

July 15, 1941.

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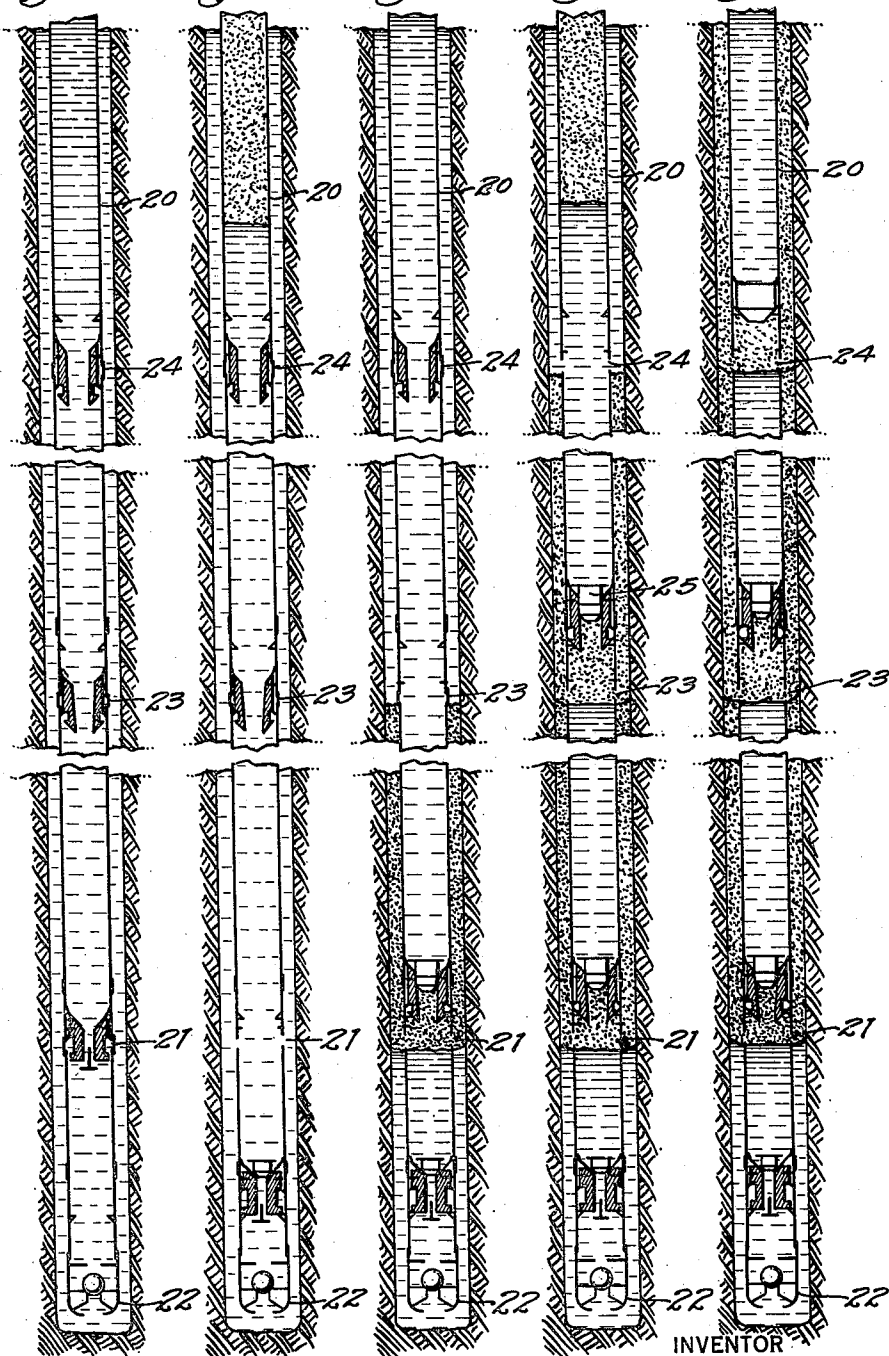
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APPARATUS AND METHOD FOR CEMENTING WELLS

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3 Sheets-Sheet 1

Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5



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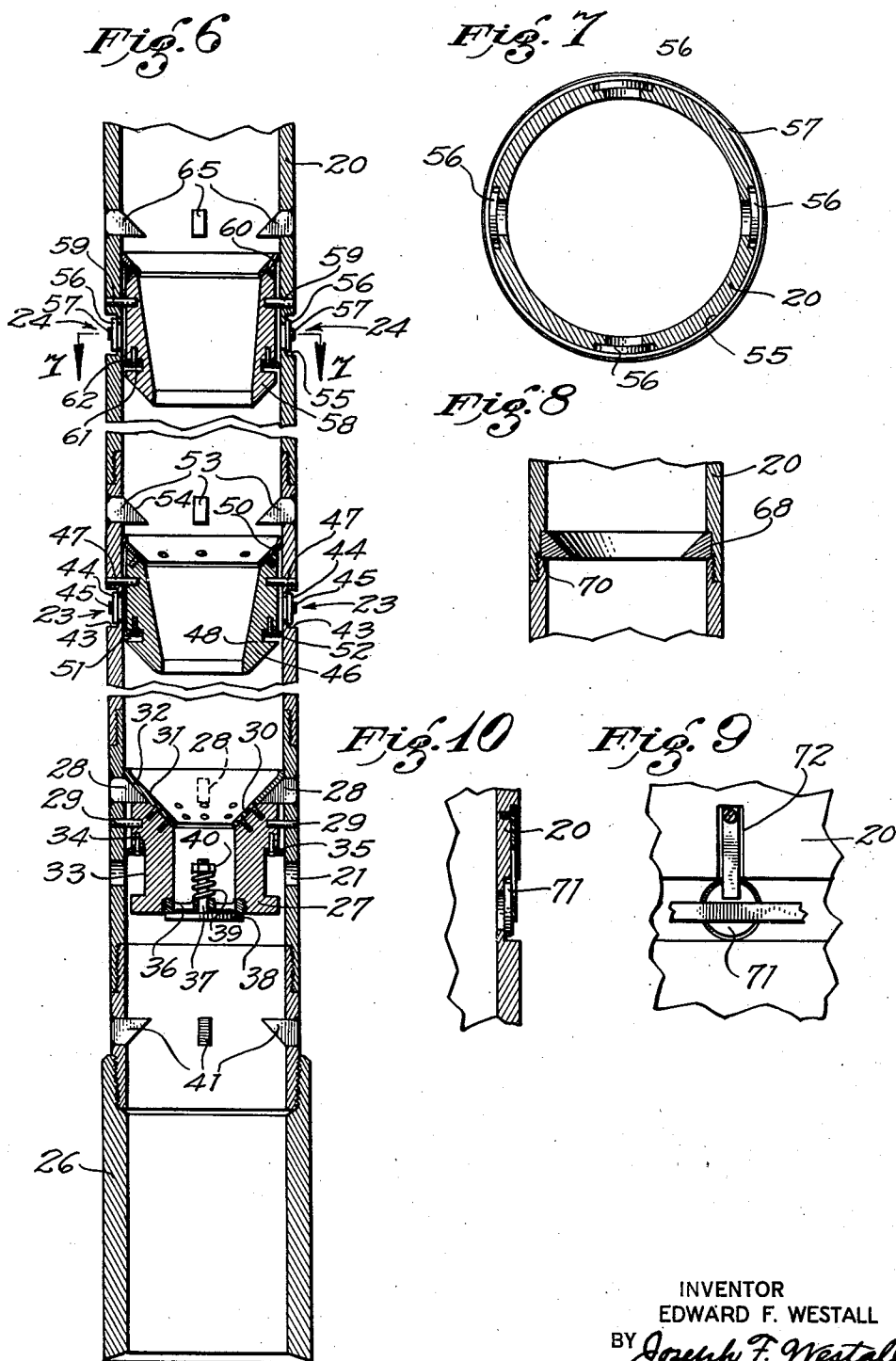
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3 Sheets-Sheet 2



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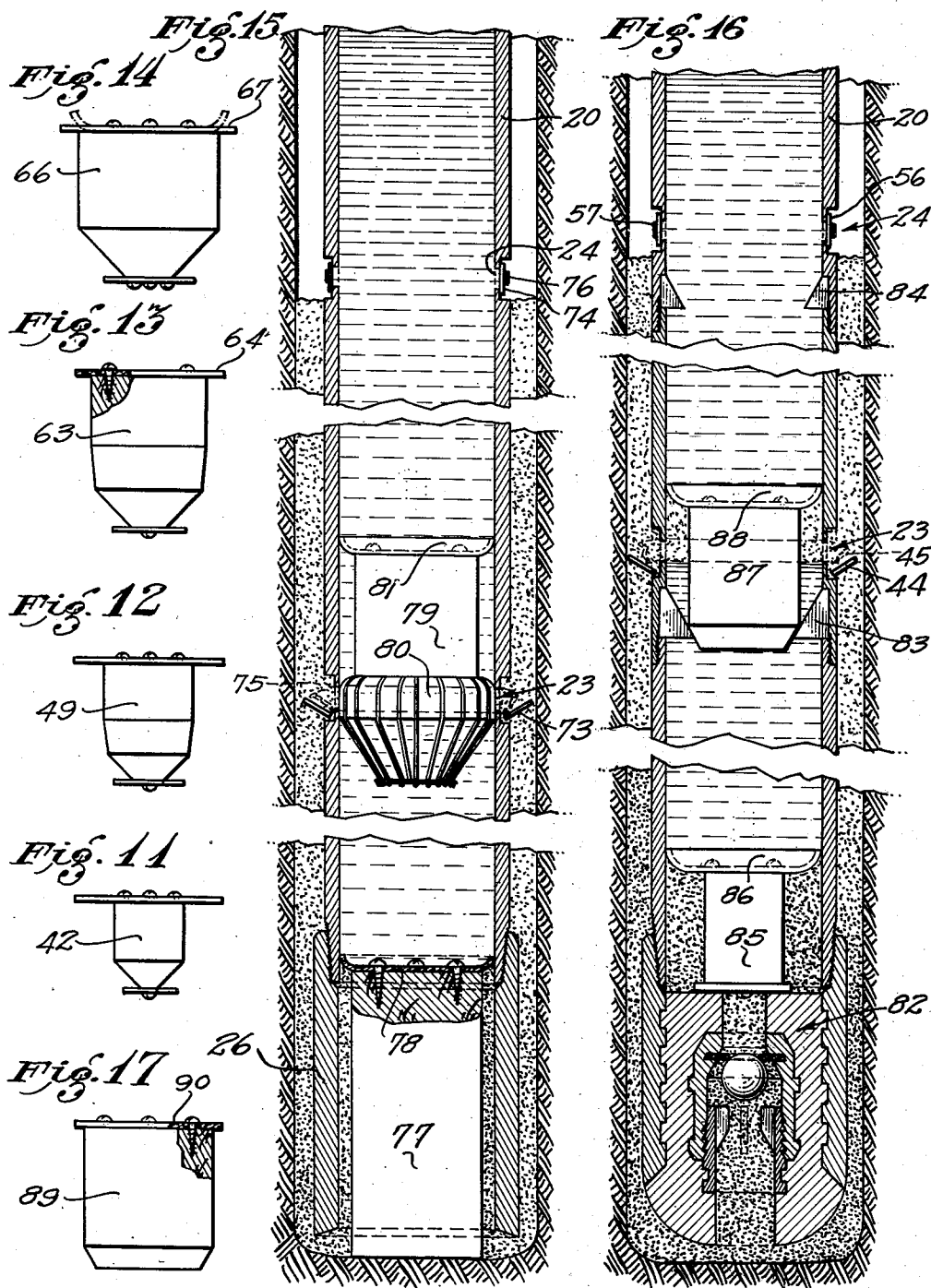
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APPARATUS AND METHOD FOR CEMENTING
WELLS

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This invention relates to apparatus and methods of cementing casing in oil wells to, primarily, lend support to the casing, isolate subterranean fluids from foreign strata and exclude corrosive constituents of the fluids from contact with the casing.

To obviate the well-known disadvantages incident to the passage of cement through the entire string of casing, and thence upwardly, around the casing to the desired location in the well-bore, lateral port cementing was introduced to the art whereby cementitious material is spotted through ports in the casing at any desired predetermined elevation, eliminating the passage of all cement through the lower end of the casing. By pumping separate volumes of cement through individual series of lateral ports, located in the casing at spaced levels, the distance each volume travels through the casing and the annular area of the hole, to the position at which it will subsequently be permitted to set, is reduced to a minimum.

It is usually desirable to provide one or more float valves in the bore of the casing which are adapted to close to pressure therebelow during the lowering of the casing, thus enabling the operator to partially "float" the casing to position for cementing to reduce strain on the derrick and equipment. To effectively perform this function, at least one of such valves should be located above the uppermost lateral ports, or valves provided on individual ports to maintain pressure in the casing less than that in the well hole. However, simple hinged or spring valves on the outside of the casing ports cannot ordinarily be relied upon to maintain their closure in the face of the great pressure of deep wells.

Float valves of the prior art, which are located in the bore of the casing, are adapted to open downwardly to permit circulating fluid to be ejected from the lower end of the string, if necessary, to remove obstructions in the well hole to the lowering of the string and to enable hydraulic fluid circulation and cementing through lower lateral ports. While the valve seats rigidly formed in the bore for such float valves must be composed of easily drillable material, they must also be heavy and large to resist the pressures to which they may be subjected. In both single and multiple stage lateral port cementing, however, obstructions in the casing bore to the passage of the cementitious mixture, as above noted, adversely affect the efficacy of the operation, particularly in deep wells.

It is a general object of the present invention to obviate the disadvantages above mentioned by

the provision of a ported well casing normally sealed to pressure in the well by valvular means but which casing may be cleared prior to the passage of cement therethrough to present a substantially unobstructed bore from the well surface to each series of ports.

Another object is to provide a casing string having a series of lateral ports located at different levels thereof, including closure means for said ports adapted to be successively opened in upward series by individual key fluid pressures within the casing.

Another object is to provide closure means for a plurality of lateral ports located in substantially horizontal alignment in the casing, which may be simultaneously opened by predetermined pressure within the casing.

Another object is to provide a casing string having a lateral port therein embodying a valve and valve seat removably supported in the bore of the casing above the lateral port, the valve of which is adapted to open to pressure thereabove, and the entire valve assembly adapted to be moved below the port to present a substantially unobstructed bore to the passage of cementitious material from the mouth of the casing to the lateral port.

Another object is to provide a method of well cementing whereby a plurality of volumes of fluent cement, separated by hydraulic fluid may be ejected from a string of casing at different levels in a single operation to permit the volumes to set simultaneously.

Another object is to provide a composite multiple-stage cementing method for serially sealing portions of the annular area between the well hole and a casing string having a plurality of lateral ports, whereby the opening of each set of ports in the casing string may be confined to the individual cementing operation there-through.

Another object is to provide a method of single or multiple stage lateral port well cementing which may be performed in a casing having an entirely unobstructed bore if desired, to permit the casing to be "carried" with the drilling tools in cavey formations, and subsequently cemented at its final location in the hole without withdrawal.

Other objects and corresponding advantages will be obvious to those of skill in this art upon an examination of the following description read in the light of the accompanying drawings, in which—

Figs. 1 through 5 illustrate schematically a

series of steps in the performance of a simple embodiment of the method of my invention;

Fig. 6 is a sectional view of a casing equipped with one form of apparatus of my invention;

Fig. 7 is a transverse sectional view of the casing taken on correspondingly-numbered lines of Fig. 6, with the apparatus normally disposed therein removed;

Fig. 8 is modified form of abutment for the casing bore upon which any or all of the cementing valves illustrated in Fig. 6, an indicator plug, or the travelling plugs of Fig. 16, may seat;

Fig. 9 is a broken elevation of a modification of the closure means for the casing ports depicted in Figs. 6 and 7;

Fig. 10 is a section of a ported casing, partially broken away, with the modified closure means of Fig. 9 in normal relation therewith;

Figs. 11, 12 and 13 are elevations of cementing plugs adapted to seat in the bore of the hollow float plug and sleeve valves, in upward series, respectively, shown in Fig. 6;

Fig. 14 is an elevation of an indicator plug adapted to close the bore of the casing;

Fig. 15 is a sectional view of a ported casing, illustrating another embodiment of the apparatus and method of my invention;

Fig. 16 is a sectional view of a third embodiment hereof;

Fig. 17 is an elevation of a top plug adapted to cooperate with the apparatus of Fig. 16 to close the casing bore.

Referring particularly to Figs. 1 through 5, one embodiment of the method of my invention is initiated by the lowering of a casing 20 into a well hole in which a series of lateral ports are provided at spaced levels. For example, the lowest series of ports 21 may be located near the bottom of the string just above the casing shoe 22 which is provided with a valve to close the lower end of the casing to an external balance of pressure, as hereinafter described in detail. The next-above series of ports 23 may perforate the casing at approximately one third the length of the casing from the bottom, and the uppermost series of ports 24 at approximately one third the length of the casing from the top of the well. If it is desired to cement through the lower end of the string, the ports 21 above the shoe may be eliminated. Ports may be provided in the casing at any number of levels and with any appropriate relative spacing, as will be obvious. Each set of lateral ports may be normally closed to pressure from either direction by means hereinafter described with reference to ports 23 and 24.

When the casing has been landed or positioned as desired hydraulic circulating fluid is introduced therein and pumped through its lower end, if it is suspended above the well bottom as is usual practice (Fig. 1), or through the lowest series of ports, as is hereinafter described. The fluid under pressure then passes upwardly around the casing to the top of the well to remove miscellaneous debris, such as drillings, cavings, etc. When it has been determined that the bore of the hole is clear, a plug is inserted into the casing and moved downwardly below the lowest series of ports 21 by fluid under pressure introduced into the casing on top of the plug, which ports are opened by fluid pressure from within the casing while the bore of the casing below said ports is closed by the seating of the plugging means in the casing. The opening of the ports will be indicated to the operator by the pressure required of the pump. Additional circulating fluid thereabove may then

be pumped through the casing and, under pressure, will be deflected through said ports by the closure of the casing therebelow. A volume of cementitious fluid in an amount sufficient to fill the annular area of the well hole around the casing from ports 21 to ports 23 is then introduced into the casing (Fig. 2). On top of the cement a second plug is inserted into the casing. The cement slug with the second plug on top thereof is then forced downwardly to said ports 21 by the introduction into the casing of additional mud fluid under pump pressure. Continued introduction of mud fluid under pressure will expel the cement slug from the casing through ports 21 and cause it to flow upwardly in the hole. As the last few feet of cement, the exact amount depending upon the depth of the well, reach ports 21 in its downward passage, the casing bore is plugged directly above said ports by the seating of the plug in the casing, preventing further pressure from moving the fluid therebelow (Fig. 3). With the casing thus closed, and the first charge of cement in final position outside thereof, extending upwardly to ports 23, pressure will build up in the casing, which will indicate to the operator the completion of the first stage of the operation, as will be apparent to those of skill in this art.

The second set of ports 23 in upward series are then opened by fluid pressure. The volume of cement intended for discharge therefrom may or may not have been introduced into the casing prior to the opening of ports 23. With the second set of ports open, fluid under pressure thereabove will be deflected outwardly through the ports and up around the casing by the immovable fluid column in the casing between the lower point of plugging (above ports 21) and ports 23. If the second charge of cement is in the casing when ports 23 are opened it may be pumped through these ports in the manner indicated. Preferably, however, the ports are opened first, and circulation therethrough established before the second volume of cementitious fluid is introduced into the casing. A third plug is inserted into the casing on top of the second volume of cement. The cement and plug are then moved through the casing and through ports 23 principally by hydraulic fluid under pressure. Before the entire volume of cement is discharged, the casing bore is plugged as at 25 by the seating of the plug, moved with the cement in the casing, adjacent ports 23 or between ports 23 and 24. Further displacement of any portion of this cement volume either in or out of the casing being prevented, the cement tailings of the second volume of cement between the second point of plugging 25 and ports 23, are left in the casing for subsequent removal by drilling tools in a well known manner. The portion of the volume of the second charge of cement which is discharged from the casing is preferably sufficient to fill the annular area of the well hole from ports 23 to the next-above series of ports 24, thus providing with the cement expelled from ports 21 a column of cement around the casing from the lowest ports to ports 24.

Other volumes of cement may be introduced into the casing (Fig. 4) and discharged from upper lateral ports at any number of spaced levels in a similar manner as will be apparent without further detailed description. At the conclusion of the last cement discharge, which completes the annular column of cement in the hole from the lowest series of ports to the surface of the well,

the casing bore is again plugged (Fig. 5), by a plug introduced with the last volume of cement, above the uppermost ports and sufficient fluid pressure maintained thereon to prevent displacement of the cement outside of the casing until it has had opportunity to set. Drilling tools may then clear the bore to permit further development of the well.

It will be understood that in the method described individual hydraulic circulation through each set of ports before the introduction of cement for discharge from the respective sets of ports may be eliminated. After the opening of the lowest set of ports and the first charge of cement is introduced in the well, the quantity of hydraulic fluid pumped in on top of the cement may be predetermined as sufficient to only fill the bore of the casing from the point at which the casing bore is closed intermediate the two lower series of ports and the second series of ports, or slightly less than that amount. On top of this fluid the next charge of cement may be placed, on which another volume of hydraulic fluid may be pumped, equal in amount to a column having a cross-section of the casing and a length equal to the distance from the point above the second set of ports and below the third set of ports at which the casing is closed (as indicated at 25) to ports 24. The third and subsequent volumes of cement may then be introduced into the casing, being separated by hydraulic fluid. The ports may then be opened in upward series as indicated, closing the bore of the casing between each relatively adjacent pair of ports at the conclusion of the cementing discharge through the lowest set of each pair, as above noted, which, in this embodiment will be in quick succession.

While the method of my invention is indicated above as involving the introduction of predetermined quantities of cement into the casing it will be noted that in the performance of the method where the discharges of cement are made in quick succession, i. e., before the lowest charge has had an opportunity to set, no exact limits to either the quantities of cement or the hydraulic fluid need be imposed, as it is obvious that if the cement fluid discharged from a lower series of ports is sufficient to fill the annular area around the casing to a point above the next higher series of ports the following cement charge, expelled from the higher ports, will displace that portion of the lower-expelled mixture which extends above said higher ports, as it will still be in fluent form.

In a modification of the above method, after circulation is established a volume of cement is discharged through the bottom of the casing and forced upwardly therearound, which is preferably in an amount sufficient to fill the hole from the bottom to the level of the lowest series of ports. The bore of the casing below the lower lateral ports is then closed off and the operation completed in the manner above described. In this or other modifications the lower end of the casing string may be equipped with a conventional type float valve, as will be obvious.

Referring to the embodiment of the apparatus of my invention illustrated in Figs. 6 through 14, the numerals of which indicate similar parts throughout the several views, 26 designates a casing string having a common form of shoe 26 in its lower end. Several series of lateral ports perforate the casing at spaced levels. A hollow plug 27 slidably closing the bore of the casing, is

supported therein over the lowest series of ports 21, by shear pins 29, with its upper end in contact with a plurality of lugs 28 extending into the bore of the casing in relative horizontal alignment slightly above the ports. The upper end 30 of the bore of plug 27 is bevelled, and has secured thereto, by rivets or the like, an annular packing member 31 adapted to slidably seal the area between the casing and plug 27 to pressure thereabove. Packing member 31 normally lies on the upper bevelled edges 32 of lugs 28 but may be collapsed to pass the lugs upon downward movement of the plug.

An annular recess 33 in the outer wall of the plug forms a downwardly-directed annular shoulder 34 which is normally located above ports 21, i. e., when supported by shear pins 29. An annular packing member 35 secured to shoulder 34 faces downwardly and engages the wall of the casing to seal the area around the plug adjacent the ports 21 with respect to pressure in the casing therebelow.

In the lower bore of plug 27 a spider 36 is threaded or otherwise secured supporting in its center the vertically movable stem 37 of a float valve 38 adapted to normally seat on the lower end of plug 27. A helical spring 39 encircling stem 37 above spider 36 expands against an abutment 40 at the upper end of the stem to resiliently resist downward displacement of the valve and maintain the bore of the plug closed to pressure therebelow.

A series of lugs 41 secured to the casing in horizontal alignment and extending into the bore thereof are provided below ports 21 a distance substantially equal to the length of plug 27 plus the length of a lead plug 42 (Fig. 11) later referred to.

The next-above series of ports 23 in the casing extend into an annular recess 43 in the outer wall of the casing. These ports are normally maintained closed by individual plugs 44, which plugs are held in position by a frangible band 45 extending around the casing in recess 43. Band 45 may be composed of resilient material bent around the casing over plugs 44 and having its ends secured by a frangible portion or pin (not shown) or the entire band may be frangible. Regardless of its composition, to provide sufficient margin of safety against premature breakage, band 45 should be of sufficient strength to withstand maximum hydraulic circulating pressures through the lower bore of the casing, the pressure required to break shear pins 29, and 47, later referred to, and the pressure necessary to pump hydraulic fluid and cement through the string to ports 21, or cement through the lower end of the casing and thence upwardly in the annular area to the level of ports 23, all of which pressures may in specific embodiments be exerted through ports 23 against the plugs 44 from the bore of the casing before it is desired to break the band, as will be obvious from the following description.

In this particular embodiment (Fig. 6) a sleeve valve 46, slidable within the casing bore is supported over the lateral ports 23 by shear pins 47. The bore of sleeve valve 46, which is of larger diameter than the bore through plug 27 is tapered inwardly toward its lower end as indicated at 48 to guide a plug 49 (Fig. 12) therein but prevent its passage entirely through the valve. In the upper bore of valve 46 an upwardly-directed annular packing ring 50 is riveted or otherwise secured to engage the wall of

the casing to seal the area therearound with the casing to pressure from above. In an annular recess 51 in the periphery of the valve 46 a downwardly-directed packing ring 52 is similarly secured which engages the wall of the casing below the ports and extends downwardly to form a seal with the casing. Thus while the shear pins 47 are unbroken, the ports 23 are isolated from pressures in the casing on opposite sides of packing rings 50 and 52. The lower periphery of sleeve valve 46 is tapered inwardly at an angle corresponding to the bevel 32 of lugs 28 on which it is adapted to seat.

Intermediate ports 23 and the upper series of ports 24 a plurality of lugs 53 similar in size to lugs 28 are secured in the bore of the casing having upwardly-directed beveled faces 54.

The outer wall of the casing is recessed at 55 at the upper series of ports 24 and plugs 56 are held in the recess in a position closing said ports by a frangible band 57 in a manner identical to the structure of ports 23. The frangible band 57, however, is composed of a material adapted to withstand, in addition to the pressures from within the casing to which band 45 may be subjected, as above noted, the pressures required to break shear pins 59, later referred to, to circulate hydraulic fluid through ports 23 and to pass cementitious fluid downwardly through the casing through ports 23 and upwardly in the annular area around the casing.

A sleeve valve 58 similar to valve 46 but having a tapered bore of larger minimum diameter than that of sleeve valve 46 is normally suspended in the bore of the casing over ports 24 by shear pins 59. The upper end of valve 58 carries an annular packing member 60 which engages the casing to seal the area around the valve above ports 24. Below the ports 24 a peripheral recess 61 is formed in the valve in which a downwardly extending annular packing member 62 is secured by well known means to seal the area around valve 58 to pressure within the casing therebelow. A plug 63 (Fig. 13), of a diameter larger than the smallest diameter of the bore of valve 58, carries an upwardly-directed calathiform packer 64, which is adapted to engage the wall of the casing upon insertion therein. The plug 63 may accordingly be moved downwardly by fluid pressure into the bore of valve 58 and cooperates with the valve to close the bore of the casing. Continued pressure will break shear pins 59 and move valve 58 and plug 63 downwardly against lugs 53.

A plurality of lugs 65 which may be identical with lugs 28, 41 or 53 in size, shape and number, are secured in the casing bore preferably just slightly above ports 24 in substantially horizontal alignment. An indicator plug 66, having an upwardly-directed calathiform packer 67, slidable with the casing, is adapted to seat on lugs 65 and thereby close the bore of the casing above the uppermost ports 24 to pressure thereabove.

As above noted I do not limit my invention to three levels at which lateral ports are located for cement discharge, as it is obvious that more or fewer levels of the casing may be perforated to comply with specific requirements. However the bore of each of the sleeve valves employed in upward series is larger than the bore of the sleeve valve or plug 27 therebelow. In the embodiment here alluded to (Fig. 6) where the sleeve valves and plug 27 are employed, each set of lugs of the series 28, 41, 53 and 65 are preferably small

enough to permit the passage of a plug having the diameter of the largest sleeve valve-actuating plug.

Annular valve seats, each comprising a beveled ring 68 (Fig. 8) may be substituted for any or all series of horizontally-aligned sets of lugs. The valve seats 68 may be secured in the bore of the casing by any means well known in the art, such as by clamping against a shoulder 69 formed in the bore of a section of casing or coupling by an adjacent section of casing or coupling, as indicated at 70.

Conventional spring valves 71 (Figs. 9 and 10) may be substituted for plugs 44 or 56 on any or all of the lateral ports as desired. Valves 71 will close to pressure outside of the casing at the conclusion of the cementing operation to prevent back flow of cement. The casing is preferably vertically recessed as at 72 at each port in which recesses the valves 71 are riveted or otherwise secured. Apparatus wherein valves 71 are employed also preferably incorporates the frangible bands, above described, to maintain each set of horizontally-aligned valves closed until the bands are broken, in the manner indicated.

In the operation of the particular embodiment just described and illustrated in Figs. 6 through 14, the casing string 20 is lowered in the well, equipped as shown in Fig. 6 with plug 27 and sleeve valves 46 and 58 supported in a position covering respective ports. Hydraulic fluid introduced into the casing is pumped through the bore of each sleeve valve and opens valve 38. It then passes through the lower end of the casing string or through the lower ports 21 depending upon the pressure differential, thence upwardly around the casing as above described. On top of the hydraulic fluid, lead plug 42 (Fig. 11) is inserted and pumped downwardly through sleeve valves 46 and 58 to close the bore of plug 27. The shear pins 29 are then broken by the hydrostatic weight of the fluid plus sufficient pump pressure from the well surface, and the plug 27 and lead plug 42 are forced downwardly exposing ports 21. The introduction of more fluid under pressure at the well surface expels a substantially equal amount of fluid from the lower ports as plugs 27 and 42 seat on lugs 41, closing the bore to pressure from above. The freedom of circulation indicates to the operator that the well and casing are in condition for placement of the first volume of cement. A charge of fluent cement is then introduced into the casing on which plug 49 (Fig. 12) is placed. Hydraulic fluid under pressure pumped in on plug 49 causes the cement in advance thereof to move downwardly through the casing and valves 46 and 58. As the upper end of the cement volume passes through sleeve valve 46, plug 49 will seat therein closing the bore of the casing. The fluid pressure on the top of plug 49 and sleeve valve 46 will break shear pins 47 and downward movement of the second charge of cement therebelow will be resumed until substantially all the cement has been expelled through the ports, at which time sleeve valve 46 and plug 49 will be seated on lugs 28. The resistance to the introduction of more hydraulic fluid into the casing due to closure of its bore by sleeve valve and plug will indicate to the operator the completion of the discharge.

With the bore of the casing thus closed at a point just above ports 21 pressure may be increased until ports 23, which have been exposed to pressure within the casing by the downward

movement of valve 46, are cleared by the breaking of frangible band 45. Circulation may then be established through ports 23 as described above with reference to the lower ports. The second cement charge is then introduced into the well, plug 63 (Fig. 13) being inserted on top of the cement, and forced downwardly by hydraulic fluid pressure. Plug 63 and the cement will pass freely toward ports 23 until the plug seats in the bore of sleeve valve 56. Continued pressure will break the shear pins 59 and the cement, with valve 58 and plug 63 thereon, will again be moved downwardly, the cement being discharged from ports 23. Sleeve valve 58, coming to rest on lugs 53, cooperates with plug 63 to close the bore of the casing to pressure thereabove. With this position of plug 63 and valve 58, the completion of the second cementing discharge is indicated at the well surface by the laboring fluid pump as will be understood from the above description.

The third, and still other cement discharges to which particular embodiments of my invention may be adapted, from respective series of ports in upward series, such as from ports 24, are performed in the same manner, as will be obvious to those of skill in this art. Plug 66 (Fig. 14) is inserted on top of the last volume of cement to seat on lugs 65 and thus close the casing bore above the uppermost lateral ports. Hydraulic fluid pressure in the casing thereabove may be maintained in the casing to prevent displacement of the cement outside of the casing, as well as of hydraulic fluid, cement tailings, and plugs and valves in the casing bore until the cement has set.

Referring particularly to the modified form of both apparatus and method of my invention, illustrated in Fig. 15, the casing is provided with ports 23 and 24, as above designated. The ports 23 and 24 of the separate levels are provided with individual plugs 73 and 74, respectively, which plugs are maintained at the outside of the casing, closing respective ports, by frangible bands 75 and 76, respectively, band 76 being preferably stronger than band 75 i. e., of relatively greater resistance to fracture by pressure from within the casing.

It is often necessary in deep wells where the formation is prone to cave to "carry" or lower the casing with the drilling tools as the hole is deepened. The present modification contemplates multiple lateral port cementing through casing having a bore sufficiently unobstructed to permit the normal and unrestrained operation of drilling tools therethrough prior to the cementing operation. In preparation for the introduction of cementitious fluid the casing is suspended slightly off bottom and circulating fluid is passed through the casing and up to the surface in the annular area of the well hole to remove debris. A quantity of cement, preferably in an amount sufficient to reach from the bottom of the casing to the lowest of the lateral ports, is introduced into the casing. A plug 77, having an upwardly-directed calathiform packing member 78 at its upper end, slidably fitting the casing, is placed on top of the cement charge and passed under pressure to the bottom of the casing from which cement is discharged. The lower end of plug 77 will urge the cement through the bottom of the casing and will abut against the bottom of the hole, the upper end of the plug and its packer 78 remaining in the casing to close the same to pressure from above. The application of more pressure will break the weakest of the frangible

bands 75, which is ordinarily located around the lowest series of plugged ports 23 and the hydraulic fluid in the casing will then be free to flow therethrough upwardly around the casing to the well surface. Another charge of cement introduced into the casing is followed by a plug 79. Plug 79 has a downwardly directed expandible swab packer 80 of a type well known in the art mounted by any well known means to its lower end. The packer is adapted to pass all couplings between casing sections and other irregularities in the casing bore upon its downward movement actuated by fluid pressure. The upper end of plug 79 carries a packer 81 similar to packer 78 of plug 77. Fluid pressure applied on top of plug 79 will move it and the cement therebelow toward open ports 23. When plug 79 reaches the ports the cement will have been discharged therefrom and extend as a continuation of the column from the bottom of the hole to the upper ports 24. The lower end of swab packer 80 will then be supported on the column of fluid in the casing between plug 77 and ports 23 which will limit its downward progress. The upper end of plug 79 and packer 81 being above ports 23, the bore of the casing above said ports will be closed, preventing both further downward movement of the fluid above ports 23, and the displacement of the discharged cement. Pressure is then built up in the casing above the plug to a degree sufficient to cause the breakage of frangible band 76 of the next higher series of ports 24.

The next volume of cement is then introduced into the casing and an upper plug (not shown), identical with plug 79 is inserted thereon. Hydraulic pressure will then move said upper plug to a position over ports 24, the charge of cement being expelled in advance thereof from the ports 24 to continue the annular column of cement around the casing to the top of the well, or the next higher series of ports (not shown) from which cement may subsequently be discharged, in a similar manner.

With the uppermost plug supported on the fluid column in the casing extending upwardly to the ported level at which the uppermost cement discharge is to be made, the casing bore at the upper end of said plug (above the uppermost ports) will be closed by a packer carried by the plug. Fluid pressure maintained on said plug will prevent displacement of the various charges of cement and permit the same to set.

It will be apparent that the plugs employed in this embodiment may be all of the same diameter to minimize manufacturing costs and simplify operation. The number of ported levels of the casing at which cement may be discharged depends only upon the proportioning of the strength of material of which the frangible bands are made in consideration of the pressures employed within the casing and the pressures encountered around the casing, to insure, in the embodiments described, their breakage in upward series.

It will be obvious that cement may be spotted at any level around an imperforate casing filled with fluid, or such a casing entirely cemented by employing a conventional type perforator to form each set of lateral ports beginning with the lowest level at which cement is to be discharged, each cement volume being finally placed before perforating for the next discharge thereabove.

Another embodiment of the apparatus for per-

forming the method described above with reference to Fig. 15, is illustrated in Fig. 16. A conventional type float valve structure, such as generally indicated at 82, is secured by well known means, in the bottom of the casing 20 to facilitate lowering the string in instances in which the casing is placed after removal of drilling tools. Float valve 82 may be provided in any of the embodiments of my invention as above noted.

The casing 20 is ported at 23 and 24, which ports are closed by plugs 44 and 56, respectively. A frangible band 45 encircling the casing over plugs 44, in the manner described above, normally maintains ports 23 closed, and a similar, but stronger, band 57 is located around the casing over plugs 56.

Below each set of ports 23 and 24 and any other sets of ports which may be provided in particular embodiments, a series of lugs 83 and 84, respectively, are secured in horizontal alignment in the bore of the casing, each set of lugs 83 and 84 and any others, in upward series, being shorter than the set of lugs therebelow. Valve seats, such as the one illustrated in Fig. 8, may be substituted for any or all of the lugs as will be obvious, each seat in upward series having a larger bore than the seats below it.

In operation circulation is established, as above noted, through the lower end of the casing and upwardly in the hole to the well surface. Cement is then pumped into the casing on top of the hydraulic fluid, in an amount sufficient to fill the area of the hole around the casing from the bottom of the hole to the level at which the lower lateral ports 23 are located. On top of the cement a plug 85 is placed, which is diametrically small enough to pass both sets of lugs 83 and 84. Plug 85 has a calathiform packer 86 secured to its upper end which is adapted to engage the wall of the casing and prevent the downward passage of fluid thereby. The cement and plug 85 are pumped through the casing, the cement being discharged from the bottom thereof, the plug 85 seating on the float valve structure 82, closing the bore to pressure from above. Increased pressure will break frangible band 45 and permit fluid to be discharged through ports 23. A second cement volume is then pumped into the casing with a plug 87 thereon, and discharged from ports 24. Plug 87, which carries a packer 88 adapted to engage the wall of the casing and close the bore to pressure from above, is of a diameter small enough to pass lugs 84 but seat on lugs 83. As the last of the cement is discharged from ports 24 plug 87 will seat on lugs 83, preventing further displacement of fluid either above, below or outside of the ports.

Fluid pressure is again applied to break the upper band 57 and the operation repeated through ports 24 with a plug 89 (Fig. 17), carrying a packer 90 at its upper end, coming to rest on lugs 84 to close the casing to pressure above ports 24. Pressure sufficient to hold plug 89 on lugs 84 will permit the respective cement volumes to set, after which the casing is cleared for a purpose and in the manner well known in the art.

It will be apparent that the float valve structure 82 at the lower end of the casing may be eliminated and that a plug similar in construction and function to plug 77, but of a diameter of plug 85 may be substituted for plug 85; also a series of ports 21 may be located just above the casing shoe through which the first cement volume may be discharged, there being lugs (not

shown) longer than lugs 83 provided in the casing bore below said ports 21 for the seating of the modified plug described; or in the absence of float valve structure in the bore of the casing a lead plug of sufficient length to seat on the bottom of the hole and having its upper end closing the bore of the casing above the lowest set of lateral ports may be substituted for plug 85, all without departing from the spirit of my invention as defined in the appended claims.

The lugs or valve seats adaptable in either of the modifications shown in Figs. 6 and 16 need not be adjacent their respective ports but may be placed at any point intermediate the ports between which they are shown. It will be obvious also that the embodiment of the method described in connection with the apparatus of Fig. 6 may include the steps required to eject a first volume of cement from the bottom of the casing by pumping the cement on top of the preliminary circulating hydraulic fluid; following the cement with a volume of hydraulic fluid sufficient to fill the casing from the shoe to the lower lateral ports; and placing the lead plug 42 directly on top of such fluid for actuation of plug 27. The lower lateral ports 21 may also be equipped in particular embodiments with plugs or valves adapted to be opened by pressure within the casing less than that required to break frangible bands 45 and 57. The lower ports 21 may also, in the absence of plug 27, be protected by a sleeve valve similar to sleeve valve 46 but having a smaller bore.

This invention is not limited to closure means for the lateral ports such as that disclosed which comprise a plug or valve retained in closed position by a frangible band, except in the claims appended hereto specifically so limited, as it will be understood that spring means, for example, of various strengths, adapted to be opened by predetermined minimum pressures may be substituted therefor.

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

1. In a well cementing apparatus, a casing having a lateral port therein, a body slidably closing the bore through the casing, means including fluid pressure within said casing at the port supporting the body above the port, said body having a hole therethrough communicating the zone above the body with the area therebelow, a valve normally closing said hole to pressure from below the body, and a plug to close the hole to pressure from above the body.

2. In a well cementing apparatus, a well casing having a pair of lateral ports therein, closure means for one of said ports adapted to be displaced by pressure within said member, closure means for said second port adapted to be displaced by pressure less than the minimum pressure required to displace said first-mentioned closure means.

3. In a well cementing apparatus, a well casing having a lateral port therein, closure means for said port adapted to be displaced by pressure from within the casing, and valvular means releasably supported in the bore of said casing closing said port to pressure from within the casing, said casing having a second lateral port therein, means closing said second port but removable to open said last-mentioned port by pressure greater than that required to displace said first mentioned closure means, and means to cause movement of said valvular means to expose said first mentioned port to pressure in the casing.

4. In a well cementing apparatus, a well casing having a lateral port therein, a body in the bore of the casing normally closing the port but movable from said port by pressure within the casing, said body having a by-pass therethrough, means to close said by-pass, auxiliary closure means for said port movable from said port by a minimum pressure greater than the pressure required to move said body.

5. In a well cementing apparatus, a well casing having an upper and lower lateral port, a body closing the bore of said casing, means to releasably support said body in a position closing the lower port to pressure in the casing at said upper port, means including fluid pressure to release said body and move the same below said lower port, closure means for said upper port adapted for displacement by pressure in the casing greater than that required to move said body below said lower port.

6. In a well cementing apparatus, a well casing having an upper and lower lateral port, a body closing the bore of said casing, means to releasably support said body in a position closing the bore of the casing between said ports, means including fluid pressure to release said body and move the same below said lower port, closure means for said upper port adapted for displacement by pressure in the casing greater than that required to move said body below said lower port, means releasably supported in the bore of the casing in a position closing said upper port to pressure within the casing, and means to move said last-mentioned means below said upper port.

7. In apparatus for cementing wells, a well casing lining the well shaft and having a pair of lateral ports therein for the ejection of cement from said casing, closure means for one of said ports movable to open its respective port by pressure within said casing and thereby enable the ejection of a volume of cement from said casing into the area around said casing, closure means for the other of said ports movable to open its respective port in response to pressure different from that required to open the port controlled by said first mentioned closure means, for ejection of a second volume of cement from said casing.

8. In a well cementing apparatus, a well casing having a lateral port therein, closure means for said port adapted to be displaced by pressure from within the casing, a body in the bore of the casing normally closing the port to pressure within the casing and having a by-pass therethrough, and means to close said by-pass and move said body to expose said port to pressure within the casing, a second lateral port in the casing below said first-mentioned port, closure means for said second port movable to open said second port by pressure less than that required to displace said first-mentioned closure means.

9. In a device of the character described, a tubular member having a lateral port therein, a hollow plug in the bore of said tubular member above said port having a downwardly-directed surface exposed to the zone at said port, means to limit downward movement of said plug, a valve in the bore of said plug adapted to open to pressure above said plug but to close to pressure below said plug, and means to move said plug below said port.

10. In a device of the character described, a tubular member having a lateral port therein, a

plug to close the bore of said tubular member, and a fluent body to support said plug in a stationary position in the tubular member to close the bore of said member above said lateral port to pressure from above in excess of pressure at the port.

11. In a device of the character described, a tubular member, means to close the bore of said tubular member at a predetermined level, a plug movable downwardly through said tubular member above said point of closure, and a fluent body supported on said closure means to limit downward movement of said plug.

12. In apparatus for cementing wells, a casing having a pair of lateral ports therein at spaced levels, means to close the lower end of the casing openable to pressure within the casing, means closing said ports respectively to different predetermined maximum pressures within the casing, means to open the lower port in the casing, means to close the bore of the casing above said lower port, and means to open said upper port.

13. In a device of the character described, a plug, a downwardly-directed calathiform packer connected to said plug, means connected to said plug engaging the outer edge of said packer to maintain the downward extension of the edges of said packer and an upwardly-directed calathiform packer connected to said plug above said first-mentioned packer.

14. In a device of the character described, a tubular member, a plug movable through said member, an arcuate packer carried by said plug extending downwardly so as to expand against the wall of said member by pressure within said member below said plug and means connected to said plug to resist upward displacement of the outer edge of said packer during downward movement of the plug in said member.

15. In a device of the character described, a tubular member, a barrier movable through said member, and a fluid column below said barrier to limit downward movement of said barrier.

16. In a device of the character described, a substantially vertical tubular member having a port therein, a fluid column in said member having its upper end terminating at said port, a plug movable downwardly through said member to said port, fluid pressure means to move said plug downwardly, said fluid column limiting downward movement of said plug, and means carried by said plug to separate said fluid pressure means from said port while said plug is supported by said fluid column.

17. In a device of the character described, a tubular member having a pair of ports therein spaced vertically with respect to each other, a plug movable through said member, means carried by said plug to close the bore of said member to pressure thereabove, a fluid column below said lower port to support said plug in a stationary position with said means between said ports against pressure above said plug in excess of pressure at said lower port, a second plug, means carried by said second plug to close the bore of said member, a second fluid column, supported on said first plug, to support said second plug stationary against pressure thereabove in excess of pressure at said upper port, with said last-mentioned means above said upper port.

18. In a device of the character described, a tubular member having an unobstructed bore and adapted to be lowered as drilling proceeds, said member having a lateral port therein, and

means including a fluid column to close the bore of said member above said port.

19. In apparatus for cementing wells, a well casing having a lateral port therein, means closing the lower end of said casing to pressure outside thereof but adapted to open to circulating fluid under pressure within said casing, means closing said port to pressure in said casing equal to the pressure required to circulate fluid through the lower end of the casing, a plug to close the lower end of said casing to pressure in the casing, fluid pressure to open said port, a second plug movable through said casing, means carried by said second plug closing the bore of said casing, and a fluid column extending from the lower end of said casing to said port to support said second plug with said last-named means above said port so as to close the bore of said casing below said port to pressure in the casing above said last-named means carried by said second plug.

20. In a method of cementing wells comprising the steps of: lowering into a well a casing string forming a fluid seat for a plug in the casing, and closing the bore of the casing section by seating a plug on said fluid seat.

21. In a well cementing apparatus, a casing having a pair of lateral ports in substantially the same horizontal plane, closure means for said ports, single means to maintain both of said closure means on the outside of said casing in a position closing said ports to pressure around the casing, said last-mentioned means being movable by pressure within the casing so as to release said closure means simultaneously.

22. In a device for cementing wells, a tubular member, a valve body having a bore therein and carrying a downwardly opening valve controlling the bore of said member, said valve body being located in the bore of the casing to divide the bore into an upper and a lower chamber, a tubular member having a port therein to communicate the lower chamber with the area around said member, and means to move said valve body and said valve in the bore thereof downwardly to communicate the upper chamber with the area around said member through said port.

23. In a well cementing apparatus, a tubular member adapted to be lowered into a well hole and having a pair of ports therein, closure means for each of said ports adapted to be displaced by pressure within said member, single means maintaining both of said first-named means closed, and means consisting entirely of fluid to render said last-named means ineffective for maintaining the closure means in closed position.

24. In a well cementing apparatus, a tubular member adapted to be lowered into a well hole, said member having a pair of ports therein, closure means for each of said ports, and frangible means maintaining both of said first-named means in positions closing said ports, said closure means being openable in response to pressure within said member upon the breaking of said frangible means.

25. In a well cementing apparatus, a member having a pair of ports therein, means including a frangible element closing both of said ports to communication with the zone in the member, and means comprising fluid under pressure to break said frangible element to open both of said ports substantially simultaneously.

26. In a device of the character described, a casing string having a lateral port therein, means secured rigidly in the casing below the port restricting the bore thereof, and a plug movable downwardly through the casing by fluid pressure to seat on said last-named means, and means carried by said plug to close the bore of the casing above said port when said plug is seated on the means restricting the casing bore.

27. In apparatus for cementing wells, a well casing string having a pair of ports therein, means closing said ports, respectively, means consisting of fluid exclusively to open one of said ports, and means consisting of fluid exclusively to subsequently open the other of said ports.

28. In apparatus for cementing wells, a well casing string having a pair of ports therein, means closing said ports, respectively, means to open one of said ports, and means consisting of fluid exclusively to subsequently open the other of said ports.

29. In apparatus for cementing wells, a well casing string adapted to be lowered into a well bore, said casing string having a port therein and an opening below said port communicating the casing bore with the well bore, means to normally maintain said port closed, fluid means to wash the well bore upon ejection from the casing through said opening in the casing, and means consisting of fluid exclusively to subsequently displace said closure means from the port.

30. In a device of the character described, a casing string having a lateral port therein, means in the bore of the casing secured rigidly against vertical movement, and a plug movable downwardly through the casing into contact with said last-named means to close the bore of the casing adjacent said port.

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