July 21, 1953 J. E. HALL 2,646,125

APPARATUS FOR MULTISTAGE CEMENTING OF DEEP WELLS

Filed Nov. 29, 1946 3 Sheets-Sheet 1

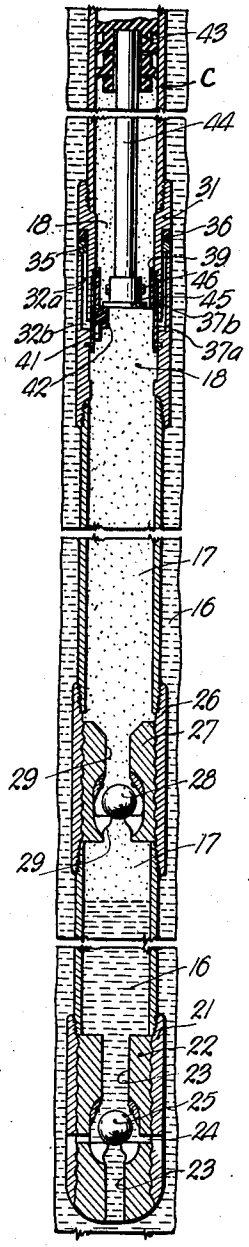


Fig. 1.

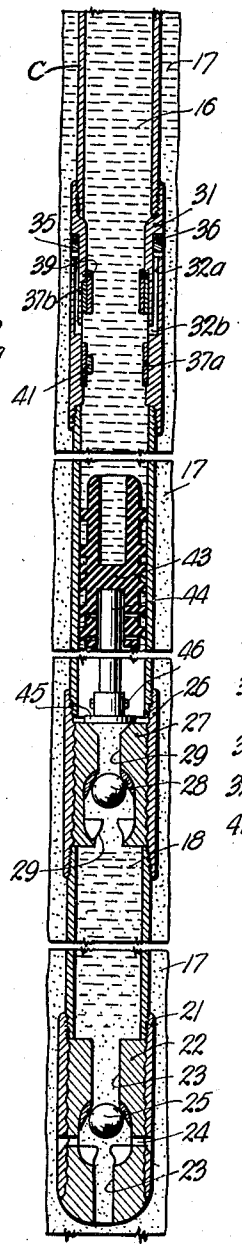


Fig. 2.

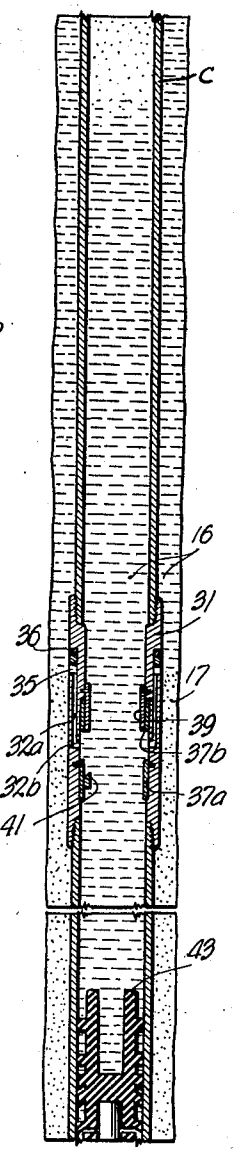


Fig. 3.

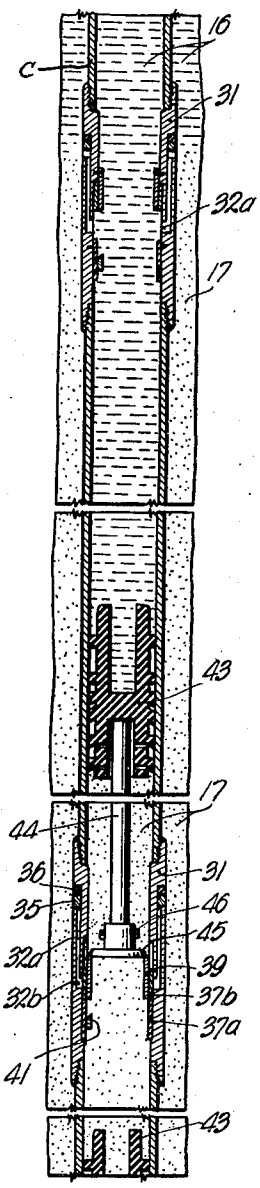


Fig. 4.

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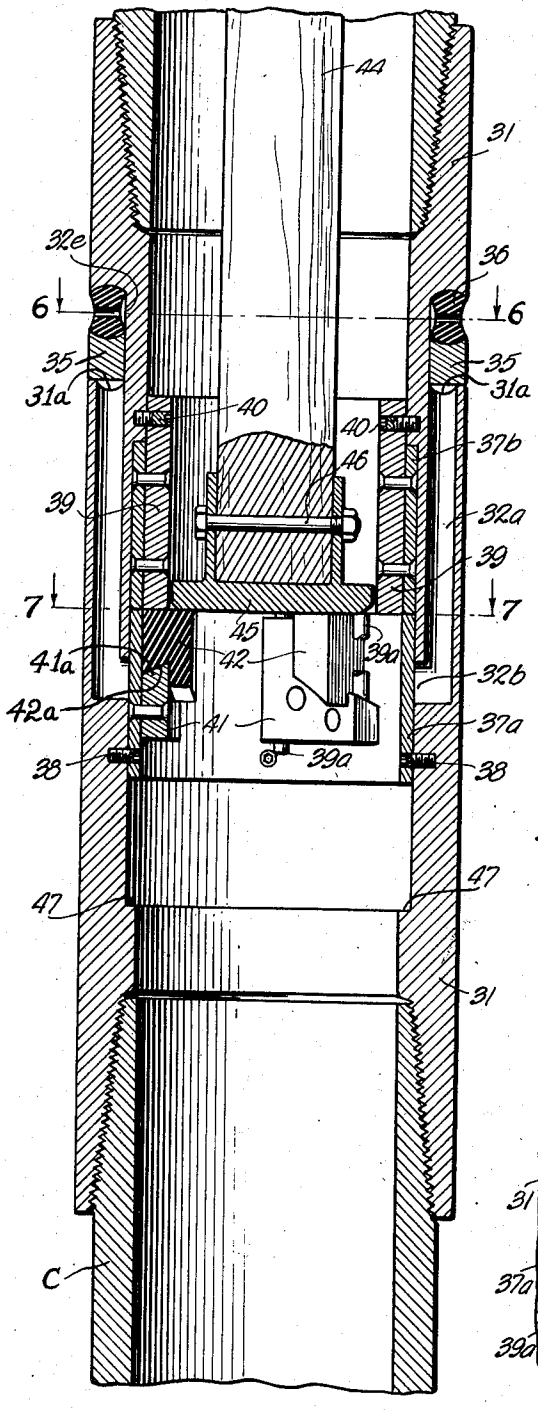


Fig. 5.

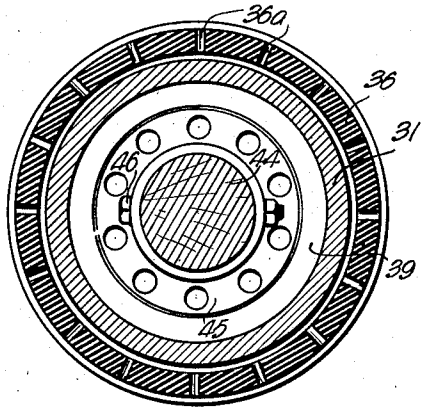


Fig. 6.

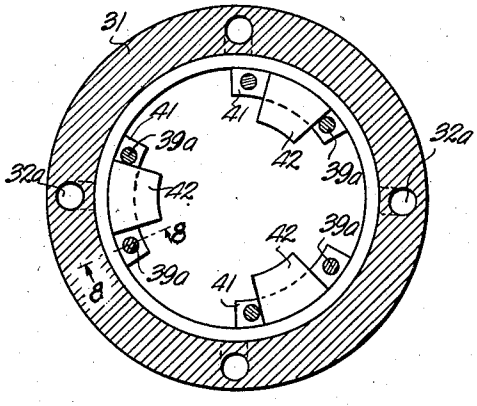


Fig. 7.

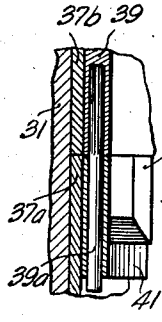


Fig. 8.

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APPARATUS FOR MULTISTAGE CEMENTING OF DEEP WELLS

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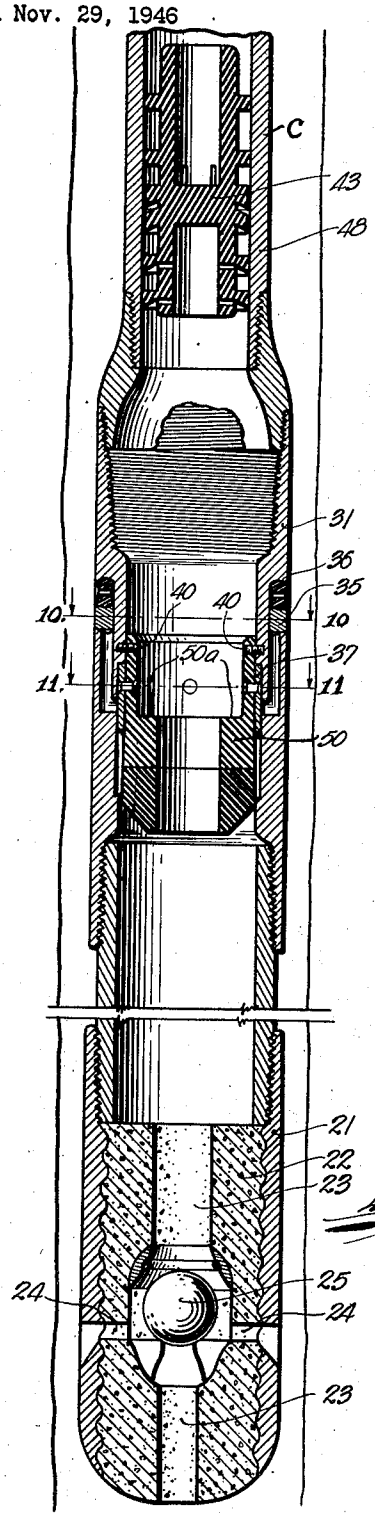


Fig. 9.

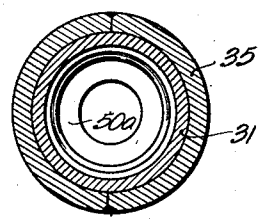


Fig. 10.

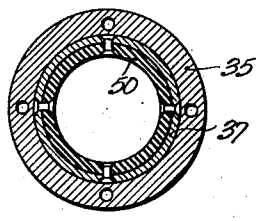


Fig. 11.

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APPARATUS FOR MULTISTAGE CEMENTING OF DEEP WELLS

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Application November 29, 1946, Serial No. 712,950

10 Claims. (Cl. 166—1)

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This invention relates to improvements in multistage cementing apparatus and refers more particularly to apparatus for placing successively columns of cement around the casing in a deep well, or locating in a well not fully cased cement columns outside a section of casing at different heights in a well to seal off troublesome or selected formations.

The salient novelty resides in being able to place cement columns outside of well casing at predetermined heights or intervals in the well while continuing mud circulations above the placed cement during its setting period.

In multistage cementing apparatus now employed, multiple cementing collars are located along the string when the casing is run to establish the location of the lower end or bottom of each cement stage. These collars are equipped with valved ports which are closed while cement is being placed below the level of the ports and are opened thereafter in order that cement may be discharged into the space surrounding the casing above the ports after the lower cement stage has set.

If the valves at the successive collars function properly and no difficulties are encountered with plugging due to cement rising above the collar levels, and if, due to the necessity of interrupting reciprocation of the string and mud circulation, bridging and cave-ins are avoided in the space above the cemented areas, and if all calculations with respect to quantities of cement and character of the well bore in which the cement is to be placed are accurate, it is possible to obtain a satisfactory multistage cementing job. Invariably, however, one or more of the above factors intervene and failures are the rule rather than the exception.

The instant invention, therefore, has for its object the elimination of these difficulties by providing uninterrupted mud circulation above each cement column after it has been placed, and during the setting stage. It provides a medium in the form of the circulating mud which prevents the accumulation of cement at or above the ports in the cementing collars, thereby avoiding difficulties later when cement is discharged through these ports.

It permits uninterrupted reciprocation of the string until the first cement stage is set, reducing likelihood of stoppage and obstructions occurring in the mud circulating passageway or annular space around the casing where later cement columns are to be placed. It greatly reduces failures in multistage cementing and assures success under normal conditions.

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Other and further advantages will appear from the following description.

In the accompanying drawings which form a part of the specification and are to be read in conjunction therewith, and in which like reference numerals indicate like parts in the various views:

Fig. 1 is a fragmentary section of a well bore in which multistage cementing is being carried on with the apparatus of the present invention, showing the cementing shoe, float valve, and lower cementing collar with the lower end of the cementing plug about to open the ports of the collar.

Fig. 2 is a view of a well bore as shown in Fig. 1 after the plug has opened the ports in the collar and has seated at the float valve.

Fig. 3 is a view of the well bore and casing string showing conditions adjacent the cementing collar after the plug has passed and has seated at the float valve, a definite level of cement appearing at the collar ports due to mud circulation thereabove.

Fig. 4 shows a well bore wherein two cementing collars have been interposed in the casing string. Only the top of the first plug which has seated in the float collar is visible at the bottom; the second plug has opened the ports of the upper collar and is seated at the lower collar. In this view, cement has been placed to the level of the ports of the upper collar and mud circulation continues thereabove.

Fig. 5 is an enlarged sectional detail of the cementing collar shown in Figs. 1, 2, 3, and 4.

Fig. 6 is a view taken along the line 6—6 in Fig. 5 in the direction of the arrows.

Fig. 7 is a view taken along the line 7—7 in Fig. 5 in the direction of the arrows.

Fig. 8 is a fragmentary section taken along the line 8—8 in Fig. 7 in the direction of the arrows.

Fig. 9 is a sectional view of a portion of a well bore showing apparatus for cementing a short length of casing in the well by temporarily supporting it at the end of the drill pipe.

Fig. 10 is a view taken along the line 10—10 in Fig. 9 in the direction of the arrows.

Fig. 11 is a view taken along the line 11—11 in Fig. 9 in the direction of the arrows.

Dashed areas inside and outside the casing designated by numeral 16 indicate mud. Dotted areas 17 are cement and mixed areas 18 are intended to indicate mud contaminated cement.

The apparatus

Referring more particularly to Figs. 1 to 4, inclusive, shown therein is a casing string equipped

at its lower end with a cementing shoe housing 21. The housing is cylindrical in form with its inner surface ridged or corrugated to hold firmly the drillable substance 22 molded into the housing and forming the support for the cage and valve seat located centrally of the housing. Extending vertically through the molded substance is a duct or passageway 23 from which radiate ports 24. A ball 25 is adapted to seat upwardly in the valve of the shoe.

Interposed in the casing above the shoe, at a suitable distance to retain mud contaminated cement in the bottom of the casing, is a float valve consisting of a housing 26, a molded drillable valve supporting substance 27, and an upwardly seating ball valve 28. A central vertical duct 29 extends through the drillable support 27.

Also interposed in the casing above the float valve, where it is desired to locate or superpose, a cement column upon one which has already been placed, is a specially designed cementing collar. As can best be appreciated from Figs. 5 to 8, inclusive, the preferred structure of the collar includes a cylindrical housing 31 threaded at the top and bottom to be screwed onto the correspondingly threaded ends of the casing so that it becomes in effect a part of the casing. Through the wall of the housing at intervals about the circumference are ports which have parallel ducts or passageways 32*a* running longitudinally thereof and radial openings 32*b* into the housing's interior.

At the upper end of ducts 32*a* and seated in a recess 32*e* machined in the housing is a closure ring 35 held in place by a compressible holding ring 36, the lower wall 31*a* of recess 32*e* constituting a seat for the ring 35. Holding ring 36 has convex surfaces at its top and bottom to fit the concave surfaces in the housing recess and closure ring. The holding ring is of a flexible material constricted centrally and perforated radially at 36*a* with a sufficient number of holes to increase its compressibility when pressure is imposed upon the closure ring from below. Compression of the holding ring permits the closure ring to slide upwardly within the housing recess 32*e* opening ports 32 at their upper ends so there is permitted a free passage for fluid from the interior of the casing to the well bore outside the casing.

Housing 31 is internally machined to receive a two part slidable sleeve, the lower portion designated 37*a*, the upper portion 37*b*. Portion 37*a* is held in its uppermost position closing ports 32*b* by shear pins 38. Riveted or otherwise fastened to the upper sleeve portion 37*b* is an abutment cylinder 39 made of a readily drillable substance such as plastic, hard rubber or the like, and although slidable with portion 37*b*, it is held in position in the housing by shear pins 40. Fastened into the bottom edge of abutment sleeve 39 and depending into the space surrounded by the lower portion 37*a* of the sleeve are guide pins or dowels 39*a*. Vertically slidable on the guide pins and riveted or otherwise fastened to and movable with the lower sleeve portion 37*a* are supports 41 also made of a drillable substance. A portion of the top edges of these supports have shoulder surfaces 41*a* inclined downwardly and outwardly. Between the guide pins 39*a* are slides or thrust members 42 having inclined surfaces 42*a* resting on surfaces 41*a*, which thrust members 42 are of a thickness to extend somewhat further into the central portion of the housing than abutment sleeves 39 and supports 41.

The cementing plug used in multistage cementing operations employing the improved method comprises a hollow deformable plug member 43 constructed preferably according to the teachings of my application for Letters Patent Serial No. 678,298, filed June 21, 1946, Patent No. 2,509,922, May 30, 1950. From the lower chamber of the plug depends a stem 44 having a disk shaped piston head 45 attached to its lower extremity by bolt 46. The diameter of head 45 is such that it freely passes through abutment sleeve 39 and supports 41, but will seat against slides 42. The plug 43 made of resilient material is sufficiently deformable to pass through the sleeves 39 and supports 41.

Multistage cementing method

With the apparatus shown in place in the well bore mud is circulated downwardly through the casing and upwardly in the annular space surrounding the casing. During mud circulation the casing is reciprocated and calculations are made as to the amount of cement necessary to raise the cement to the desired level outside the casing. The cement mix is introduced into the casing at the wellhead and plug 43 with its stem 44 and piston head 45 are inserted behind the cement charge. Mud pressure is applied behind the plug which forces the cement out of the bottom cementing shoe moving the remaining mud before it. In Figs. 1 and 5 the piston head disk 45 has reached slides 42 and is seated upon the upper shoulders of the slides which now act as a barrier to the passage of the head through sleeve 37*a*. Downward mud pressure upon the plug causes slides 42 to impose a downward thrust on supports 41, which, transmitted to the sleeve 37*a* will shear pins 38 causing the lower sleeve portion 37*a* to slide downwardly and seat at 47 in the housing. Supports 41 and the slides or thrust members 42 will, of course, move with the sleeve, and pins 39*a* form a vertical guideway preventing lateral shifting of members 42 during the initial portion of such movement; when sleeve 37*a* reaches shoulder 47, however, members 42 are clear of the lower ends of the pins, and hence can advance laterally or spirally along their inclined supporting surfaces and fall into the central passageway. This removes the rests or abutments theretofore acting as a barrier to the piston head, and permits the piston head and plug to pass through lower sleeve portion 37*a*. With the lower sleeve portion seated at 47, ports 32*b* will be open as indicated in Fig. 2. Note too that piston head 45 has now seated at float valve 26 sealing the casing above the float valve from the casing below. Mud contaminated cement is trapped in the bottom of the casing between the float valve and cementing shoe.

Since a secondary mud circulation begins through ports 32*a*, immediately the plug passes through the cementing collar, cement rising to the level of the ports will be carried away with the mud and a cement level automatically created at the ports. Thus a cement level is not only definitely established, but excess cement is carried away and cement accumulations prevented which would normally clog ports in the conventional methods. The size of the ports in the collar are such that there is sufficient mud pressure to seat the plug at the float valve, thereby forcing the cement into place and maintaining an active circulation of mud through the ports above the cement. Pressure of the mud discharged through the ports 32*b* and ducts 32*a* acts up-

wardly against closure ring 35, compressing holding ring 36, thereby opening the upper ends of the ducts below ring 35. As mud pressure is reduced or is lost for any reason, the resiliency of the holding ring will return closure ring 35 to a shut position and prevent ingress of materials from the well bore into the casing.

When the lower column of cement has set around the casing from the cementing shoe to the lower cementing collar as shown in Fig. 3, a second batch of cement is calculated for placement above the collar and to the second or upper collar shown in Fig. 4. As before, the amount of cement, if in excess, will be carried away by mud circulation set up above the second collar during placement of the second cement column or while the second batch of cement is setting. After introduction of the second cement batch, a second plug of the same type is inserted but with a piston head of somewhat greater diameter than the first. It is desired now to have the piston head of the second plug seat on the upper shoulder of sleeve 39 of the lower collar instead of upon slides 42 as did the first plug. To obtain this result, sleeve 39 and supports 41 of the upper cementing collar have central passageways of somewhat greater diameter than the lower collar in order that the larger plug head 45 of the second plug will seat first on the slides 42 of the upper collar and open the ports of the upper collar as previously explained with respect to the lower collar. After opening the ports the plug will pass through the upper collar and seat on the shoulder of sleeve 39 of the lower collar as shown in Fig. 4.

Upon reaching the lower collar the second plug has forced the second cement batch through the ports in the lower collar and into the space surrounding the casing above the lower cement column as shown in Figs. 2 and 3. Since the first plug was seated at the float valve, as shown in Fig. 2, sealing the lower end of the casing below the valve, the second batch of cement is placed by being discharged through the ports in the lower collar during the travel of the second plug to its seat. The seating of the second plug on top of the sleeve 39 and pressure imposed upon the plug by mud pressure shears pins 40 in the lower collar, causing the upper sleeve portion 37*b* to slide downwardly into abutment with the lower portion 37*a* again closing ports 32*b* in the lower sleeve.

As explained, ports in the upper collar are now open and ports in the lower collar are closed with the first plug seated in the float valve and the second plug seated in the lower collar. The lower column of cement initially placed has set to the height of the ports in the lower collar. The second batch forced through ports in the lower collar has been placed around the casing superimposed upon the lower cement column. Mud is circulated above the level of the cement now being established at the level of the ports of the upper collar, as shown in Fig. 4.

Thus it will be seen that successive columns of cement may be superimposed in a multistage operation and the level of cement definitely established by maintaining mud circulation during placement and setting of the successive batches of cement.

Cementing of a separate casing section with drill pipe

In Figs. 9, 10 and 11 is shown an apparatus for cementing a separate section of casing in a well bore where the well has not been cased. Upon the lower end of the drill pipe 48 is screwed an adapter 49 to increase the diameter of the drill pipe sufficiently to receive the threaded upper end of the cementing collar housing 31. To the bottom of the housing is screwed a section of casing long enough to span the formation to be cemented. At the lower end of the casing is attached a cementing shoe 21 of conventional construction similar to the one hereinbefore described. Details of the ports and ducts through the collar wall and the closure and holding rings 35 and 36 are the same as those in the collar shown in Figs. 5, 6 and 7.

In the interior wall of the collar is machined an annular recess in which slides the closure sleeve 37. This sleeve is shown in its uppermost position, closing ports 32*b* at the lower ends of ducts 32*a* which communicate through the housing wall to the well bore. Inside sleeve 37 and riveted or otherwise fastened thereto is a shouldered abutment cylinder 50. The central passageway through the cylinder is of two sizes, the upper somewhat larger than the lower with an intermediate shoulder 50*a*. The inside diameter of the upper portion of the passageway is substantially that of the outside diameter of plug 43; the lower portion of the passageway is somewhat smaller than the plug body so passage of the plug is prevented. As a result, when the plug is run it seats on shoulder 50*a*. The abutment cylinder is formed of a drillable substance in two parts, the upper section of hard rubber or plastic, the lower section of soft rubber and of sufficient diameter to wipe clean the wall of the casing as it passes downwardly therethrough. The cylinder and closure sleeve are held in a raised position closing the collar ports by shear pins 40.

When it is desired to cement a section of casing in an uncased location in the well bore, the section with a cementing shoe at its bottom and a collar at the top is attached to the lower end of the drill pipe by means of an adapter 49 as shown. A cement plug may be set in the well bore below the cementing shoe prior to starting the cementing job if the casing section is to be placed above the bottom of the well. This will prevent filling the drilled hole below the cementing shoe with cement. The casing section is then lowered on the drill pipe to the desired location in the well opposite the formation to be cemented. Mud circulation may be maintained through the cementing shoe, if necessary, while the casing section is being placed.

A cement batch sufficient in quantity to fill the well bore throughout the length of the casing section is then introduced into the drill pipe at the well head and a plug 43 without the stem and piston head is inserted behind the cement. Mud pressure is applied behind the plug and the cement is forced out of the shoe around the casing opposite the formation to be cemented.

When plug 43 seats at 50*a* in the cement collar, pins 40 are sheared and closure sleeve 37 slides with the abutment cylinder to its seat on a shoulder at the bottom of the machined recess in the interior wall of the collar housing. With the movement of the sleeve and cylinder, ports 32*b* are opened, permitting free passage of mud existing as a fluid column behind the plug into the well bore. In other words, with the seating of the plug and opening of the collar ports, mud circulation is created above the level of the ports. This circulation carries away excess cement to the surface and establishes the top level of the cement column at the collar ports. It

also prevents accumulation of cement at the adapter joints which would later cause difficulties in detaching the drill pipe after the cement was set.

In this fashion a section of casing can be cemented at any location in the well bore and drill pipe easily detached after the cement has set.

Thus it will be seen that an improved apparatus for multistage cementing and cementing separate sections of casing in a well bore has been devised. The apparatus of my invention also provides means for accurately locating the upper level of the cement and eliminates difficulties heretofore encountered with the placing of excess cement in the well bore.

Having thus described my invention, I claim:

1. Well cementing apparatus comprising a well casing having a lateral port therein, a lower sleeve and upper sleeve in the bore of the casing and movable longitudinally thereof, a member smaller in diameter than said sleeves adapted to travel downwardly through the casing, the lower sleeve initially covering said port and having an inwardly extending projection in the path of the member, means including a retaining element on the upper sleeve initially connecting said projection to said lower sleeve whereby said projection transfers the downward movement of said member to said lower sleeve, said last means controlled in accordance with the position of the lower sleeve and effective responsive to a downward movement of the lower sleeve sufficient to uncover said port to free said projection from the lower sleeve, thereby to permit said member thereafter to advance through the lower sleeve.

2. Apparatus as in claim 1 having means for moving said upper sleeve downwardly to cover said port.

3. Well cementing apparatus comprising a well casing having an annular recess in the exterior wall thereof, a ring encircling the casing, said ring disposed in said recess and enjoying limited axial movement therein; resilient means between one side of the recess and said ring urging said ring axially of the casing toward the opposite side of the recess, said opposite side comprising a seat for the ring, a duct in the wall of the casing opening at one end into said recess through said opposite side thereof and opening at the other end into the interior of said casing, said ring being effective when seated against said opposite side to close said duct at said one end thereof, a closure for the other end of said duct comprising a body in the bore of the casing initially covering the duct opening, a member adapted to travel through the casing under the influence of fluid pressure behind said member, means on said body in the path of movement of said member releasably engaged by said member while the member passes said duct opening for moving said body with said member away from the duct opening and thus uncovering the latter.

4. Well cementing apparatus comprising a well casing having an annular recess in the exterior wall thereof, a ring encircling the casing, said ring disposed in said recess and enjoying limited axial movement therein, resilient means between one side of the recess and said ring urging said ring axially of the casing toward the opposite side of the recess, said opposite side comprising a seat for the ring, a duct in the wall of the casing opening at one end into said recess through said opposite side thereof and opening at the other end into the interior of said casing, said ring being effective when seated on said opposite side to close said duct at said one end thereof, a closure for the other end of the duct comprising a body against the inside wall of the casing slidable to cover and uncover the duct opening in alternative positions of the body, said body initially occupying one of said positions, said body having a support portion, a thrust member releasably supported on said support portion of the body, holding means releasably securing said thrust member on said body for movement therewith, said thrust member becoming released from said holding means upon movement of said body to its said alternative position, and coacting means on said body support portion and thrust member operable when said thrust member is released from said holding means whereby said body and member become separated from each other and said body is freed from the thrust of said thrust member, means for applying a thrust to said member thereby to cause same to shift said body from said initial position to its alternative position.

5. Well cementing apparatus comprising a well casing having a lateral port therein, a movable closure in said casing adapted to cover said port in one of its positions and to uncover said port in another of its positions, said closure initially occupying one of said positions, a support integral with said closure, a thrust member carried on said support, stationary means on the casing initially retaining said member on said support, means for applying a thrust on said member to shift said closure from said initial position to said other position, said member adapted on such shifting of the closure to move with the closure to a position clear of said stationary retaining means, and said support being constructed and arranged to give inadequate support to said member when the latter is clear of said retaining means whereby said member is released from said support and said closure is relieved of the influence of said thrust when it reaches said last position.

6. Well cementing apparatus comprising a well casing having a lateral port therein, a movable sleeve in said casing adapted to cover said port in one of its positions and to uncover said port in another of its positions, said sleeve initially occupying one of said positions, barrier means partly closing the bore of said sleeve, cooperating elements on said sleeve and casing respectively, both of said elements having operative connection with said barrier means when said sleeve is in said initial position and effective jointly to secure said barrier means to said sleeve for movement therewith, a member smaller in size than the bore of said sleeve adapted to travel through said casing under the influence of fluid pressure behind said member, said member effective on reaching said sleeve to apply a thrust on the barrier means thereby to move the latter and thus cause said sleeve to shift from said initial position to said other position, said cooperating elements on the sleeve and casing being separated by the movement of said sleeve relative to the casing, and said elements constructed and arranged on separation to release said barrier means from said sleeve whereby said member is adapted to pass through said sleeve and continue its travel through said casing under the influence of said fluid pressure.

7. Well cementing apparatus comprising a well casing, a sleeve axially slidable in the casing and

initially occupying a predetermined position, stationary means in the casing providing a limited vertical guideway open at one end, a member movable in said guideway, means for applying a force on said member to advance same toward and beyond the open end of the guideway, a thrust connection between said member and said sleeve including a shoulder on said sleeve initially engaged by said member whereby said sleeve is adapted to move with said member axially of the casing from said predetermined position to a second position responsive to said advance of the member, said shoulder constructed and arranged to give said member inadequate support in the absence of said guideway whereby said member leaves said shoulder when it passes beyond the open end of the guideway and thus relieves said sleeve of said thrust, and said casing having a lateral port covered by said sleeve in one of said positions.

8. Well cementing apparatus comprising a well casing, a sleeve axially slidable in the casing and initially occupying a predetermined position, stationary means in the casing providing a limited vertical guideway open at one end, a member movable in said guideway, means for applying a force on said member to advance same toward and beyond the open end of the guideway, a thrust connection between said member and sleeve including a segmental shoulder on the sleeve extending spirally part way around the axis of the casing, said shoulder initially engaged by said member whereby said sleeve is adapted to move with said member axially of the casing from said predetermined position to a second position responsive to said advance of the member, said member adapted when it passes beyond said guideway to advance spirally along said shoulder and slip off the end thereof whereby said sleeve is relieved of said thrust when it reaches said second position, and said casing having a lateral port covered by said sleeve in one of said positions.

9. Well cementing apparatus comprising a well casing having a lateral port therein, a movable sleeve in the bore of the casing initially covering said port, a member smaller in diameter than the bore of said sleeve adapted to travel through said casing under the influence of fluid pressure behind said member, said sleeve having an inwardly extending projection in the path of said

member for transferring the movement of said member to said sleeve, thus to cause the latter to uncover said port, said projection being releasably secured on and separable from said sleeve, cooperating elements on the casing and sleeve initially securing said projection to the sleeve, said elements being movable apart to release said projection from the sleeve upon movement of the sleeve to uncover said port thereby to permit said member then to advance completely through the sleeve and continue its movement through said casing through the sleeve.

10. Well cementing apparatus comprising a well casing having a lateral port therein, a movable sleeve in said casing constructed and arranged to cover said port in one of its positions and to uncover said port in another of its positions, said sleeve initially occupying one of said positions, a plurality of circumferentially spaced projections extending inwardly from said sleeve and partially closing the bore thereof, separate means for each projection releasably securing that projection on said sleeve, said projections and sleeve being movable out of engagement with said means upon movement of the sleeve from its initial position to said other position to release said projections from the sleeve and said securing means, said projections when thus released being free to drop from the bore of said sleeve thereby to permit passage through the sleeve of solid objects substantially the full size of the bore of the sleeve.

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