Sept. 11, 1956 D. W. REED 2,762,440

APPARATUS FOR CEMENTING WELLS

Filed May 17, 1954 2 Sheets-Sheet 1

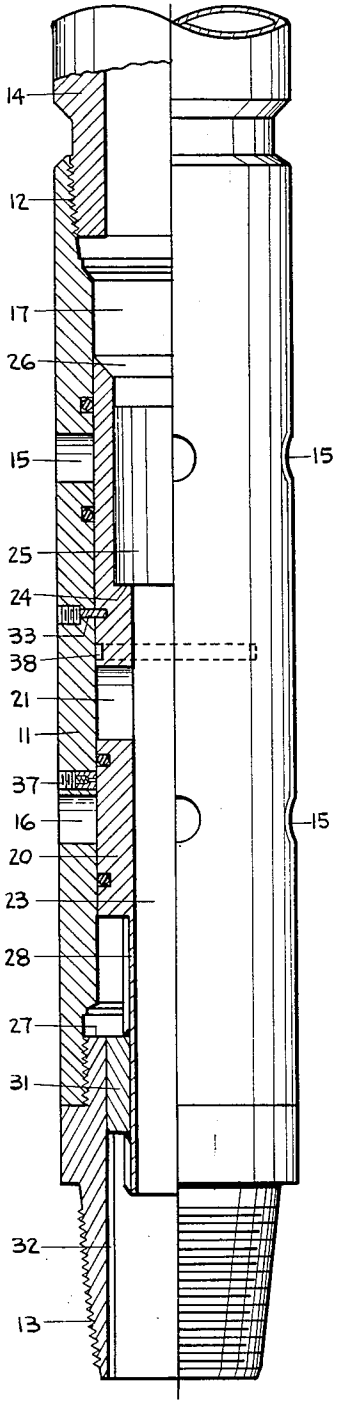


Fig. 1

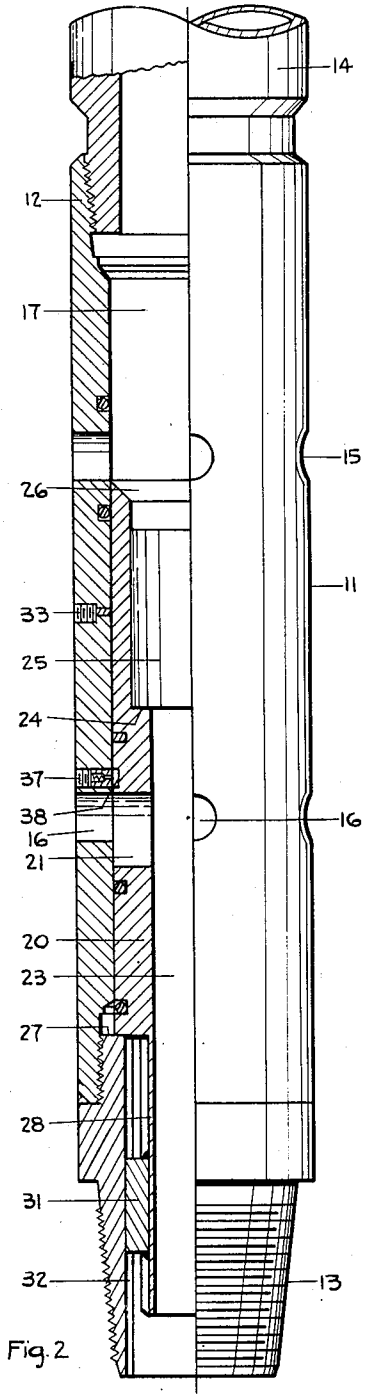


Fig. 2

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APPARATUS FOR CEMENTING WELLS

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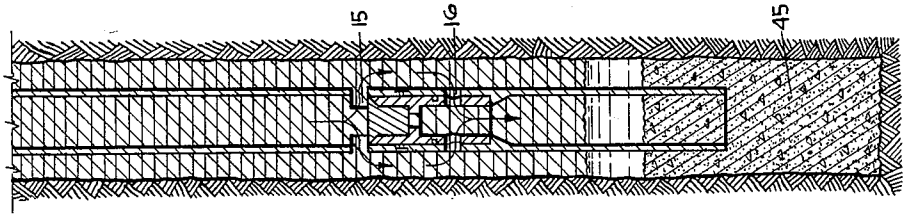


Fig. 7

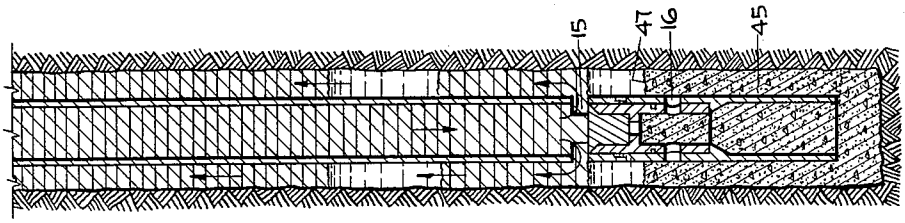


Fig. 6

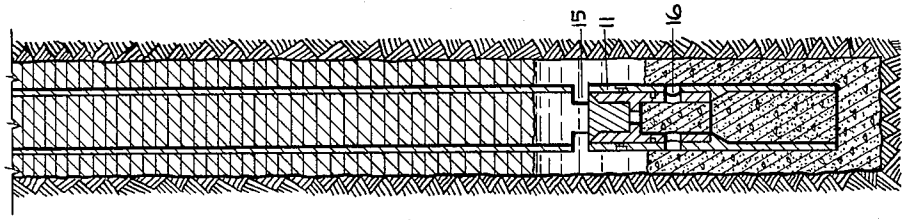


Fig. 5

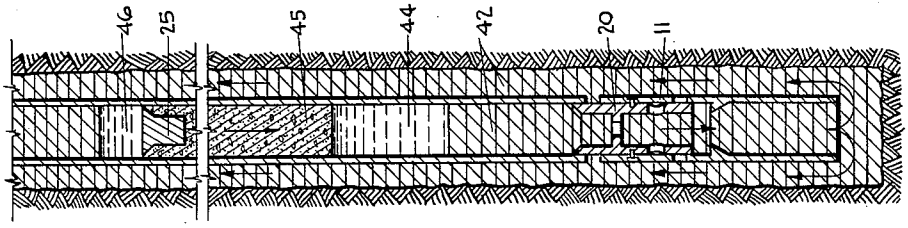


Fig. 4

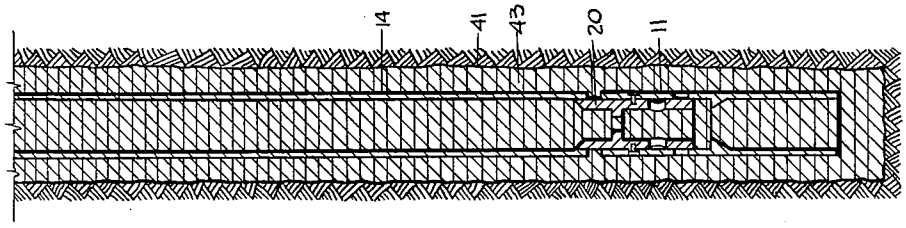


Fig. 3

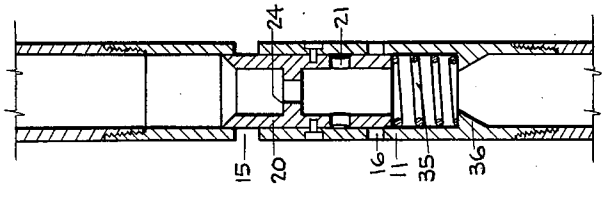


Fig. 8

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APPARATUS FOR CEMENTING WELLS

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Application May 17, 1954, Serial No. 430,006

4 Claims. (Cl. 166—154)

This invention relates to apparatus and methods of cementing oil wells and pertains more particularly to valve mechanisms forming part of the equipment employable in connection with the cementing, acidizing, washing, production, etc., of oil and gas wells.

In oil well drilling operations, it frequently occurs that a well is drilled several hundred feet or more below the oil or gas producing formations traversed by the well borehole. In many instances, the non-oil bearing strata below the producing formations may contain water. Thus, if these water-bearing formations are not sealed off, the contaminating water materially interferes with the production of oil from the oil-bearing strata.

At present, the lower end of a well borehole is filled with cement in an operation known as plugging-back the well, which comprises hanging a cementing pipe string in the borehole, circulating cement slurry down the pipe stream followed by drilling mud, balancing the pressures between the inside of the pipe and the annulus between the pipe and the borehole wall at the level where the cement plug is to be placed by calculations, and subsequently withdrawing the pipe string from the well.

The above-described cementing procedure for plugging back a well has several drawbacks. In the first place, errors are quite common in calculating the amount of cement to be employed, or the amount of drilling mud to be pumped following the cement to place the cement in its desired position within the well. For example, if eroneous drill pipe calculations are used, the slug of cement being pumped into the well may never reach the bottom of the pipe string or it may be pumped out of the bottom of the pipe string and a substantial distance up the annulus between the pipe string and borehole wall to an undesired location. Errors in calculation are commonly made either by using an incorrect diameter of pipe in the calculations, or due to the fact that old cement may be sticking to the inside wall of the pipe string, thus decreasing the assumed volume of the string. A cement plug which is inaccurately placed within a borehole may fall to the bottom of the borehole when the cementing pipe string is withdrawn therefrom, and in addition may be contaminated with drilling fluid. It has been found that cements need be contaminated with only as little as 1% of foreign matter to lose their required strength.

A second disadvantage with normal plug-back cementing operations is that considerable swabbing may take place when the cementing pipe string is withdrawn from the well borehole. The swabbing action within a well results in the drawing of fluid from the formation into the borehole upon the withdrawal of a pipe string therefrom.

A third disadvantage of the presently known cementing methods is that there are often unbalanced pressure conditions between the column of drilling mud in the pipe string and the cement slurry and drilling mud in the annulus outside the pipe string. Thus, when the pressures at the well head are equalized, substantial amounts of fluid may be forced out of either the pipe string or the annulus in an undesirable manner.

Another disadvantage is that cementing valves which are presently used in cementing operations often open prematurely, or on the other hand, fail to open at all due to small amounts of cement becoming lodged within the valve structure.

It is, therefore, a primary object of the present invention to provide an apparatus for placing a plug of cement in the bottom of a well borehole and equalizing the pressure within a pipe string used for cementing purposes and the annulus outside said pipe string at a point in the borehole just above the cement plug.

It is a further object of this invention to provide a positive-action cementing valve which is not rendered inoperative by the passage of cement or other contaminating materials therethrough.

Another object of this invention is to provide an apparatus for accurately placing a small volume cement plug at a predetermined position within a well borehole.

A further object of this invention is to provide apparatus for placing a plug of cement in the bottom of a well borehole filled with a drilling fluid in a manner so as to eliminate contamination between the drilling fluid and the cement and to minimize any swabbing action as the cementing pipe string is withdrawn from the well borehole.

Still another object of the present invention is to provide an apparatus adapted to compensate for errors in volumetric calculations of the amounts of cement and drilling fluid employed in placing the cement at the predetermined position in the well borehole.

Other objects and advantages will be apparent from the following description taken in reference to the drawing, wherein:

Figures 1 and 2 are views in front elevation, partly in longitudinal cross-section, of a valve assembly of the present cementing apparatus with the ports of the valve assembly in their closed and open positions, respectively.

Figures 3 through 7 illustrate schematically a series of steps in the performance of plug-back cementing operations in a well borehole according to the method of this invention.

Figure 8 is a diagrammatic view showing the principal elements of the equalizing valve of the present cementing apparatus.

Referring to Figures 1 and 2 of the drawing, a special sub or elongated tubular housing **11** is threaded at its upper and lower ends **12** and **13**, respectively, for connection between any two sections of a string of pipe **14**, which is lowered into a well borehole for cementing purposes. The sub or housing **11** is provided with two sets of fluid ports **15** and **16** which are positioned in axially spaced relationship in the sub.

Mounted for sliding vertical movement in the bore **17** of the sub **11** is a tubular sleeve **20** provided with a set of fluid ports **21**, which are adapted to register with the lower fluid ports **16** of the sub. The length of the tubular sleeve **20** above the fluid ports **21** is no greater than the distance between the upper and lower fluid ports **15** and **16** of the sub. In order to minimize the effect of a poor seating of the sleeve **20** within the sub **11**, the fluid ports **21** in the sleeve are elongated so that they may register with the ports **16** under all operating conditions whenever the sleeve **20** is actuated. Thus, when the fluid ports **21** of the sleeve are in register with the lower fluid port **16** of the sub, as shown in Figure 2, the upper fluid ports **15** of the sub are also open.

Preferably, the bore **23** of the tubular sleeve **20** is enlarged or machined to a greater diameter at the top of the sleeve to form a shoulder **24**. The shoulder **24** acts as a stop for a plug or wiper **25** adapted to be propelled through the string of pipe **14** and received in the recessed bore portion at the top of the sleeve **20**. Preferably,

the top edge of the sleeve 20 is beveled inwardly as at 26 to prevent any cement from accumulating thereon.

A shoulder 27 is provided on the inner wall of the sub 11 near the bottom thereof to act as a stop limiting the downward movement of the tubular sleeve 20. A downwardly extending tubular skirt 28 is secured to the lower end of the sleeve 20. This skirt 28 has been found to be extremely important since it prevents any cement passing through the bore 23 of the sleeve 20 from settling on the shoulder 27. Any accumulation of cement on shoulder 27 limits the movement of the sleeve 20 within the sub 11 and thus prevents ports 16 and 21 from coming into register. The skirt 28 is slightly smaller in outside diameter than the tubular sleeve 20, so as to extend at all times through the lower shoulder 27 of the sub 11. There is sufficient clearance between the skirt 28 and the shoulder 27 to allow free passage of fluid past the shoulder as the sleeve 20 travels the length of its stroke.

A key 31 is secured to the skirt 28 or the lower end of the sleeve 20 and is mounted for sliding movement within a keyway 32 formed or cut longitudinally in the inner wall of the sub 11. A shear pin 33 is mounted in the wall of the sub 11 so as to extend into a shear pin recess 34 in the wall of the sleeve 20 and hold the sleeve 20 in its uppermost position so that the upper and lower fluid ports 15 and 16, respectively, of the sub 11 are closed. The size and strength of the shear pin 33 is selected so as to shear under a predetermined pressure.

Another alternative means which may be employed to hold the sleeve 20 in its uppermost position so as to normally close ports 15 and 16 is shown in Figure 8 of the drawing. A compression spring 35 may be employed between the lower end of the sleeve 20 and shoulder or spring-retaining stop 36. The spring 35 may also be used in combination with the shear pins 33 of Figure 1, thus providing means for raising the sleeve 20 and closing ports 15 when the circulation of fluid in the pipe string 14 has been stopped. If desired, suitable latch means may be employed to hold the sleeve 20 in its lowermost position after it has once been forced to this position. The latch may be in the form of a spring loaded pin 37 mounted in the wall of the sub 11 and adapted to extend radially into a recess of circumferential groove 38 formed in the outer wall of the sleeve 20, as shown in Figure 2.

Referring to Figures 3 through 7 of the drawing, the method of the present invention is initiated by lowering into the borehole 41 a cementing pipe string 14 which extends nearly to the bottom of the borehole. If the borehole 41 has not been thoroughly washed, hydraulic circulating fluid is pumped down through the pipe string 14 and out the open lower end thereof passing upwardly around the outside of the pipe string 14 in the annulus 43 between the pipe string and borehole wall 41. As the fluid circulates upwardly, it carries with it any miscellaneous debris, such as drillings, cavings, etc., which may be in the well.

If it has been decided to plug-back the lower 200 feet of the borehole, that is, fill in with cement, the sleeve-valve apparatus described hereinabove with reference to Figures 1 and 2, is coupled into the pipe string 14 at a location so that it will be suspended substantially 200 feet from the bottom of the borehole when the pipe string is placed therein, as shown in Figure 3.

If the fluid filling the borehole 41 and the pipe 14 is drilling mud, a small volume of wash fluid, such as water 44, is introduced into the pipe string 14 ahead of the cement slurry 45 so as to wash any mud from the inner wall of the pipe string 14 and to separate the drilling mud 42 and the cement 45 so that the cement does not contaminate the mud and the mud does not contaminate the cement, as shown in Figure 4. The volume of cement 45 introduced into the pipe string 14 and pumped therethrough is an amount sufficient to fill the lower 200 feet of the borehole after the pipe string 14 has been withdrawn therefrom.

With the predetermined amount of cement slurry 45 introduced into the pipe string 14, the plug or wiper 25 is inserted into the pipe string on top of the volume of cement. The cement slurry 45 and the plug or wiper 25 are then moved through the pipe string 14 by hydraulic fluid which is pumped down the pipe string on top of the plug 25. If this hydraulic fluid is drilling mud, another small volume of water or wash fluid 46 is interposed between the plug 25 and the drilling mud and follows the plug so as to wash any remaining traces of cement from the inner wall of the pipe string and prevent contamination of both the cement and the mud. Figure 4 indicates the relative positions of the wash fluid 44 ahead of the cement slurry 45 followed by the displacement wiper 25, a second volume of wash fluid behind the wiper followed by displacement mud. If desired, the wiper 25 can be placed behind a second volume of wash fluid 46, but, in that case, the catcher sub 11 and its sleeve valve 20 must be positioned proportionately higher in the cementing pipe string 14. In some wells, the height of the wash fluid column 46 should preferably be equal to the height of the cement column for optimum conditions.

It may be seen from Figure 4 that the circulation of fluid is entirely down through the bore of the sleeve valve 11 and out the lower end of the pipe string 14, thereafter passing upwardly between the pipe string and the borehole wall, since the sleeve valve 20 is still in its uppermost position closing both sets of ports in the sub 11. In Figure 5, the wiper 25 has reached the wiper stop shoulder 24 (Figure 1) within the sleeve 20 and additional pump pressure on the column of hydraulic fluid above the wiper 25 has caused the shear pins 33 to shear allowing the tubular sleeve 20 to be forced downwardly against the sleeve stop shoulder 27, as illustrated in Figure 2.

With the ports 15 and 16 of the hub 11 open, any further displacement of fluid between the space inside and outside of the pipe string 14 will take place through the open ports 15 and 16, as shown in Figure 6, with the top of the cement plug 47 coming between the open ports 15 and 16. Thus, the introduction of any more hydraulic fluid into the pipe string 14 will flow out the open fluid ports 15 above the cement slurry which remains undisturbed in the bottom of the borehole. The displacement of fluids through the open ports may be in either direction and may be intentional, as by the introduction of more hydraulic fluid, or may be due to the unbalance of the fluid columns within and without the pipe string 14.

After the cement slurry 45 has been placed at the bottom of the borehole, the pipe string 14 is withdrawn from the borehole. Since the ports 15 and 16 remain open as the pipe string 14 is withdrawn from the well, any fluid within the pipe string passes out the upper fluid ports 15 into the annulus outside the pipe string while other fluid is passing from the annulus through open lower ports 16 into the bottom of the pipe string, thus flushing the bore of the pipe string and minimizing the swabbing action that normally takes place when a cementing pipe string is withdrawn from a well.

The present cementing method and apparatus were first tested in an oil well in the Ventura field in California. It was decided to plug-back to 11,050 feet a well which was bottomed at 11,259 feet with 3½ inch, 15.5 pounds per foot drill pipe hung in a 6 inch borehole just off bottom. A volume of 75 cubic feet of water was used as wash fluid ahead of the cement slurry, which comprises 40 sacks of cement mixed to 122 pounds per cubic foot. The wiper was inserted in back of the cement slurry and 10 cubic feet of water was pumped behind the wiper with drilling mud added to displace the cement to its desired location. It was calculated that 400 cubic feet of mud would be required to displace the plug down to a level where it would actuate the sleeve valve and open the circulation ports. However, an additional 50 cubic feet of mud were

pumped with the excess passing through the upper open ports of the sleeve valve. The pipe string was then pulled from the well dry, and it was found that the apparatus had operated in its designed manner. After waiting 12 hours for the slurry to set, the top of the cement plug was located at 11,046 feet within four feet of the sleeve valve's estimated location during the cementing operation. The cement was hard and the job was considered a success. In normal operation, the actuation of the sleeve valve within the well is determined by observing a change in gauge pressure at the top of the well when the wiper is being displaced through the pipe string.

Thus, by employing the present cementing apparatus and method of cementing in plug-back cementing operations, any unbalanced pressure conditions between the pipe string and the borehole are eliminated, swabbing action within the borehole during the removal of the pipe string is minimized, premature actuation of the sleeve valve or additional displacement of hydraulic fluid through the pipe string does not affect the cement plug, less time is required for performing a plug-back cementing operation, and only small amounts of cement slurry need be employed with relative high assurance of the cement being properly positioned within the borehole. In general, the present invention provides a safe, efficient and economical method and apparatus for securing satisfactory plug-back cementing jobs.

I claim as my invention:

1. Apparatus for controlling the flow of fluids during cementing operations whereby a cement slurry is injected into a well borehole through a string of pipe, said apparatus comprising a tubular body open at both ends adapted to be secured into said pipe string at any desired location, said tubular body being provided with upper and lower port means through the wall thereof in longitudinal spaced relationship with each other, said port means being in open communication between the bore of said tubular body and a well borehole in which said apparatus is positioned, a tubular sleeve normally open at both ends mounted for sliding movement within said tubular body and normally closing said upper and lower port means in said body, said sleeve having port means through the wall thereof adapted to register with the lower port means of said body, stop means fixedly secured to the inner wall of said tubular body for limiting the downward travel of said tubular sleeve, skirt means extending from the lower end of said sleeve for preventing cement from accumulating on said stop means, means in contact between said body and said sleeve to hold said sleeve temporarily in position within said body so that the sleeve closes the port means in said body, and hydraulically operable plug means adapted to pass through said pipe string, said plug means being engagable with said tubular sleeve intermediate the port means of said body for sliding said sleeve in said body to a position opening the upper and lower port means of said body.

2. Apparatus for controlling the flow of fluids during cementing operations whereby a cement slurry is injected into a well borehole through a string of pipe, said apparatus comprising a tubular body open at both ends adapted to be secured into said pipe string at any desired location, said tubular body being provided with upper and lower port means through the wall thereof in longitudinal spaced relationship with each other, said port means being in open communication between the bore of said tubular body and a well borehole in which said apparatus is positioned, a tubular sleeve normally open at both ends mounted for sliding movement within said tubular body and normally closing said upper and lower port means in said body, said sleeve having port means through the wall thereof adapted to register with the lower port means of said body, stop means fixedly secured to the inner wall of said tubular body for limiting the downward travel of said tubular sleeve, skirt means extending from the lower end of said sleeve for preventing cement from accumulating on said stop means, a shear pin in contact between said body and said sleeve to hold said sleeve temporarily in position within said body so that the sleeve closes the port means in said body, and hydraulically operable plug means adapted to pass through said pipe string, said plug means being engagable with said tubular sleeve intermediate the port means of said body for sliding said sleeve in said body to a position opening the upper and lower port means of said body.

3. Apparatus for controlling the flow of fluids during cementing operations whereby a cement slurry is injected into a well borehole through a string of pipe, said apparatus comprising a tubular body open at both ends adapted to be secured into said pipe string at any desired location, said tubular body being provided with upper and lower ports through the wall thereof in longitudinal spaced relationship with each other, said port means being in open communication between the bore of said tubular body and a well borehole in which said apparatus is positioned, a tubular sleeve normally open at both ends mounted for sliding movement within said tubular body and normally closing said upper and lower ports in said body, said sleeve having ports through the wall thereof adapted to register with the lower ports of said body, said sleeve ports being larger than the lower ports in said body, stop means fixedly secured to the inner wall of said tubular body for limiting the downward travel of said tubular sleeve, skirt means extending from the lower end of said sleeve for preventing cement from accumulating on said stop means, a shear pin in contact between said body and said sleeve to hold said sleeve temporarily in position within said body so that the sleeve closes the upper and lower ports in said body, and hydraulically operable plug means adapted to pass through said pipe string, said plug being engageable with said tubular sleeve intermediate the port means of said body for sliding said sleeve in said body to a position opening the upper and lower port means of said body.

4. Apparatus for controlling the flow of fluids during cementing operations whereby a cement slurry is injected into a well borehole through a string of pipe, said apparatus comprising a tubular body open at both ends adapted to be secured into said pipe string at any desired location, said tubular body being provided with upper and lower ports through the wall thereof in longitudinal spaced relationship with each other, said port means being in open communication between the bore of said tubular body and a well borehole in which said apparatus is positioned, a tubular sleeve normally open at both ends mounted for sliding movement within said tubular body and normally closing said upper and lower ports in said body, said sleeve having ports through the wall thereof adapted to register with the lower ports of said body, said sleeve ports being larger than the lower ports in said body, stop means fixedly secured to the inner wall of said tubular body for limiting the downward travel of said tubular sleeve, skirt means extending from the lower end of said sleeve for preventing cement from accumulating on said stop means, a coil spring positioned within said tubular body and in contact between said body and said sleeve to hold said sleeve temporarily in position within said body so that the sleeve closes the upper and lower ports in said body, and hydraulically operable plug means adapted to pass through said pipe string, said plug means being engageable with said tubular sleeve intermediate the port means of said body for sliding said sleeve in said body to a position opening the upper and lower port means of said body.

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