Feb. 3, 1953 R. C. BAKER ET AL **2,627,314**

CEMENTING PLUG AND VALVE DEVICE FOR WELL CASINGS

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Fig. 1.

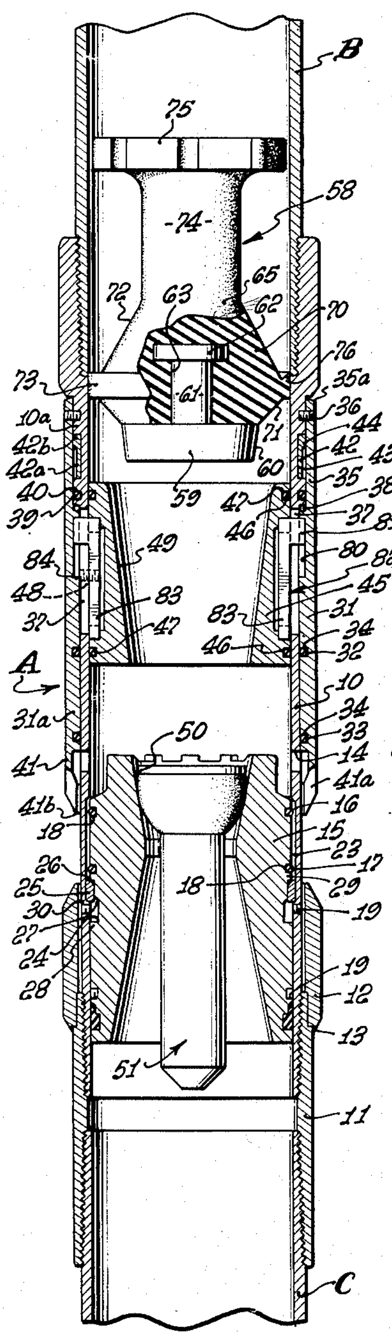


Fig. 2.

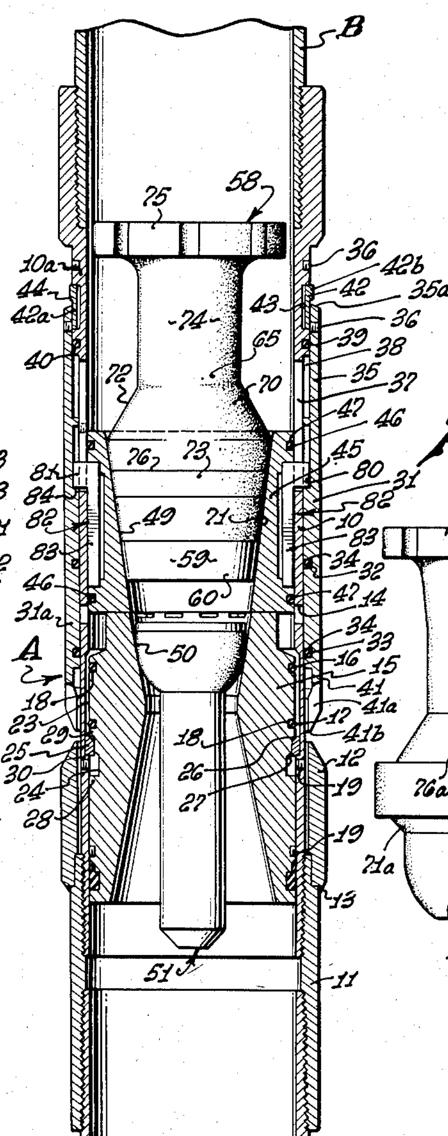
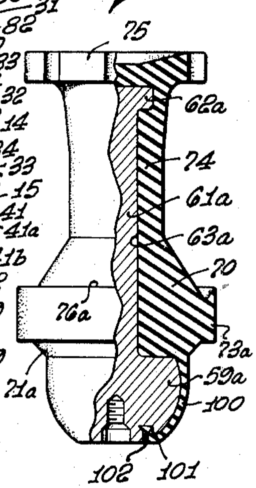


Fig. 3.



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CEMENTING PLUG AND VALVE DEVICE FOR WELL CASINGS

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10 Claims. (Cl. 166—1)

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The present invention relates to subsurface well devices, and more particularly to combination plug and valve devices adapted for downward movement through well conduits, such as casing strings, in the performance of several desirable functions therein.

This application is a continuation-in-part of our application for "Positive Shut-Off Ported Casing Apparatus," Serial No. 22,886, filed April 23, 1948.

An object of the present invention is to provide improved cementing plugs especially useful at the upper end of a charge of cementitious material, and capable of effectively closing a passage in a well bore upon engaging a companion valve seat.

Another object of the invention is to provide a cementing plug that is slidable along the wall of a casing string, and capable of cooperating with a sleeve valve to effect its hydraulic shifting from port closing position without interfering with the passage of fluids through the ports.

A further object of the invention is to provide a cementing plug adapted to slidably seal with the wall of a well casing, and also capable of being squeezed into a cooperable valve seat to obtain positive sealing with the seat and to insure that the plug will not interfere with fluid passage through a side port in the well casing above the seat.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a longitudinal section through a ported well apparatus, with the ports open, after having been closed, and with a top cementing plug and valve device descending towards a cooperable valve seat;

Fig. 2 is a view similar to Fig. 1, with the ports reclosed and with the top cementing plug and valve device squeezed into an upper sleeve valve;

Fig. 3 is a combined longitudinal section and side elevation through a modified form of cementing plug and valve device.

As disclosed in the drawings, a casing collar A has its upper and lower ends threadedly connected to the ends of upper and lower casing sections B, C forming part of a casing string adapted to be run in a well bore to position the collar at the desired location therein.

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The collar A includes a tubular member 10 whose lower end consists of a coupling 11 threaded onto the upper end of the lower casing section C. A stop member 12 is secured to the exterior of the coupling, as by the use of welding material 13, to serve a purpose described below.

The tubular member 10 has a plurality of circularly spaced side ports 14 through which fluids are adapted to pass between the interior and exterior of the collar apparatus. These ports are closed initially by a lower inner sleeve valve member 15 having seal rings 16, 17 disposed in suitable ring grooves 18 on opposite sides of the ports. These rings may be of rubber and of round cross-section to prevent leakage thereby in both longitudinal directions.

The lower inner sleeve valve member 15 is retained in position to locate its seal rings 16, 17 on opposite sides of the ports 14 by one or more frangible devices in the form of shear screws 19 threaded through the tubular member 10 and extending into the valve member.

It is to be noted that the inside diameter of the tubular member 10, at the region where it is engaged by the lower seal ring 17, is less than the internal diameter of a groove 23 in the member 10 immediately below this region. Also, the sleeve valve member 15 is reduced in external diameter to form a peripheral groove 24 below the lower seal ring 17, in which a split, inherently expansible stop ring 25 is located. The stop ring has an upper inner inclined surface 26 tapering downwardly and inwardly for cooperation with a corresponding tapered surface 27 on the base of the peripheral groove 24. The length of the groove 24 is much greater than the length of the stop ring to permit downward movement of the sleeve valve member 15 relative to the stop ring.

The ring 25 is received within the enlarged diameter portion 23 of the tubular member. This enlarged portion is much longer than the height of the stop ring. The stop ring may rest upon a shoulder 28 provided by the lower end of the peripheral groove 24, the upper end of the stop ring being engageable with an upper shoulder 29 of the peripheral groove 24. Downward movement of the stop ring is limited by its engagement with the shoulder 30 formed by the lower end of the tubular member groove 23.

The shear screws 19 are adapted to be disrupted and the lower inner sleeve valve member 15 moved downwardly to a position in which the upper seal ring 16 is disposed below the ports 14. The ports are then open to the passage of fluid between the interior and exterior of the apparatus (Fig. 1).

After the ports have been opened, it is desired to reclose them. To accomplish this purpose, an external sleeve valve member 31 is provided on the tubular member 10. This external member has a plurality of longitudinally spaced seal rings 32, 33 disposed in internal grooves 34 and slidably engageable with the outer surface of the tubular member 10. The outer member 31 has an upwardly extending cylinder 35 integral therewith, or otherwise suitably secured thereto, which is slidable along an enlarged portion 10a of the tubular member.

The outer member 31 is retained initially in an upward position, in which it does not close the ports 14, by one or more shear screws 36 threaded through the cylinder 35 into the enlarged portion 10a of the tubular member. These screws are disruptable hydraulically by fluid pressure, including fluid under pressure entering through one or more elongate ports, slots or openings 37 in the tubular member into a cylinder space 38. This space is formed between the enlarged portion 10a of the tubular member, the cylinder skirt 35 and the part 31a of the sleeve valve member carrying the seal rings 32, 33. Leakage in a downward direction between the sleeve valve member 31 and tubular member 10 is prevented by the seal ring 32. Leakage in an upward direction therebetween is prevented by a seal ring 39 disposed in a peripheral groove 40 in the enlarged portion 10a of the tubular member, which sealingly engages the inner surface of the cylinder 35.

When sufficient hydraulic force is exerted on the outer sleeve valve member 31, the shear screws 36 will be disrupted and the outer sleeve valve member 31 shifted downwardly to a position in which its seal rings 32, 33 are located on opposite sides of the ports 14, closing such ports against passage of fluids therethrough in both directions between the interior and exterior of the apparatus. This position of the sleeve valve member 31 is determined by engagement of its depending skirt 41 with the upper end of the stop member 12. It is to be noted that the upper portion of the skirt 41 is spaced outwardly from the tubular member 10 so as to avoid interfering with passage of fluids through the ports 14 after they have been opened. This fluid flows through the ports 14 and through slots 41a in the lower end of the skirt. The end is slidable upon the member 10 and has a lower, knife-like edge 41b capable of cutting through any materials that might coat the member 10, or tend to prevent downward movement of the outer sleeve valve member 31.

After the outer sleeve valve member 31 has been shifted downwardly to port closing position, it is prevented from moving upwardly again by a latch or lock ring 42 disposed within a peripheral groove 43 in the tubular member 10 above its seal ring 39. This lock ring consists of a split, inherently expansible member having a reduced diameter lower portion 42a forming a shoulder 44 with the upper portion 42b. The shoulder is inclined outwardly in a downward direction to a slight extent.

When the outer sleeve valve member 31 has been forced downwardly to essentially its fullest extent, the upper end 35a of the cylinder is disposed below the shoulder 44 of the split lock ring, but not below the lower end of its reduced diameter portion 42a. As a matter of fact, the upper part of the cylinder 35 will be in engagement with the outer surface of the reduced diameter portion 42a, the lock ring 42 inherently expanding outwardly to a certain extent upon riding of the cylinder off its upper portion 42b. Any tendency for the outer sleeve valve member 31 to move upwardly will be limited by engagement of the upper cylinder end 35a with the lock ring shoulder 44, the lock ring being forced against the upper end of the peripheral groove 43. To insure against inward forcing of the lock ring 42 from engagement with the end 35a of the cylinder, the latter is tapered in the same direction as the shoulder 44, so that the two will remain in snug contact with one another.

The force of fluid under pressure is prevented from acting upon the external sleeve valve member 31 by an upper inner sleeve valve member 45 having longitudinally spaced seal rings 46 disposed in ring grooves 47 on opposite sides of the elongate ports or slots 37. This valve member is held in position by one or more shear screws 48 threaded through the tubular member 10 into the upper valve member 45. Disruption of the shear screws 48 and downward shifting of the upper sleeve valve member 45 will expose the ports 37 and permit fluid under pressure to pass through the latter into the cylinder space 38, in order to assist in shearing the cylinder screws 36 and moving the outer sleeve valve member 31 downwardly to port closing position.

The upper inner sleeve valve member 45 is not only used for the purpose of controlling the passage of fluid through the elongate ports 37, but is also used in assisting downward movement of the external sleeve valve member 31 to port closing position.

To accomplish this latter purpose, the upper inner sleeve valve member 45 and external sleeve valve 31 have an intervening lost motion connection. As specifically disclosed in the drawings, the outer sleeve valve 31 is formed with a plurality of inner keyways 80, in which are received the lug or arm portions 81 of keys 82 secured to the upper inner sleeve member 45 and extending outwardly through the elongate ports or slots 37. Each key includes a leg portion 83 depending from the arm portion 81 and adapted for movement within the tubular member 10 with the upper inner valve member 45.

It is to be noted that the arm 81 of each key is disposed originally above the lower end or shoulder 84 of the keyway 80. This arrangement is provided for the purpose of permitting the inner valve member 45 to move downwardly to an extent sufficient to shift the upper seal ring 46 below the upper ends of the ports 37, and thereby allow fluid to pass into the annular cylinder space 38 for action upon the sleeve 31 to effect shifting, or at least assisting in shifting, the sleeve valve 31 downwardly to port closing position. As described in detail below, once the elongate ports 37 are open, fluid under pressure may enter the cylinder space 38 through these ports, disrupt the shear screws 36 and shift the outer valve member 31 downwardly to port closing position. If this hydraulic force is insufficient, then pressure may be imposed upon the entire cross-sectional area of the upper inner sleeve valve 45, which will be transmitted to the external sleeve valve 31 through the keys 82 and abutting shoulders 84.

As stated above, the lower sleeve valve member 15 is held initially in closed position by its shear screws 19. Similarly, the upper sleeve valve member 45 is held in closed position over the elongate ports 37 by shear screws 48, preferably closely adjacent or in abutting relation with the upper end of the lower valve member 15. The upper valve 45 has a central bore 49 whose wall tapers downwardly and inwardly. Similarly, the lower valve member 15 has a downwardly and inwardly tapering central bore 50, which, in effect, forms a continuation of the upper member bore 49. The cylinder screws 36 hold the outer valve member 31 in its upper position.

With both sets of ports 14, 37 closed, a fluent material, such as cement slurry, may be pumped directly into the casing string and through the central bores or passages 49, 50 in both sleeve valve members 45, 15, for discharge from the well casing at some point below the collar, as, for example, from a casing shoe (not shown). This charge of cement slurry will pass upwardly through the annulus around the casing string and may extend approximately to the location of the collar A, or slightly thereabove.

When it is desired to eject a second or upper charge of cement slurry through the collar ports 14, a trip device or plug member 51 is dropped into the well casing and is allowed to gravitate through the fluid therein into engagement with the wall of the central bore 50 in the lower sleeve valve member 15.

Pressure may now be applied to the fluid in the casing above the trip member 51 and sleeve 15 in an amount sufficient to shear the screws 19 and shift the lower sleeve valve member 15 downwardly to port opening position, as shown in Fig. 1.

Downward movement of the lower valve member is limited by engagement of the stop ring 25 with the shoulder 30 of the tubular member 10, and of the shoulder 29 on the lower sleeve member 15 with the stop ring. Washing fluid, followed by cement slurry or other cementitious material, may now be discharged outwardly through the open ports 14, passing through the annular space between the tubular member 10 and the depending skirt 41 of the outer valve member 31, and through the slots 41*a* in the lower end of this skirt, for upward movement through the annulus around the collar A and casing string.

Upon discharging the required quantity of cement slurry, the outer sleeve valve 31 is forced downwardly to port closing position. This act may be accomplished by placing a top cementing plug 58 at the upper end of the charge of cement slurry pumped outwardly through the ports 14. This plug will come to rest within the bore 49 of the upper sleeve valve member 45, allowing the fluid in the casing string above the collar A to be pressurized to an extent sufficient for shearing the screws 48, to shift the upper inner valve member 45 downwardly to a position in which the upper ends of the elongate ports 37 are open.

The top cementing plug 58 disclosed in the drawings is of a composite character. It includes a lower nose 59, which may be made of magnesium, aluminum or other suitable, readily drillable material, having a tapered periphery 60 adapted to conform to the taper of the passage 49 in the upper sleeve 45. This nose is so proportioned as to seat within the passage and cause the top cementing plug 58 to come to rest therewithin. From its tapered nose, the lower end of the plug is integral with a central shank 61 terminating in a flange 62, received within a companion bore and recess 63 of a flexible portion 65 of the cementing plug. These two parts are suitably vulcanized together.

The flexible plug 65 is formed essentially of rubber or similar material. It has an inwardly compressible body portion 70 defined by tapered forward and rearward surfaces 71, 72 merging into an annular peripheral sealing surface 73 slidably engageable with the wall of the well casing. The plug 65 also has a tail portion 74 terminating in a fluted guide 75. Its annular sealing portion includes an upwardly extending lip 76 adapted to be forced outwardly by fluid pressure against the wall of the casing.

The tapered nose 59 on the lower plug portion has a greater diameter than the minimum diameter through the upper sleeve valve 45. As a result, it comes to rest within the tapered bore 49 of the latter, closing it against passage of fluid and allowing pressure to be built up in the casing fluid above the cementing plug 58, sufficient in extent to shear the screws 48 and shift the upper member 45 downwardly to a position limited by engagement of the key lugs 81 with the shoulders 84 forming the lower end of the keyways 80 in the outer sleeve 31. When in this position, the upper ends of the elongate ports 37 are exposed, allowing fluid to pass into the cylinder space 38 for the purpose of shearing the cylinder screws 36 and moving the outer sleeve 31 downwardly to port closing position (Fig. 2).

A standard top cementing plug would not permit fluid to pass by it and enter the ports 37. The flexible plug 65 described above, however, will have its body 70 and annular sealing portion 73 deformed inwardly to a sufficient extent to compress the rubber material into the tapered passage 49 through the upper inner valve member 45, sealing off this passage completely, while removing the annular sealing portion 73 of the plug from engagement with the casing wall or inner wall of the tubular member 10 (see Fig. 2). The plug, therefore, offers no restriction or barrier to passage of fluid through the ports 37, for action upon the outer sleeve valve member 31.

The top cementing plug 58 serves its normal function of confining the charge of cement slurry in advance of it, by slidably sealing with the wall of the well casing during its downward passage. It insures the release of the upper valve member 45, to open the elongate ports 37, since it is squeezed to a substantial extent into the sleeve valve member 45. Such squeezing action insures a tight seal with the sleeve valve 45, and also removes the peripheral sealing portion 73 completely from engagement with the casing wall, in view of the squeezing of this peripheral portion into the sleeve valve. As a result, the peripheral sealing portion cannot interfere with the ability of fluid to pass through the elongate ports 37, for the purpose of hydraulically shifting the outer sleeve valve member 31 downwardly to a position closing the ports 14.

Squeezing of the peripheral portion 73 into the sleeve valve occurs as a result of locating such peripheral portion substantially adjacent the nose or valve head 59 of the device. The leading face 71 of the flexible cementing plug body 70 extends from the peripheral sealing portion 73 to the valve head 59, and cooperates with the tapered wall 49 in the sleeve valve 45 to assist in bodily compressing the peripheral portion 73 within the sleeve valve 45.

A modified form of cementing plug and valve device is illustrated in Fig. 3, in which a generally spherical nose or head 59*a* depends from a central shank 61a fitting within a companion central bore 63a of the flexible cementing plug. The shank extends through the body portion 70 of the flexible plug and also through its tail portion 74, the central shank terminating in an upper flange 62a disposed adjacent the fluted guide 75, which is integral with the tail portion.

As in the other form of invention, the flexible plug has a peripheral portion 73a for slidable sealing with the wall of the well casing, as well as an upwardly extending peripheral lip 76a. In addition, the leading surface 71a is present in the flexible body, converging from the peripheral portion 73a towards the generally spherical nose or head 59a.

To insure against any leakage between the valve head 59a and the tapered wall 49 of the sleeve valve 45, a spherical seal 100 is provided over the surface of the spherical valve head 59a. This spherical seal may be made of rubber or rubber-like material, and is preferably integral with the flexible cementing plug portion of the device. The seal extends around the head 59a and terminates in an upwardly directed annulus 101 fitting within an end groove 102 in the forward or lower portion of the valve head 59a, for the purpose of securing the lower end of the seal firmly within the valve head.

In all respects, the device illustrated in Fig. 3 functions in the same manner as the cementing plug and valve device shown in Figs. 1 and 2. The plug slidably seals with the wall of the well casing in maintaining the cement slurry separate from the displacement fluid above the plug. Its head and seal 59a, 100 can fit within the valve sleeve 45 with the seal 100 insuring against leakage thereby. The peripheral portion 73a can also be squeezed into the tapered portion 49 of the sleeve valve 45, to insure that a leakproof seal is present between the device and the sleeve valve 45, and also to remove such portion 73a completely from contact with the casing wall. In this manner, fluid above the plug device can pass freely through the elongate ports 37 into the cylinder space 38, to move the outer sleeve valve 31 downward through hydraulic action.

The inventors claim:

1. A cementing plug, including a forward rigid valve head portion and a trailing inwardly compressible elastic body having a peripheral portion for slidable sealing engagement with the wall of a well conduit, said body also having a leading portion adjacent said head portion which has an outer surface converging from said peripheral portion to said head portion, the maximum diameter of said valve head portion being materially less than the maximum diameter of said peripheral portion.

2. A cementing plug, including a forward rigid valve head portion and a shank extending upwardly from said head portion, an inwardly compressible elastic body receiving said shank, said body having a portion adjacent said head portion for slidable sealing engagement with the wall of a well conduit, the maximum diameter of said valve head portion being materially less than the maximum diameter of that portion of the body which slidably engages the wall of the well conduit.

3. A cementing plug, including a forward rigid valve head portion and a shank extending upwardly from said head portion, said shank having a flange at its upper end, an inwardly compressible elastic body receiving said shank and flange, said body having a portion adjacent said head portion for slidable sealing engagement with the wall of a well conduit, the maximum diameter of said valve head portion being materially less than the maximum diameter of that portion of the body which slidably engages the wall of the well conduit.

4. A cementing plug, including a forward rigid valve head portion, a rigid shank integral with and extending upwardly from said head portion, an inwardly compressible elastic body receiving said shank, said body having a peripheral portion for slidable sealing engagement with the wall of a well conduit, said body also having a leading portion adjacent said head portion which has an outer surface converging from said peripheral portion to said head portion, the maximum diameter of said valve head portion being materially less than the maximum diameter of said peripheral portion.

5. A cementing plug, including a forward rigid valve head portion and an inwardly compressible elastic body having a portion adjacent said valve head portion for slidable sealing engagement with the wall of a well conduit, and an elastic seal integral with said body and disposed on the forward face of said head portion.

6. A cementing plug, including a forward rigid generally spherically curved valve head portion, an inwardly compressible elastic body having a portion adjacent said valve head portion for slidable sealing engagement with the wall of a well conduit, and an elastic generally spherically curved seal integral with said body and disposed over said spherically curved head portion.

7. A cementing plug, including a forward rigid valve head portion and a shank extending upwardly from said head portion, an inwardly compressible elastic body receiving said shank, said body having a portion adjacent said head portion for slidable sealing engagement with the wall of a well conduit, and an elastic seal disposed over said valve head portion, said seal being integral with said body.

8. A cementing plug, including a generally conical forward rigid valve head portion and a shank extending upwardly from said head portion, an inwardly compressible body receiving said shank, said body having a peripheral portion adjacent said head portion for slidable sealing engagement with the wall of a well conduit, said body also having a leading portion which has an outer surface converging from said peripheral portion to said head portion.

9. A cementing plug: including a forward generally spherically curved rigid valve head portion; a rigid shank integral with and extending upwardly from said head portion; an inwardly compressible elastic body receiving said shank, said body including a trailing portion disposed around said shank, a peripheral portion adjacent said head portion for slidable sealing engagement with the wall of a well conduit, and a leading portion having an outer surface converging from said peripheral portion to said head portion.

10. A cementing plug: including a forward generally spherically curved rigid valve head portion; a rigid shank integral with and extending upwardly from said head portion; an inwardly compressible elastic body receiving said shank, said body including a trailing portion disposed around said shank, a peripheral portion adjacent said head portion for slidable sealing engagement with the wall of a well conduit, and a leading portion having an outer surface converging from said peripheral portion to said head portion; and

a spherically curved seal on said spherically curved valve head portion, said seal being integral with said body.

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