the solid plugs, which have to be inserted into the pipe from the top. The hollow plugs would be placed in the casing and drill string prior to being inserted in the bore

hole and could be activated by dropping balls or plugs into seats in the hollow plugs, pressuring up the tubing and shearing the shear pins holding the cementing plugs in place. It would also be possible to alter the distance between the opening and closing positioners to gain more latitude in the lifting up and setting down steps of the operation.

It is further contemplated that instead of collet fingers on the lower end of valve sleeve **3**, one or more circular rings could be placed around the sleeve in grooved channels in the sleeve, which rings would project outward from the vlave sleeve wall and act as spring clips sliding in and out of matching sloped wall grooves in the housing **2**, as sleeve **3** moved up and down in the housing. The spring constant of the rings could be preset to prevent premature or unwanted movement of sleeve **3** in housing **2**. The invention is declared to cover all changes and modification of the specific example of the invention herein disclosed for purposes of illustration, which do not constitute departures from the spirit and scope of the invention.

What is claimed is:

1. A full opening cementing tool for multiple stage oil well cementing comprising:

a. an outer cylindrical housing having a plurality of ports through the wall;

b. a valve sleeve located telescopically within said housing and having a plurality of ports through the wall capable of fluidically communicating with said ports in said housing in a first open position and fluidically sealed from said housing ports in a second closed position;

c. spring tension means between said housing and said sleeve for preventing premature or unwanted movement of said sleeve in said housing;

d. means attached to said housing for inserting said housing into a standard casing string;

e. first means for engaging said sleeve and moving said sleeve from said first position to said second position; and

f. second means for engaging said sleeve and moving said sleeve from said second position to said first position, said first and second means for engaging said sleeve being fixedly attached to a drill string or tubing string located concentrically within said sleeve and telescopically movable within said sleeve.

2. The cementing tool of claim **1** wherein said tool further comprises seal means between said housing and said sleeve arranged to prevent fluid communication between the walls of said housing and said sleeve, and said housing further having an inner annular circumferential recess communicating with said ports in said housing and an inner annular ridge having sloping walls and located inside said housing.

3. The cementing tool of claim **2** wherein said sleeve further has a first inner annular recess in said sleeve, having a sloping side wall, a perpendicular side wall, and a circumferentially coaxial wall; a second inner annular recess having a sloping side wall, a perpendicular side wall, and a circumferential coaxial wall; a beveled end at one end of said sleeve; a skirt at the opposite end of said sleeve, said skirt being formed by an enlargement in the bore through said sleeve; and an outer annular recess in said sleeve arranged to receive said inner annular ridge in said housing.

4. The cementing tool of claim **1** wherein said spring tension means comprises a plurality of collet fingers located around one end of said sleeve, an inner annular ridge on said housing, an inner annular recess in said housing between said ridge and said means for inserting said housing into a casing string; with said collet fingers having an outer annular ridge adapted to abut said ridge and fit within said recess.

5. The cementing tool of claim **1** wherein said spring tension means comprises one or more circular rings made of an elastic metal and located within an outer annular recess in said sleeve, said rings adapted to project outward from said sleeve and being capable of being contracted sufficiently to place the outer surface of said rings flush with the outer surface of said sleeve; said housing having two inner annular recesses having sloping walls, one of said recesses adapted to receive said rings in a closed sleeve position and the other of said recesses adapted to receive said rings in an open sleeve position.

6. The cementing tool of claim **1** wherein said first and second means for engaging said sleeve each comprises a plurality of spring arms integrally attached to a spring collar, said spring collar encircling and fixedly attached to a spring mandrel, said spring mandrel containing a plurality of shielding drag lugs, one for each said spring arm, and said spring mandrel being adapted to be interposed between two sections of standard drill pipe or tubing.

7. The cementing tool of claim **6** wherein said spring arms each contain a perpendicular shoulder capable of and adapted to engage a mating perpendicular shoulder within said sleeve and also adapted to transmit sufficient force to said sleeve to move said sleeve within said housing from an open to a closed position and from a closed to an open position; and said spring arms each further comprise an outer shoulder arranged to engage an inward projecting shoulder in said means for inserting said housing in a casing string, said shoulder arranged to disengage said spring arms from said sleeve after moving said sleeve a predetermined distance.

8. Oil well cementing apparatus capable of cementing any number of annulus cementing stages and adapted to be interposed between sections of oil well casing comprising:

a. one or more sliding sleeve cementing valves adapted to be interconnected within a casing string, each said valve comprising ported sliding inner sleeve means and a ported stationary outer housing, said sleeve valves each being movable from a closed position to an open position and from an open position to a closed position an indefinite number of times, each said valve adapted to be placed one at each cementing stage location;

b. opening means adapted to be arranged axially on a drill string or tubing string to be moved telescopically within the casing and through said cementing valves, said opening means adapted to engage said inner sleeve means so as to move said inner sleeve means to a valve-open position; and

c. closing means adapted to be arranged axially on a drill string or tubing string, to be moved telescopically within the casing and through said cementing valves, said closing means adapted to engage said inner sleeve means so as to move said inner sleeve means to a valve-closed position.

9. The apparatus of claim **8** further comprising:

a. isolation packer means located on the drill string and in close proximity to said opening and closing means;

b. circulating valve means on the drill string capable of providing fluid communication from the interior of the drill string tubing to the annulus between the drill string and the casing; and

c. means for sealing the bottom end of the drill string against fluid flow therethrough.

10. The apparatus of claim **9** wherein said isolation packer means comprises an upper packer and a lower packer, said upper packer having two annular elastomeric cups, one said cup being concave upward and one said cup being concave downward; said lower packer having one elastomeric cup, which cup is concave upward and said upper and lower packers adapted to fluidically seal off a cross section of the casing against fluid flowing from the direction of concavity of each said elastomeric cup.

11. The apparatus of claim **10** wherein said opening means is located above said closing means on the drill string, said upper packer is located on the drill string between said opening and said closing means, said lower packer is located below said closing means on the drill string, said circulating valve is located below said lower packer; and said isolation packer means further comprises a tubular mandrel body to which said elastomeric cups are attached, said mandrel body having ports therethrough capable of communicating fluidically between the inner bore of said tubular mandrel and the annulus between the tubing string and the casing, said ports located directly below said upper packer cups.

12. The apparatus of claim **11** wherein said tubular mandrel body further comprises a packer bypass channel within the wall of said mandrel body providing fluid communication from the annulus area above said upper packer to the annulus area below said lower packer, and said circulating valve means is adapted to be actuated by remote control from ground surface to provide pressure balance when coming out of the hole with the drill string.

13. The apparatus of claim **8** further comprising spring tension means in said sliding sleeve cementing valves adapted to prevent opening or closing of said valves until a certain predetermined tensile or compressive force is applied to said inner sleeve means, and seal means between said sleeve means and each of said housings preventing fluid flow between the walls of said sleeve means and said housings.

14. A method of cementing the outer casing annulus of a well bore in any desired number of stages wherein the casing in the well bore has a predetermined number of casing valves located in the casing wall in preset locations therein; said method comprising:

a. flowing a precalculated quantity of cement slurry down the interior of the well casing, out the bottom of the casing and back up the annulus between the casing and the well bore;

b. inserting a wiper plug in the casing immediately behind said cement slurry;

c. pumping a working fluid behind the wiper plug, said fluid having the consistency and specific gravity near that of the cement slurry, thereby forcing the wiper plug and cement slurry to the bottom of the casing;

d. applying pressure to said working fluid until the wiper plug seats in sealing engagement in the bottom of the casing thereby causing an indicative rise in fluid pressure in the casing;

e. running in a string of tubular pipe in the well casing, said string of pipe having an opening positioner and a closing positioner located thereon;

f. engaging said opening positioner in the lowermost of said casing valves and thereby opening said valve and providing fluid communication channels between the annulus inside the casing to the annulus outside the casing;

g. pumping a second predetermined quantity of cement slurry down the interior of the pipe string and out the bottom end of the pipe, whereby said second slurry flows through said casing valve and into the second stage of the exterior casing annulus;

h. engaging said closing positioner in said lowermost casing valve and thereby closing said valve against additional fluid flow;

i. lifting the string of pipe to the next adjacent area of the casing to be cemented, which area contains another casing valve; and

j. repeating said steps (f) through (i) above until all stages of cementing in the exterior casing annulus have been completed.

15. A method of cementing the annulus between a well casing and the well bore hole in a plurality of separate distinct stages wherein the casing contains a casing valve for each stage to be cemented, said casing valves being interposed between sections of casing in predetermined locations; the method comprising the steps of:

a. inserting a string of pipe within the casing into fluidically sealed engagement with the lower end of the casing, said string of pipe having an internal bore passage communicating through the bottom of the casing, said sealed engagement serving to close off the bottom of the annulus area between the pipe and the casing, said string of pipe also having valve opening means and valve closing means attached exteriorly thereto;

b. pumping a predetermined quantity of cement slurry through the pipe string inner bore, out the bottom of the casing, and up the annulus between the casing and the well bore;

c. placing a latch-down plug in the pipe behind said cement slurry;

d. pumping into the pipe behind said plug a working fluid having a specific gravity similar to that of the cement slurry, thereby forcing said plug down the pipe string into latching engagement with the bottom of the casing, thereby effecting a seal across the entire casing passage at the bottom;

e. lifting the pipe string partially out of the casing until said opening means engages and opens the lowermost of said casing valves and the bottom of the pipe string is slightly above the opened valve;

f. pumping a second predetermined quantity of cement slurry down the pipe bore and through the opened casing valve into the exterior casing annulus thereby effecting a cementing of the second stage;

g. engaging said closing means in said casing valve thereby closing the valve;

h. lifting the pipe string to the next adjacent casing valve at the next stage to be cemented; and

i. repeating said steps (e) through (h) above until the entire annular area to be cemented has been cemented.

16. A method of cementing the annulus between a well casing and a well bore hole in a plurality of distinct and separate stages wherein the casing contains a casing valve for each stage to be cemented, said casing valves being interposed between sections of casing in predetermined locations; the method comprising the steps of:

a. pumping a precalculated quantity of cement slurry down the interior of the casing, out the bottom of the casing, and back up the annulus between the casing and the well bore;

b. inserting a wiper plug in the casing immediately behind the cement slurry;

c. pumping a working fluid behind the wiper plug, said fluid having similar specific gravity to that of the cement, thereby forcing the wiper plug and cement slurry to the bottom of the casing, forcing all of the cement into the annulus, and sealingly engaging the wiper plug in the bottom end of the casing;

d. running in a string of pipe in the casing, said string of pipe containing casing valve opening means, upper isolation packer means below said valve opening means, cementing ports through the pipe wall below said upper packer means, casing valve closing means below said cementing ports, lower packer means below said valve closing means, seal means closing off the lower end of the drill pipe, fluid bypass means providing fluid communication from the annular area above said upper packer means to the annular area below said lower packer means, and circulating valve means in said pipe for providing fluid communication between the internal pipe bore and the casing bore, and being opened only when coming out of the hole with the pipe string;

e. engaging said valve opening means in the lowermost of said valves in the lowermost uncemented stage thereby opening said valve and providing fluid communication through the casing;

f. aligning said cementing ports in the pipe with said opened casing valve;

g. pumping another predetermined amount of cement slurry into the pipe string, out the cementing ports in the pipe below said upper packer, and through the casing valve into the area of outer casing annulus to be cemented during this stage;

h. engaging said closing means in said opened casing valve by lifting up and then setting down on the pipe string sufficiently enough to move said closing means upward and downward through said valve, thereby closing said valve;

i. lifting the pipe string to align the opening means with the next upper adjacent casing valve in order to accomplish the next cementing stage; and

j. repeating the above said steps (e) through (i) until all desired cementing stages have been completed.

17. The method of claim 16 further comprising the step of reversing out after each cementing stage the excess cement slurry remaining between said upper and lower packer means and in the pipe string, said reversing out comprising pumping a working fluid into the annulus between the pipe and casing, through the fluid bypass means into the annular area below the lower packer means, and up past the lower packer means, thereby forcing the excess cement through the cementing ports in the pipe and up the bore of the pipe in front of the working fluid.

18. The method of claim 17 further comprising the steps of opening said circulating valve by manipulation from the surface and removing said pipe string from the borehole.

19. A method of cementing the annulus between a well casing and a well bore hole in a plurality of distinct and separate stages wherein the casing contains a casing valve for each stage to be cemented, said casing valves being interposed between sections of casing in predetermined locations, the method comprising the steps of:

a. running in a string of pipe in the casing, said string of pipe containing casing valve opening means, upper isolation packer means below said valve opening means, cementing ports through the pipe wall immediately below said upper packer means, casing valve closing means below said cementing ports, lower packer means below said valve closing means, fluid bypass means providing fluid communication from the annular area above said upper packer means to the annular area below said packer means, and circulating valve means in said pipe for providing fluid communication between the pipe bore and the casing bore when said pipe string is coming out of the well;

b. engaging said pipe string in a sealing adapter in the bottom of the casing thereby sealing off the annulus between the pipe and the casing while maintaining a clear passage from the bore of the pipe through the bottom of the casing;

c. pumping a first latch plug down the pipe to sealingly engage in the float shoe;

d. pumping a predetermined quantity of cement slurry behind the first latch plug, down the pipe, through the bottom of the casing, and back up the annulus;

e. inserting a second plug in the pipe immediately behind the cement slurry;

f. pumping working fluid into the pipe behind the second plug, said fluid having a similar specific gravity to that of the cement slurry, thereby forcing the second plug and cement slurry to the bottom of the pipe, forcing all of the cement into the exterior casing annulus and sealingly engaging the second plug in the bottom end of the pipe;

g. engaging said valve opening means in the lowermost of said valves in the lowermost uncemented stage thereby opening said valve and providing fluid communication through the casing;

h. aligning said cementing ports in the pipe with said opened casing valve;

i. closing said circulating valve means;

j. pumping another predetermined amount of cement slurry into the pipe string, out the cementing ports in the pipe and through the casing valve into the area of outer casing annulus to be cemented during this stage;

k. engaging said closing means in said casing valve by appropriately manipulating the pipe string, thereby closing said casing valve;

l. lifting up on the pipe string to bring the opening means to the next upper adjacent casing valve in order to begin the next cement stage; and

m. repeating the above said steps (g) through (l) until all desired cementing stages have been completed.

20. The method of claim **19** further comprising reversing out after each cementing stage the excess cement slurry remaining between said upper and lower packer means and in the pipe string, said reversing out comprising pumping a working fluid into the annulus between the pipe and casing, through the fluid bypass means into the annular area below the lower packer means, and up past the lower packer means thereby forcing the excess cement through the cementing ports in the pipe and up the bore of the pipe in front of the working fluid.

21. A tool for passing inside a sleeve valve to selectively open and close said sleeve valve, comprising:

a. tubular body means adapted to be connected to a string of pipe and passed axially into the sleeve valve;

b. first collar means encircling said body means and snugly attached thereto;

c. second collar means encircling said body means and attached thereto, below said first collar means;

d. a plurality of first spring arms attached to said first collar means, and adapted to engage said sleeve valve when closed and move said sleeve valve into an open position when passing in one direction therethrough;

e. a plurality of second spring arms attached to said second collar means, and adapted to engage said sleeve valve when open and move said sleeve valve into a closed position when passing in one direction therethrough;

f. means on said first spring arms for disengaging said first spring arms after said sleeve valve has been opened; and

g. means on said second spring arms for disengaging said second spring arms after said sleeve valve has been closed.

22. The tool of claim **21** further comprising:

a. upper packing means comprising two upper back-to-back concave elastomeric sealing cups located circumferentially on said tubular body means between said first and second collar means;

b. lower packing means comprising a lower concave elastomeric sealing cup located circumferentially on said tubular body below said second collar means and adapted so that the concave portion of said lower sealing cup faces said upper packing means;

c. said tubular body having cementing ports passing through the wall thereof and located between said upper packing means and said second collar means, in close proximity to said upper packing means;

d. said tubular body having fluid bypass means adapted to fluidically communicate the exterior of said tubular body above said upper packing means to the exterior of said tubular body below said lower packing means; and

e. means for sealing the bore passage through said tubular body, said means adapted for sealing the ends of said tubular body below said lower packing means.

23. The tool of claim **22** further comprising circulating valve means located on said tubular body wall below said lower packing means and adapted to selectively provide fluid communication from the interior of said tubular body to the exterior of said tubular body.

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