Feb. 23, 1937. E. V. CROWELL 2,071,389

WELL CEMENTING

Filed Dec. 5, 1932

Fig.1.

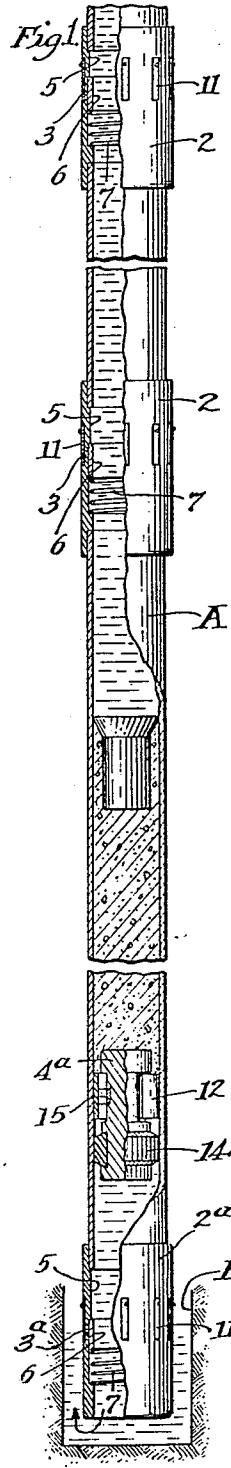


Fig.2.

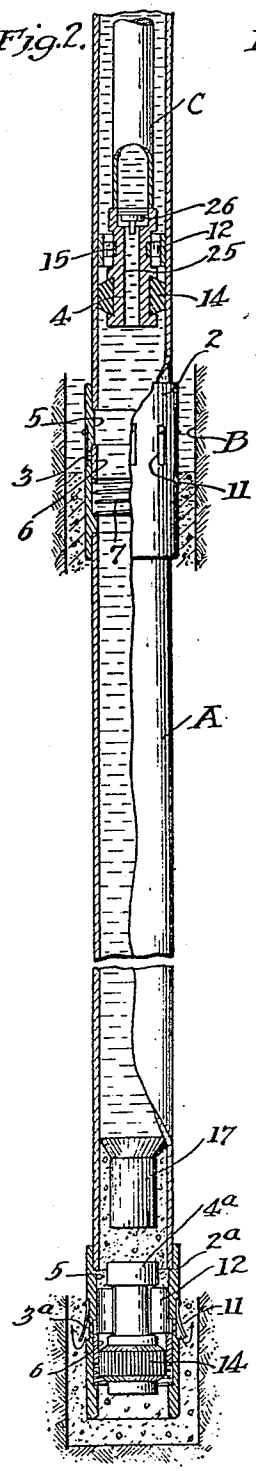


Fig.3.

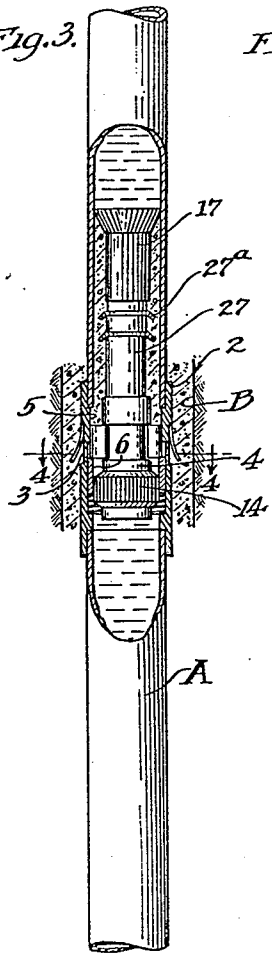


Fig.5.

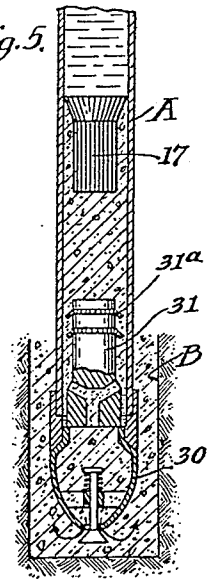


Fig.4.

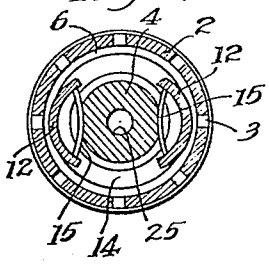
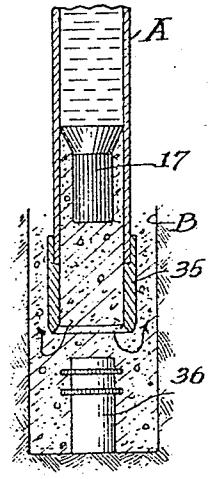


Fig.6.



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2,071,389

WELL CEMENTING

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10 Claims. (Cl. 166—21)

This invention relates to that method of cementing wells whereby cementitious material may be discharged from a casing string into a surrounding well bore, and additional cement may then be ejected from the casing string at a predetermined higher level so that the casing string may be cemented-off at predetermined levels or throughout any desired length. Certain subject-matter disclosed in this application has been reserved for my co-pending applications, S. N. 27,041, filed June 17, 1935, and S. N. 119,986, filed January 11, 1937, and to those parts of the present disclosure no claim is made herein. It is an object of the invention to discharge the cement at different levels from a casing string which has an open bore of unrestricted cross-sectional area prior to the cementing operation, and which is adapted to be drilled-out to the same unrestricted bore subsequent to the cementing operation, so that a plurality of strings of minimum successive reduction in diameter may be received one within another for increasing the depth of the well while maintaining the bore of the casing of maximum size, and usual drilling operations may be continued through the casing, and fluid circulation established, all in accordance with present practice.

It is a further object of the invention to discharge cement at one level by the pressure of a column of hydraulic fluid filling the entire length of the casing string above the cement, and to then discharge the fluid standing in the casing above a higher level at which another batch of cement is to be discharged, with additional cement then ejected at said higher level by the pressure of a column of hydraulic fluid which again fills the entire length of the casing string above the additional cement.

Further objects of the invention will be readily understood from the following description of the accompanying drawing which shows a preferred means for carrying out the improved process, and in which:

Figs. 1, 2, and 3 are vertical sections through a string of casing received in a well bore, and illustrating the successive steps of the cementing operation.

Fig. 4 is a transverse section on the line 4—4 of Fig. 3.

Figs. 5 and 6 are fragmentary views similar to Fig. 2, showing modifications of the invention.

The cementing operation may be carried on in connection with a usual string of well casing A which is received in a well bore B; and in addition to the usual practice of discharging cement at or adjacent the lower end of the casing string, the invention provides for ejecting cement at one or more higher levels, with the casing string having an unrestricted open bore prior to the cementing operation and adapted to be drilled-out so as to provide the same unrestricted open bore subsequent to discharge of cement, and with the cement ejected at each of the predetermined levels by the pressure of hydraulic fluid above the cement and filling 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 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 string being thus unrestricted throughout its length, usual drilling operations may be carried on through the string and fluid may be circulated in usual manner; and 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 ce-

ment, 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 2^a having normally closed lateral ports 3^a. The sections 2 and 2^a 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 above the sleeve valve. Valves 11 are preferably provided for ports 3 and 3^a at the exterior of sections 2 and 2^a, and are adapted to open responsive to pressure of outward discharge through the ports 3—3^a, 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 4^a cooperates with the ported section 2^a. 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 alines with its cooperating recess 5, springs 15 expand 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 2^a—2 are of successively reduced length; and the slips 12 of the plugs 4—4^a are of different length corresponding to the recesses 5 of their cooperating sections 2—2^a, 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; and a plug having slips 12 corresponding to the recess 5 of the ported section at which cement is to be initially discharged, is then lowered into the casing. If in accordance with usual practice, initial discharge of cement is to be at the lower end of the casing string, it is the plug 4^a, adapted for cooperation with ported section 2^a, which is 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 4^a, 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 and extending to the top of the well. The circulating medium in advance of plug 4^a is thus discharged from the open lower end of the casing by the pressure in back of plug 17, so that the plug 4^a is finally anchored in ported section 2^a as shown in Fig. 2, thereby opening the ports 3^a and shutting-off the bore of the casing below the open ports. The pressure on plug 17 then forces the cement through the ports 3^a so as to open valves 11 for discharge into the surrounding well bore, with the plug 17 seating on the anchored plug 4^a 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 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 alining with the corresponding ported section 2 and opening its sleeve valve 6.

When the plug 4 has been anchored in its corresponding 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 27^a 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.

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. If desired the operation may then be repeated at a selected ported section at a still higher level.

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. 5, 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.

As shown in Fig. 6, initial discharge of cement at the lower end of the casing may be via a usual shoe **35**, with a washing medium initially circulated in usual manner, and a batch of cement then forced downwardly through the casing between a lower plug **36** and an upper traveling plug **17**, and with a column of hydraulic fluid above the traveling plug and extending to the earth's surface. The plug **36** drives the washing medium before it and is finally ejected from shoe **35**, so that the cement is discharged into the surrounding well bore with the plug **17** finally anchoring on plug **36**; and when additional cement is to be subsequently ejected at a selected higher level, a plug **4** is lowered through the column of hydraulic fluid standing in the well above the anchored traveling plug, and is anchored at its cooperating ported section at the selected higher level, as previously described.

The invention thus provides for cementing a well at a plurality of predetermined levels as integral 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 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.

I claim:

1. The method of cementing casing in a well bore, which includes circulating hydraulic fluid through the casing, and while retaining the hydraulic fluid in the casing to a level above that of normally closed ports in the side wall of the casing, opening said ports and closing the bore of the casing below said ports, discharging through the open ports the hydraulic fluid standing in the casing above said ports, and then ejecting cement from the casing through the open ports.

2. The method of cementing casing in a well bore, which includes circulating hydraulic fluid through the casing, and while retaining the hydraulic fluid in the casing to a level above that of normally closed ports in the side wall of the casing, lowering a plug through said hydraulic fluid for opening the ports and closing the bore of the casing below said ports, and then establishing circulation downwardly through the casing and outwardly through said open ports.

3. The method of cementing casing in a well bore, which includes circulating hydraulic fluid through the casing, and while retaining the hydraulic fluid in the casing to a level above that of normally closed ports in the side wall of the casing, lowering a plug through said hydraulic fluid for opening the ports and closing the bore of the casing below said ports, discharging through the open ports the hydraulic fluid standing in the casing above said ports, and then ejecting cement from the casing through the open ports.

4. The method of cementing casing in a well bore, which includes circulating hydraulic fluid through a string of casing having an open bore which is unrestricted throughout its length, and while retaining the hydraulic fluid in the casing to a level above that of normally closed ports in the side wall of the casing, opening said ports and closing the bore of the casing below said ports, discharging through the open ports the hydraulic fluid standing in the casing above said ports, and then ejecting cement from the casing through the open ports.

5. The method of cementing casing in a well bore, which includes discharging cement at the lower end of the casing by a column of hydraulic fluid retained in the casing in back of the cement and extending above a predetermined higher level at which additional cement is to be subsequently ejected, discharging from the casing at said higher level the hydraulic fluid standing in the casing above said level, and then ejecting cement from the casing at said higher level.

6. The method of cementing casing in a well bore, which includes discharging cement from the casing by a column of hydraulic fluid retained in the casing in back of the cement and extending above a predetermined higher level at which additional cement is to be subsequently ejected, discharging from the casing at said higher level the hydraulic fluid standing in the casing above said level, and then ejecting cement from the casing at said higher level.

7. The method of cementing casing in a well bore, which includes circulating hydraulic fluid through the casing and retaining said hydraulic fluid in the casing to a point above a predetermined level at which cement is to be ejected, discharging from the casing at said level the hydraulic fluid standing in the casing above said level, ejecting cement from the casing at said level by a column of hydraulic fluid retained in the casing in back of said cement and extending above a predetermined higher level at which additional cement is to be subsequently ejected, and then establishing circulation downwardly through the casing and outwardly therethrough at said higher level.

8. The method of cementing casing in a well bore, which includes circulating hydraulic fluid through the casing and retaining said hydraulic fluid in the casing to a level above that of normally closed ports in the side wall of the casing, lowering a plug through said hydraulic fluid for first opening the ports and then closing the bore

of the casing below said ports, introducing cement into the casing in back of the hydraulic fluid and separated therefrom by a barrier, and forcing the cement downwardly by hydraulic fluid in back of the cement and separated therefrom by a barrier, so as to discharge through the open ports the hydraulic fluid between the plug and the first mentioned barrier, and then cause said first mentioned barrier to yield for discharge of the cement through the open ports.

9. The method of cementing casing in a well bore, which includes circulating hydraulic fluid through the casing and retaining said hydraulic fluid in the casing to a level above that of normally closed ports in the side wall of the casing, lowering a plug through said hydraulic fluid for first opening the ports and then closing the bore of the casing below said ports, introducing cement into the casing in back of the hydraulic fluid and separated therefrom by a barrier, forcing the cement downwardly by hydraulic fluid in back of the cement and separated therefrom by a barrier, so as to discharge through the open ports the hydraulic fluid between the plug and the first mentioned barrier, and then cause said first mentioned barrier to yield for discharge of the cement through the open ports, the hydraulic fluid in back of the cement being retained in the casing to a level above that of additional normally closed ports in the side wall of the casing, lowering a plug through said hydraulic fluid for opening the last mentioned ports and closing the bore of the casing below said ports, and then establishing circulation downwardly through the casing and outwardly through said open ports.

10. The method of cementing casing in a well bore, which includes discharging cement from the casing by a column of hydraulic fluid retained in the casing in back of the cement and extending above normally closed ports in the side wall of the casing, lowering a plug through said hydraulic fluid for first opening the ports and then closing the bore of the casing below said ports, introducing cement into the casing in back of the hydraulic fluid and separated therefrom by a barrier, and forcing the cement downwardly by hydraulic fluid in back of the cement and separated therefrom by a barrier, so as to discharge through the open ports the hydraulic fluid between the plug and the first mentioned barrier, and then cause said first mentioned barrier to yield for discharge of the cement through the open ports.

ERD V. CROWELL.

DISCLAIMER

2,071,389.—*Erd V. Crowell*, Los Angeles, Calif. WELL CEMENTING. Patent dated February 23, 1937. Disclaimer filed November 14, 1939, by the patentee.

Hereby enters this disclaimer to claims 1, 4, 5, 6, and 7 of said patent.

[*Official Gazette December 5, 1939.*]