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APPARATUS FOR CEMENTING WELLS

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This invention relates to apparatus and methods for cementing wells whereby cementitious material may be discharged from a casing string at a plurality of different levels into the surrounding well bore either simultaneously or selectively in upward series as an integral operation or in a series of operatively independent steps in accordance with specific requirements. The present application is a continuation in part of my copending application, Serial Number 645,656, filed December 5, 1932, which matured as Patent No. 2,071,389, dated February 23, 1937. Certain subject-matter hereof has also been disclosed in other of my applications which were copending with application Serial No. 645,656, namely, applications Serial Nos. 436,434 and 327,081, filed March 17, 1930, and December 19, 1928, respectively. The latter applications matured as Patents Nos. 1,896,482 and 1,938,955, on February 7, 1933, and December 12, 1933, respectively.

It is a general object of this invention to provide apparatus for sealing the annular area of a well hole around a casing string by expelling separate charges of a fluent cementitious mixture from different levels of the string.

Another object is to provide a well casing having a shoe guide and float valve at its lower end to facilitate lowering of the casing in an open well bore, embodying a ported section whereby the lower end of the casing may be cemented without passing the cement through the restrictions of the float valve.

Another object is to provide apparatus for cementing a well casing string, whereby a quantity of fluent cement is placed in the annular bore of a well hole around the casing and subsequently, either immediately upon placement of the first cement discharge and while the same is in a fluid form, or later after the first charge has set, expelling one or more additional volumes of the cementitious material at different upper levels to form a single annular unitary column of cement around the casing, or two or more separate barriers of any desired lengths.

Another object is to provide a fluid barrier having an opening therethrough, movable through the fluid standing in the casing string, the area within the casing below the barrier being communicable with the area above the barrier through the opening.

Another object is to provide means to mount the barrier in the casing string against substantial axial displacement.

Another object is the provision of a ported well casing having a bore for the passage downwardly

therethrough of pressure fluid, and a float valve for the lower end thereof, with a sleeve valve inside the casing tending normally to maintain closure of the ports but longitudinally slidable therein to open the ports and forming a seat for a barrier plug, the barrier plug being adapted to be driven through the casing by the pressure fluid for seating on the sleeve valve to open the ports by shifting the sleeve valve and close the bore of the casing below the ports, thus deflecting the flow of the pressure fluid outwardly through the ports above the float valve and obviating the necessity of forcing the cement through a float valve.

Other objects and salient features of my invention will be apparent to those of skill in this art upon an examination of the following description read in the light of the accompanying drawing, in which—

Fig. 1 is a sectional view illustrating one form of apparatus of my invention and the first steps of one embodiment of the method of its use;

Fig. 2 is a sectional view similar to Fig. 1 showing subsequent steps of the method illustrated in Fig. 1 and the apparatus therefor;

Fig. 3 is an upper continuation of the apparatus shown in Figs. 1 and 2, or 4;

Fig. 4 is a modified form of the lower end of a casing string adapted to and embodying my invention, and comprises a lower continuation of Fig. 3;

Fig. 5 is a sectional view taken on lines 5—5 of Fig. 3;

Fig. 6 is a sectional view illustrating a casing section of the embodiment of Figs. 1—3 assembled in a string having a float valve at its lower end adapted for cementing the lower end of the casing.

The cementing operation may be carried on in connection with a usual string of well casing which is received in a well bore B. In addition to discharging cement at or adjacent the lower end of the casing string, the invention provides for ejecting cement at one or more higher levels. The casing string is provided with an unrestricted open bore prior to the cementing operation or equipped with a float valve, which is adapted to be drilled out so as to provide an unrestricted open bore subsequent to the discharge of cement. The cement is ejected at each or any of the predetermined levels by the pressure of hydraulic fluid above the cement to fill the entire length of the casing string to the earth's surface.

For this purpose, and at each level above the lower end of the casing string where it may be

desired to discharge additional cement, a fixed section 2 of the casing string has ports 3 in its side wall, a plurality of these successively higher ported sections being shown at Fig. 1. Aside from the ported sections 2, the casing string may have a usual open bore of uniform cross-sectional area as shown at Figs. 1, 2 and 6; and the bores of the ported sections 2 form open and unrestricted continuations of this uniform bore, with the exterior diameters of the ported sections substantially the same as the exterior diameters of usual coupling collars for the lengths of the casing string. The bore of the casing being unrestricted throughout its length; the casing string may be lowered with the drilling tools and uninterrupted hydraulic circulations may be maintained to facilitate placement of the casing in the well bore in a position most conducive to effective cementing. If in accordance with usual practice, one or more successively smaller casing strings are to be lowered through the first string for increasing the depth of the well, any of the smaller strings may be provided with ported sections 2 at the levels where it may be desired to discharge additional cement, and since these ported sections of a string do not increase its maximum exterior diameter nor restrict the cross-sectional area of its bore, there need be but minimum reduction in the size of the successively smaller strings, and as a consequence the final bore of the casing may be of appreciable size, as is of extreme importance when the well is put on production.

The lateral ports 3 of sections 2 are normally closed so that a fluid such as a washing medium or cementitious material may be directed downwardly through the unrestricted bore of the casing to its lower end; and when the well is to be cemented, a batch of cement is preferably first discharged at the lower end of the casing string, and the bore of the casing is then shut off below the ports of a section 2 which is at the level where it is desired to discharge additional cement, and the ports 3 of said section are opened for discharge of cement.

Initial discharge of cement at the lower end of the casing string may be in accordance with any usual practice; and as shown in Figs. 1 and 2, is via a cementing shoe or casing section 2a having normally closed lateral ports 3a. The sections 2 and 2a are of similar construction, the bore of each section being annularly recessed as shown at 5, with a sleeve valve 6 slidable in said recess to open or close the cooperating lateral ports, and the bore of the sleeve valve forms an unrestricted continuation of the bore of the casing string. The sleeve valve is normally held in position overlying and closing its cooperating lateral ports, as for example, by a spring 7, with the annular recess 5 forming an enlargement of the bore of the casing below the sleeve valve. Valves 11 are preferably provided for ports 3 and 3a at the exterior of sections 2 and 2a, and are adapted to open responsive to pressure of outward discharge through the ports 3-3a, when the corresponding sleeve valves 6 have been opened, but are adapted to automatically close against back-flow through the ports, irrespective of the position of the cooperating sleeve valves.

A plug 4 cooperates with each of the ported sections 2, and a plug 4a cooperates with the ported section 2a. Each of these plugs has slips 12 which are radially retracted while the plug is being lowered in the well casing, with packing

14 on the plug maintaining fluid tight engagement with the casing bore; and when the plug aligns with its cooperating recess 5, springs 15 extend the slips 12 so as to engage and open sleeve valve 6, and then anchor the plug with its packing 14 shutting off the bore of the casing below the cooperating lateral ports.

As shown in Fig. 1, the recesses 5 of the successively higher sections 2a and 2 are of successively reduced length; and the slips 12 of the plugs 4a and 4 are of different length corresponding to the recesses 5 of their cooperating sections 2a and 2, so that when one of the plugs is lowered into the casing, its slips 12 will pass the shorter recesses 5 of higher ported sections without expanding and anchoring therein, and will thus anchor only at the ported section with which the plug is adapted to cooperate. It will thus be seen that by successively lowering plugs having slips corresponding in length to the recesses of predetermined ported sections, the ports of selected ported sections may be successively opened for discharge of cement. Prior to lowering one or more of the plugs into the casing string, and with the sleeve valves 6 in normal closed position and the casing string elevated from the bottom of the well bore, circulation may be readily established downwardly through the casing and thence upwardly in the surrounding well, since the unrestricted bore of the casing is open for flow of fluid throughout its length.

If the initial discharge of cement is to be at the lower end of the casing string, plug 4a, adapted for cooperation with ported section 2a, may be initially lowered into the casing in back of the circulating medium which fills the casing. As shown in Fig. 1, a predetermined quantity of cement is introduced into the casing in back of plug 4a, which is preferably a solid plug, with a traveling plug 17 in back of the cement, and a column of hydraulic fluid above the traveling plug extending to the top of the well. The circulating medium in advance of plug 4a is thus discharged from the open lower end of the casing by the pressure in back of plug 17, so that the plug 4a is finally anchored in ported section 2a as shown in Fig. 2, thereby opening the ports 3a and shutting off the bore of the casing below the open ports. The pressure on plug 17 then forces the cement through the ports 3a so as to open valves 11 for discharge of the cement into the surrounding well bore, with the plug 17 seating on the anchored plug 4a when all of the cement has been discharged, and the valves 11 then closing against back-flow of the cement.

Additional cement may then be ejected at a ported section 2 which is at a selected higher level, by lowering into the casing one of the plugs 4 which has slips 12 corresponding to the recess in a selected ported section. The plug 4 is lowered through the column of hydraulic fluid standing in the casing, and for this purpose each of the plugs 4 has a bore 25, normally closed by an upwardly opening valve 26; and as shown in Fig. 2 the plug 4 which is to be lowered into the casing, is forced downwardly by a suitable string of tools C, and its valve 26 opens to permit the plug being readily lowered through the hydraulic fluid to its operative position aligning with the corresponding recessed ported section 2 and opening its sleeve valve 6.

When the plug 4 has been anchored in its corresponding recessed ported section and the tool string C has been withdrawn, a predetermined quantity of cement is forced downwardly

through the casing in back of the hydraulic fluid which is standing in the casing above the anchored plug, and the column of fluid, which is separated from the cement by a plug 27, is thus discharged through the open ports 3 by the pressure of a column of hydraulic fluid above the cement and separated therefrom by a traveling plug 17. The plug 27 thus eventually seats on anchored plug 4, and as shown in Fig. 3 the packing 27a of plug 27 is adapted to then yield so that the cement is ejected through ports 3, with the traveling plug 17 finally seating on plug 27, and the fluid column above the traveling plug extending to the earth's surface.

Either before or after the cement has set, the operation may be repeated for discharge of cement at a ported section 2 which is at a selected higher level, a plug 4 having slips 12 of a length to cooperate with the recess 5 of the selected ported section being forced downwardly through the fluid column standing in the well casing, by means of tool string C, and with the valve 26 of the plug opening for passage of the fluid as previously described. The plug 4 is thus anchored in the selected section and the ports 3 are opened, so that when the tool string C has been withdrawn, the column of fluid standing in the casing above the anchored plug and a predetermined quantity of cement which is introduced into the casing in back of the fluid and separated therefrom by a plug 27, may be successively ejected through the open ports by a column of fluid above and separated from the cement by a traveling plug 17 and extending to the earth's surface. While any number of ported sections equipped with sleeve valves may be incorporated in the string of casing, each of which may be utilized in the manner just above indicated in upward series, cement may be discharged from any selected one or number of the ported sections most favorable to producing the results desired.

One feature of the invention is that in a preferred embodiment of the method hereof the desirability of discharging cement from any one or each of the ported sections may be definitely determined by opening their respective ports and establishing hydraulic circulation therethrough before introducing into the casing, the cement to be ejected therefrom. As above indicated, each volume of cement may be allowed to set before repeating the operation at a selected higher level, or the entire string may be cemented utilizing all or any particular combination of ported sections as an integral operation.

The initial discharge of cement at the lower end of the casing string, as preferably employed in connection with subsequent ejection of cement at selected higher levels, may be by any usual means other than that hereinbefore described. For example, the lower end of the casing string may have a usual valve-controlled cementing shoe 30 as shown in Fig. 4, adapted for usual initial discharge of a circulating medium, with the cement which is to be discharged from the valvular shoe then forced downwardly through the casing between a Y-plug 31 and a traveling plug 17, and the Y-plug being adapted to anchor at the shoe 30, with its packing 31a then yielding for passage of the cement so that it may flow through the Y-port of the plug for discharge from the valvular shoe, and the cement being forced downwardly by a column of hydraulic fluid above the traveling plug 17, with the fluid extending to the top of the well and through

which a plug 4 is adapted to be subsequently lowered as previously described, when additional cement is to be discharged at a selected higher level.

The lower end of the casing may be provided with a valve-controlled cementing shoe 30 and a ported section 2a as shown in Fig. 6. A solid plug 4a is adapted to engage in recess 5 to actuate the sleeve valve 6. Cement is introduced into the casing on top of plug 4a and is followed by a plug 17 in the same manner as above described in reference to Figs. 1 and 2. Thus the hydraulic circulating fluid in advance of plug 4a is ejected from the shoe 30 through the valve therein and the lower end of the casing is cemented by passing the cement through ports 3a in section 2a adjacent the shoe to secure the advantages of a float valve and guiding shoe without passing the cement through the restrictions of the valve. It will be apparent that a plug 4 may be substituted for plug 4a in any of the embodiments of Figs. 1, 2, or 6, and the method of cementing the lower end of the casing may be altered in accordance with the method described above in reference to the upper ported sections.

The invention thus provides for cementing a well at a plurality of predetermined levels as an integral operation, or as a series of unitary cementing operations with the cement ejected at each selected level by a column of fluid extending to the earth's surface and adapted for subsequent discharge from the casing from above the selected level and in advance of subsequent discharge of cement at a higher level; and by selectively discharging cement at different levels, any desired portion of the casing string may be readily cemented off. The construction also provides an unobstructed bore for circulation of a fluid medium, drilling or underreaming prior to cementing or for removing debris prior to any integral cementing operation, since before introducing the cement, the bore of the casing is open for flow of fluid downwardly therethrough to a selected level and thence upwardly exteriorly thereof; and after the cement has been discharged from the casing and has set in the surrounding well bore, the plugs in the casing string may be readily drilled out in usual manner so as to clear the casing.

What I claim and desire to secure by Letters Patent is:

1. In combination, a string of casing for a well bore having normally closed ports in its side wall, the string of casing being adapted to retain a column of hydraulic fluid extending above the normally closed ports, and a plug adapted for fluid-tight sliding fit in the casing and having a bore provided with a valve adapting said plug to upwardly by-pass the column of fluid to permit lowering the plug in the casing, and a member to lower said plug downwardly through said fluid retained in the casing.

2. In combination, a string of casing for a well bore having normally closed ports in its side wall, the string of casing being adapted to retain a column of hydraulic fluid in its bore extending above the normally closed ports, a barrier plug adapted to be lowered in the casing and to by-pass said hydraulic fluid upwardly within the casing for opening the ports, and a member to move said plug downwardly through the fluid retained in the casing.

3. In combination, a string of casing for a well bore having normally closed ports in its side wall and presenting an unrestricted open bore, the

string of casing being adapted to retain a column of hydraulic fluid extending above the normally closed ports, means adapted to be lowered in the casing and to by-pass said hydraulic fluid upwardly within the casing for opening the ports and closing the bore of the casing below the ports, and means to move said first-mentioned means downwardly through the fluid retained in the casing.

4. A device of the character described adapted to be connected to the lower end of a string of well casing comprising an outer ported member and an inner sleeve valve tending normally to maintain closure of said ports, a plug for the lower end of said member tapered inwardly and downwardly to form a guiding end, a passageway formed centrally through said plug, a float valve closing the bore of said passageway to pressure therebelow, and a barrier plug actuated by pressure fluid to open said ports and close the bore of said passageway to pressure thereabove.

5. In combination, a string of well casing comprising an outer ported member at the lower end of said casing and an inner sleeve valve tending normally to maintain closure of said ports, a plug for the lower end of said casing tapered inwardly and downwardly to form a guiding end, a passageway formed centrally through said plug, a float valve closing the bore of said passageway to pressure therebelow, and a barrier plug actuated by pressure fluid to open said ports and close the bore of said casing to pressure thereabove.

6. A ported well casing having a bore for the passage downwardly therethrough of pressure fluid, a float valve for the lower end thereof, a sleeve valve inside of said casing tending normally to maintain closure of said ports and longitudinally slidable therein to open the ports and forming a seat for a plug, and a plug actuated by said pressure fluid to seat on said sleeve valve for opening the ports and close the bore of said casing below the ports thus to deflect the flow of said pressure fluid outwardly through the ports above said float valve.

7. In combination, a ported well casing, a sleeve valve normally closing the ports longitudinally slidable in said casing to open the ports, a body having valve means therein connected to the lower end of said casing to close the same to pressure in the well, and a barrier plug actuated by fluid pressure to seat on said sleeve valve for opening the ports and closing the bore of said casing above said valve means.

8. In combination with a well casing, a tubular member secured thereto and forming a part thereof, a valved float plug fitted to said member and enabling the passage of fluid downwardly through the said member but not in the opposite direction, valve means for said valved float plug capable of being made effective after the casing has been positioned in the bore to prevent the passage of fluid downwardly through said plug, said member having cementing ports formed through the side thereof above said plug, valve means for said ports preventing the flow of fluid into the casing from the exterior thereof, said valves opening to permit the discharge of cement from the interior of the casing only after the fluid pressure therein exceeds a predetermined value.

9. A plug adapted to be lowered into a well casing carrying means to snugly engage the wall

of the casing, means for anchoring the plug against longitudinal movement in the casing, the plug having an opening therethrough to by-pass fluid while lowering said plug in the casing, and valve means for closing said opening against the passage of fluent material downwardly there-through when anchored in the casing.

10. In combination, a string of casing disposed in a well shaft and containing a column of fluid in its bore, a plug, means carried by said plug forming a fluid-tight closure for said casing bore, means to lower said plug in the casing while maintaining disposition of the fluid in the casing, and means to anchor said plug against axial movement in the casing.

11. In a device of the character described, a casing barrier, a tubing string to lower said barrier in a well casing, means to anchor said barrier in the casing against longitudinal movement therein, said barrier having a bore to by-pass fluid in the casing communicable with the bore of the tubing, and valve means for closing the bore of said barrier.

12. In combination, a ported string of casing disposed in a well shaft containing hydraulic fluid whereby said casing will retain a column of said fluid in the casing extending above the ports by the balancing of the hydrostatic head within and without the casing through the ports, a plug carrying means for a fluid-tight engagement with the casing, a tubular member to lower said plug through the casing while maintaining the disposition of the hydraulic fluid retained in the casing, and means to anchor said plug against longitudinal movement in the casing to form a barrier.

13. In a device of the character described, a casing barrier, a tubing string having a releasable engagement with said barrier to lower said barrier in a well casing, means to anchor said barrier in the casing against longitudinal movement therein, said barrier having a bore to by-pass fluid in the casing communicable with the bore of the tubing, and valve means for closing the bore of said barrier.

14. A device of the character described comprising a string of casing disposed in a well shaft provided with a plurality of cementing sections carried in longitudinal spaced relation by said casing, said casing containing a column of hydraulic fluid in its bore, each of said cementing sections including an outer ported member and an inner sleeve valve, and means comprising a tubing string and a barrier actuated by said tubing string for selectively closing the bores of said cementing sections below said ports therein, respectively, said tubing and barrier being movable through the casing while maintaining disposition of said hydraulic fluid retained in the casing.

15. A device of the character described comprising a string of casing disposed in a well shaft provided with a plurality of cementing sections carried in longitudinal spaced relation by said casing, said casing containing a column of hydraulic fluid in its bore, each of said cementing sections including an outer ported member and an inner sleeve valve, and means comprising a tubing string and a barrier having a releasable engagement with said tubing for selectively closing the bores of said cementing sections to pressure thereabove, said tubing and barrier being movable through the casing while maintaining disposition of said hydraulic fluid retained in the casing.

16. In combination, a string of casing disposed in a well shaft provided with a plurality of cementing sections carried in longitudinal spaced relation by said casing, each of said cementing sections including an outer ported member and an inner sleeve valve, a tubing string, a barrier actuated by said tubing string for selectively closing the bores of said cementing sections below the ports, therein, respectively, said barrier having a bore to by-pass hydraulic fluid in the casing communicable with the bore of the tubing string, and valve means for closing the bore of said barrier.

17. A device of the character described comprising a string of casing disposed in a well shaft provided with a plurality of cementing sections carried in longitudinal spaced relation by said casing, said casing containing a column of hydraulic fluid in its bore, each of said cementing sections including an outer ported member and an inner sleeve valve closing the ports, and means comprising a tubing string and a barrier actuated by the tubing string for selectively opening the ports and closing the bores of said cementing sections below the ports while maintaining disposition of the hydraulic fluid retained within the casing.

18. A device of the character described comprising a string of casing disposed in a well shaft provided with a plurality of cementing sections carried in longitudinal spaced relation by said

casing, said casing containing a column of hydraulic fluid in its bore, each of said cementing sections including an outer ported member and an inner sleeve valve, a barrier adapted to be lowered in the casing and to by-pass said hydraulic fluid upwardly within the casing for selectively opening the ports and closing the bores of said cementing sections below the ports, and a tubing string to move said barrier downwardly through the casing.

19. A device of the character described comprising a string of casing disposed in a well shaft provided with a plurality of cementing sections carried in longitudinal spaced relation by said casing, each of said cementing sections including an outer ported member and an inner sleeve valve controlling the ports, and means comprising a tubing string and a barrier actuated thereby for selectively closing the bores of said cementing sections.

20. In combination, a string of casing disposed in a well shaft provided with a cementing section intermediate the ends of the casing, said cementing section including an outer ported member and an inner sleeve valve, means comprising a tubing string and a barrier actuated thereby for closing the bore of said cementing section to pressure thereabove, said barrier having a bore communicable with the bore of the tubing, and means for closing the bore of said barrier.

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