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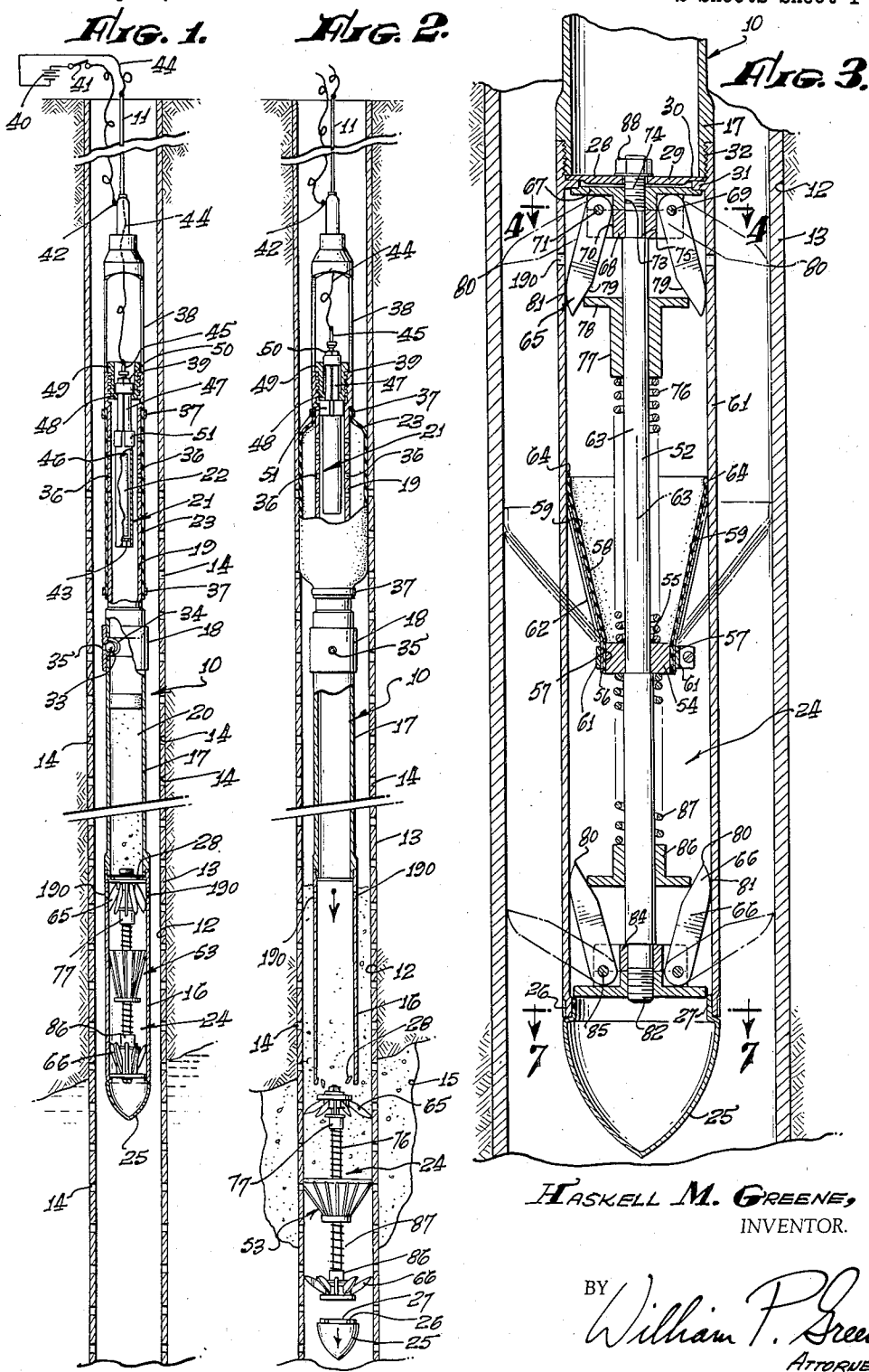
H. M. GREENE

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APPARATUS FOR FORMING A CLOSURE IN A WELL BORE

Filed May 17, 1957

2 Sheets-Sheet 1



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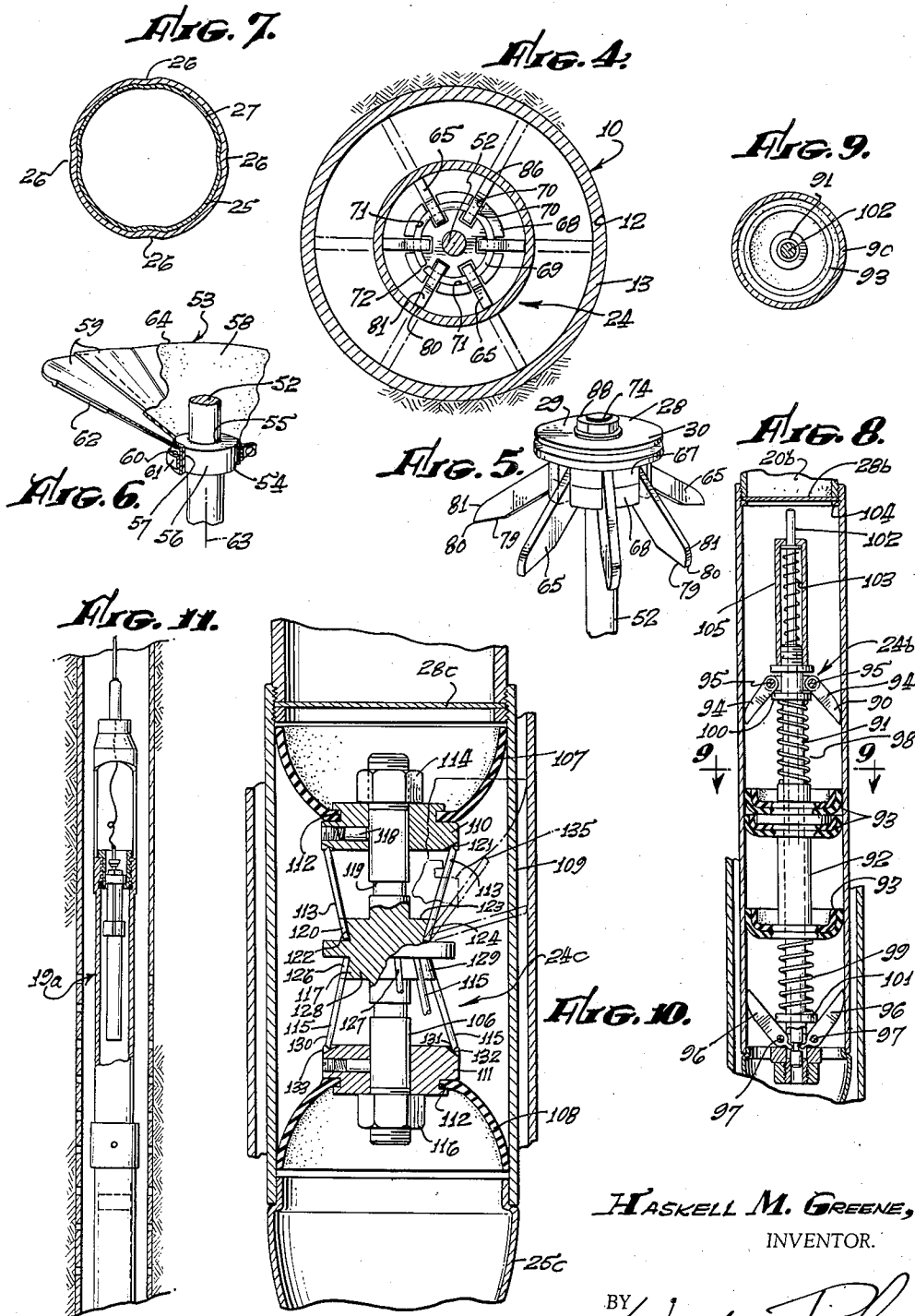
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APPARATUS FOR FORMING A CLOSURE IN A WELL BORE

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4 Claims. (Cl. 166—63)

This invention relates to improved apparatus for forming a bridge plug or closure in a well, to seal off an upper portion of the well from a lower portion thereof. The present application is a continuation-in-part of my co-pending application Serial No. 503,623, filed April 25, 1955, on "Application of Localized Gas Pressure in a Well," now abandoned. In certain respects, the apparatus disclosed in the present application may be considered as an improvement on the apparatus of my Patents Number 2,696,258, issued December 7, 1954, on "Oil Well Cementing Packer," and Number 2,696,259, issued December 7, 1954, on "Apparatus for Firing Propellant Charges in Wells."

The general object of the invention is to provide an improved type of device which is capable of being lowered into a well, and which on a single lowering can function to position a plug in fixed position in the well, and also to deposit a body of cementitious material (preferably Portland cement) on the plug, to harden while resting on the plug and thus form a permanent closure across the well bore. In the apparatus embodying the invention, the positioning of the plug and cement in the well bore is effected very rapidly, once the device is actuated after being lowered into the well. Especially contemplated is an arrangement which is so designed as to maximize the rate at which the cement will set in the well, so that it will set before the well fluid has time to force itself into the body of cement and thus adversely affect the effectiveness of the ultimate closure.

Structurally, a device embodying the invention includes a hollow body adapted to be lowered into a well and carrying a bore closing plug, and a body of cementitious material above the plug, with the plug and cement being adapted for ejection downwardly from the body after lowering into the well. For thus ejecting the plug and cement, I employ a charge of gas producing propellant material which acts when fired to produce pressurized gases above the cement in a quantity acting to force the cement and plug downwardly and from the body to their active bore plugging positions. Such ejection of the plug results in its actuation to a locking condition in which it is securely held in fixed position in the well, to thereafter effectively support the cement in the well.

As previously mentioned, a very important object of the invention is to provide for rapid setting of the cement in the well, to prevent its contamination before it can be set. For assuming this result, the propellant charge proves especially helpful, since the high temperatures developed by burning of the propellant greatly accelerate the setting of the cement. Also, the pressure of the gases has a similar effect in accelerating the setting action. This rapid setting of the cement, immediately following the ejection of the plug and cement into the well, causes the cement to become effective as a positive closure in a minimum period of time after the plug is placed in use. Consequently, the plug itself need not be designed to serve as a closure for any appreciable period of time.

Certain particular features of the invention have to

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do with the construction of a preferred type of plug. Specifically, this plug includes gripping fingers for securing the plug in fixed position in the well, and a radially expansible seal cup structure for assuring effective closure of the well. Desirably, the seal cup structure includes a flexible cup of rubber or other deformable or elastomeric material, and a plurality of backing elements positioned beneath and supporting the rubber. The backing elements may consist of a number of thin sheet metal "petals" which overlap and form together a flaring radially expansible cup arrangement.

The above and other features and objects of the present invention will be better understood from the following detailed description of the typical embodiment illustrated in the accompanying drawings in which:

Fig. 1 is a vertical sectional view of a well tool constructed in accordance with the invention;

Fig. 2 is a view corresponding to Fig. 1, but showing the tool after it has been fired and the cement and plug have been forced from it to form a closure in the well;

Fig. 3 is an enlarged vertical section through the lower portion of the Fig. 1 apparatus;

Fig. 4 is a transverse or horizontal section taken on line 4—4 of Fig. 3;

Fig. 5 is a fragmentary perspective view of the upper portion of the plug in Fig. 3;

Fig. 6 is a fragmentary perspective view of the seal cup structure of Fig. 3;

Fig. 7 is a horizontal section taken on line 7—7 of Fig. 3;

Fig. 8 is a fragmentary view of a variational form of the apparatus which is the same as that shown in Fig. 1 except as to the particular type of bore closing plug which is employed;

Fig. 9 is a transverse section taken on line 9—9 of Fig. 8;

Fig. 10 is a fragmentary vertical section through another form of the invention; and

Fig. 11 is a fragmentary view of a final form of the invention.

Referring first to Figs. 1 through 7, the tool 10 there shown is adapted to be lowered into a well at the lower end of a flexible cable or line 11, and functions when actuated to form a closure across the well bore closing off an upper portion of the well from its lower portion. In the figures, the well 12 has been represented as containing the usual tubular casing or liner 13, which may in some instances contain perforations 14 through which the interior of the casing communicates with the surrounding earth formation. When the casing or liner 13 contains such perforations, it may be desirable to force some of the cement through those perforations and into a space 15 about the casing. In other instances, where the casing 13 is entirely imperforate, it may be desired merely to form a cement wall or plug extending across but entirely within the casing.

The preferred form of tool 10 comprises essentially a tubular vertical extending body including four threaded interconnected sections 16, 17, 18 and 19, and containing a body of cementitious material 20, a "gas gun" 21 carried by the upper end of the tool body and acting to direct the gases generated by a propellant charge 22 downwardly through the body and against the cementitious material, and tubular packer sleeve 23 adapted to be radially expanded against the wall of the well (casing 13) to form a seal preventing upward dissipation of the actuating gases and their force. The cementitious material 20 is preferably Portland cement, which may contain an agent tending to speed its setting, and this material will therefore be hereinafter referred to merely as cement. In the lower portion 16 of the tubular body, there is provided a plug 24 which is ejected downwardly by

the force of the generated gases to the Fig. 2 position in which the plug serves to close off the bore at a location spaced beneath the lower end of the tool body. The gas force also acts to force the cement 20 downwardly from the tool body, and laterally, to form the desired cement closure above the plug 24.

The lower tubular portion 16 of the tool body may have its lower end closed by a downwardly tapering nose member 25 which is attached to the body in a manner permitting the nose member to be very easily blown downwardly from the body upon ignition of the propellant or gas generating charge 22. For this purpose, body section 16 may have several (typically four) evenly circularly spaced inwardly bent portions 26 (see Fig. 7), which frictionally engage the upper externally cylindrical portion 27 of nose member 25 sufficiently tightly to frictionally hold the nose member in the Fig. 1 active position of attachment to body section 16. This frictional engagement, however, is sufficiently light to allow the nose member to be very easily displaced downwardly from the tool body by downward movement of plug 24 when propellant charge 22 is fired.

The portion 17 of the tool body above its lowermost portion 16 contains the body of cement 20, to the upper surface of which the gas pressure produced by propellant charge 22 is communicated. The cement containing portion 17 of the tool body may of course be considerably longer than would appear from Figs. 1 and 2, in which views this portion of the body is broken away to allow for representation of the entire length of the tool in a single figure.

The cement 20 is supported in body section 17 by means of a horizontal or transverse bottom wall 28 which extends across the lower end of body section 17, and is formed of a frangible material, such as a frangible aluminum or resinous plastic material adapted to be broken or ruptured by the force of the generated gases when charge 22 is fired to thus allow the cement to pass downwardly through the body and out its lower open end behind the plug 24. As will be brought out in greater detail at a later point, the frangible wall 28 may be attached to, and form essentially a portion of, the plug unit 24, so that it acts to suspend the plug in its initial Fig. 1 position within the tool. Wall 28 may have a relatively thick circular portion 29 toward its center, and carrying a reduced thickness annular peripheral portion 30 about the edge of the disc. This peripheral portion 30 may rest downwardly against and annularly engage an annular shoulder 31 formed in the upper end of body section 16, and may be held downwardly against that shoulder 31 by threadedly connecting body section 17 into threaded bore 32 formed in the upper portion of section 16 above shoulder 31. The threaded bore 32 of course has an internal diameter which is greater than the internal diameter of shoulder 31, to allow disc 28 to be inserted downwardly through bore 32 into engagement with shoulder 31. The disc 28 is strong enough at all points to support the weight of the cement, and in addition to withstand a gas pressure above the cement of a predetermined value (preferably between about 80 and 200 p.s.i.) and for best results about 150 p.s.i. The pressure referred to is of course a differential pressure, as between the pressure of the gases within the tool above the cement, and the fluid pressure at the outside of the body, and particularly the pressure beneath wall 28. When this differential pressure reaches the predetermined value, the peripheral portion 30 of disc 28 breaks along an annular line defined by the inner edge of shoulder 31, so that the plug, cement, and most of the wall 28 can be rapidly ejected downwardly from the tool body.

Portion 18 of the tool body carries a number of outwardly seating check valves 33 serving to prevent outward escape of the cement displacing gases through the wall of the body, while permitting an inward flow of

well fluid into the body when the pressure is reduced below that at its outside. These check valves may be of conventional ball check valve construction including spherical valve elements free for limited movement within cages 34 toward and away from seats 35.

The upper tubular portion 19 of the body is perforated at 36 to permit outward flow of the generated gases against packer sleeve 23. This packer sleeve is formed of rubber or other resilient elastomeric material, and is peripherally clamped by bands 37 at its opposite ends to the end portions of perforated body section 19. As will be apparent, clamping rings 37 hold sleeve 23 in fluid tight sealing engagement with body section 19 at two vertically spaced locations, between which the sleeve 23 is readily expansible to the condition of Fig. 2 by the generated gases and is then resiliently returnable to the condition of Fig. 1 when the pressure within the tool returns to normal. The wire line 11 which suspends the tool 10 in the well is connected to a bail 38, whose ends attach at 39 to upper body section 19.

The gas gun or firing chamber 21 comprises a cylindrical preferably metallic vertically extending body containing the propellant charge 22, and closed at its upper end so that the gases produced by the propellant charge are directed downwardly from the lower open end of gun 21 and against the upper surface of the cement 20. Firing current is delivered to the propellant or explosive charge 22 from a battery 40 at the surface of the earth, and under the control of a switch 41 also at the surface of the earth. One side of the power source is connected to the charge by being grounded (say at 42) to the body of the tool, with current being carried from the conductive body of the tool to the charge through one or more contacts 43 attached to the lower end of charge 22 and engaging the electrically conductive wall of gun barrel 21. These contacts 43 may also serve to releasably retain the charge in its illustrated Fig. 1 position within the gun, as is brought out in greater detail in my Patent 2,696,259. The second side of the power source is connected to the charge through a wire 44 extending downwardly within the well and connecting to a terminal 45 which is electrically connected to a contact 46 for engaging an upper electrically conductive contact on charge 22. As will be apparent, terminal 45 and contact 46 are of course electrically insulated from the body of the tool. Thus, when switch 41 is closed at the surface of the earth, firing current is passed through charge 22 causing it to burn and produce large quantities of gases in the tool.

Gas gun 21 is preferably mounted for limited upward recoiling movement upon firing, and for this purpose may have a portion 47 near its upper end which is vertically slidable within shoulder portion 48 in a bushing 49, the bushing being threadedly connected into upper body section 19. A nut 50 on the upper end of the gas gun is engageable with shoulder 48 of the bushing to limit downward movement of the gun, while integral flange 51 on the gun barrel limits its upward recoiling movement at the Fig. 2 position.

Propellant charge 22 preferably comprises an explosive or combustible charge characterized by a capacity to produce a relatively prolonged pressure and temperature surge rather than a sharp instantaneous explosion to thus effectively force the cement from the container and into the well zone without danger of rupturing the tool body itself, or packer 23, or any of the other portions of the device with the exception of the purposely frangible element 28. For best results, the propellant charge should be selected to burn over an extended period of between about one and one-half and thirty seconds under the particular hydrostatic pressure encountered at the zone being cemented. The pressure differential developed by the gases, between the inside and outside of the tool, should of course be sufficiently above the breaking pressure of disc 28 to assure rupturing of that disc by the gas pressure, and yet should not be an excessive value which might

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damage the plug or other parts. Preferably, the maximum pressure differential developed by the gases is between about 160 and 500 p.s.i., and say about 300 p.s.i. for best operation where the disc 28 is constructed to break at 150 p.s.i.

Referring now particularly to Figs. 3 through 6, plug 24 includes a vertically extending shaft-like carrier member 52, which carries at its vertically central portion an upwardly facing and upwardly flaring seal cup structure 53 for engaging and forming a seal with casing 13, to support the cement in the casing. This seal cup structure 53 is initially held in the radially constricted condition of Fig. 3, by reception within the cylindrical lower body section 16, and is adapted to resiliently expand to the Fig. 2 active position when the plug is ejected from the lower end of section 16. Structure 53 may include an annular rigid ring 54 carried about and attached in fixed relation to shaft 52, as by annular welding at 55. To the outer cylindrical surface 56 of ring 54, there may be attached a reduced diameter tubular portion 57 of a flexible annular seal cup element 58. This element 58 may be formed of a suitable rubber or other elastomeric material, preferably extremely thin (say between about .010 and .020 inch), to be collapsible into an extremely small diameter tool body. The element 58 in its normal condition flares upwardly as seen in Fig. 2, and in the broken lines in Fig. 3, and is of course imperforate and fluid tight to form an effective fluid seal in the well. The lower portion 57 of element 58 may be sealed to ring 54 in any practical manner, as by annularly bonding or vulcanizing this portion to the ring.

In order to allow the use of such a thin seal cup element 58, the structure 53 includes also a number of metal elements 59, which may be identical one with the other, and have their lower ends 60 attached to ring 54. These elements 59 are desirably formed of thin spring steel, typically about .002 of an inch thick, and are distributed uniformly about ring 54. As an example of one way in which portions 60 of elements 59 may be secured to the ring, these portions may typically be clamped inwardly against portion 56 of element 58 by a clamping ring represented at 61.

As elements 59 extend upwardly above ring 54, they progressively flare, to normally form together a conical structure of a configuration corresponding essentially to the normal Fig. 2 configuration of rubber cup 58. These parts 59 overlap circularly about the axis of shaft 52, and are capable of moving to positions of progressively increasing overlap to allow the elements 59 to be collapsed or contracted with cup 58 to the Fig. 3 full line position. The resiliency of elements 59 however, normally urges those elements to their expanded Fig. 2 positions and preferably tends to urge them slightly radially outwardly beyond the Fig. 2 positions to assure effective engagement with the casing 13 in the expanded condition of the apparatus. Also, it will of course be apparent that each of the various elements or "petals" 59 has a normal curvature corresponding to the curvature of the cone defined by these parts in the Fig. 2 positions of elements 59. Each of the elements 59 may be reinforced or strengthened along one of its edges by an essentially rigid typically metal rib 62 welded or otherwise secured to that edge, but terminated at the upper edge of ring 54 rather than being in any way attached to that ring. Each of the various ribs 62 may lie in a plane which also contains the axis 63 of shaft 52, and moves radially in that plane upon expansion and contraction of the cup structure 53. In all conditions of cup structure 53, the elements 59 desirably back up or support rubber cup 58 continuously across its entire area, except at the peripheral annular edge 64 of the cup which may project beyond elements 59 to assure proper fluid tight sealing engagement with casing 13.

At its upper end, shaft 52 carries a number of evenly circularly spaced fingers 65 which are adapted to engage casing 13 in a manner locking plug 24 against down-

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ward movement in the well after ejection of the plug downwardly from the tool body. Similarly, the lower end of the plug carries a second series of fingers 66 which will function to lock the plug against upward movement relative to the casing. The fingers 65 are pivotally mounted for swinging movement relative to shaft 52 between the full line retracted positions of Fig. 3, and the expanded positions of Fig. 2 (broken lines in Fig. 3). For thus mounting the fingers, shaft 52 carries two axially abutting rings 67 and 68, between which there is clamped in fixed position a ring 69 of cylindrical cross section. The fingers 65 have openings through which ring 69 passes, so that the fingers are free to swing radially outwardly between their different positions and about ring 69. As will be apparent the ring 69 is of course centered about axis 63. The different fingers 65 have their inner ends received within recesses or grooves 70 (see Fig. 4) in rings 67 and 68, to allow engagement of fingers 65 with rings 69. Between the locations of recesses 70, rings 67 and 68 have abutting faces containing opposed complementary grooves 71 shaped to exactly receive and confine the ring 69 between rings 67 and 68. Ring 69 may be interrupted at one point along its circular extent, say at the point 72 in Fig. 4, so that by slightly expanding ring 69 at this point and before assembly of the unit, the various fingers 65 may be slipped onto ring 69. Ring 69 is then returned to its normal condition, and is positioned between rings 67 and 68, with fingers 65 received within grooves 70. All of the various parts are then attached to the upper end of shaft 52 while in this condition. To effect this attachment, the inner bore 73 of ring 67 may be threaded, to be threadedly connectible onto the upper end 74 of shaft 52, to thus tighten ring 68 downwardly against a shoulder 75 on shaft 52. The ring 68 may have a cylindrical rather than a threaded internal bore.

The fingers 65 are yieldingly urged radially outwardly toward a position beyond that of Fig. 2, by a coil spring 76 which is disposed about shaft 52 between ring 54 and an upper annular element 77 which is slidable axially along shaft 52. Element 72 has a flange 78 engaging the inner surfaces 79 of fingers 65, and acting to cam fingers 65 radially outwardly when element 77 is moved upwardly. Spring 76 is at all times under compression, to continuously urge element 77 upwardly and thus urge fingers 65 radially outwardly.

At their outer ends, fingers 65 taper to points 80, which project into the wall of casing 13 in the outwardly expanded Fig. 2 position of the fingers, to thus very effectively grip the casing and prevent downward movement of the plug and fingers relative to the casing. In this Fig. 2 position of the fingers, these fingers preferably flare downwardly, so that any downward force exerted against the plug can only tend to tighten the engagement between the fingers and the casing. Extending inwardly from point 80 each of the fingers has a typically curving cam surface 81, which acts to engage the wall of body section 16 in the Fig. 3 full line positions of the fingers, and to hold the points 80 of the fingers out of holding engagement with the tubular body member 16. Thus, the fingers 65 do not prevent the plug from moving downwardly within and from body section 16, and yet do effectively prevent downward movement of the plug relative to casing 13, and beyond the Fig. 2 position of engagement with the casing. Surfaces 81 are so designed as to allow the points 80 to move into holding engagement with a surrounding tubular member only after the fingers have swung outwardly beyond a predetermined position, typically a position of about 30° angularity with respect to a radius of axis 63, which position should be between the full line and broken line positions of Fig. 3.

The lower set of fingers 66 is identical with the upper set of fingers 65, except that the lower fingers 66 are inverted to prevent upward rather than downward movement of the plug within the casing (without interfering

with movement of the plug while it is within tubular body section 16). Without discussing the means of retaining fingers 66 in detail, it will suffice merely to state that these fingers are retained on the threaded lower end 82 of shaft 52 by three rings 83, 84 and 85 corresponding to rings 67, 68 and 69 respectively. Also, fingers 66 are yieldingly urged to their expanded positions by an element 86 and a spring 87 corresponding to parts 77 and 76 respectively associated with the upper fingers. When plug 24 is not contained within any tubular element, the parts 76, 77, 86 and 87 will function to yieldingly urge the fingers to positions outwardly beyond the Fig. 2 positions, to thus assure effective spring urged holding engagement of the fingers with casing 13 in the Fig. 2 condition.

In preparing the tool for use, the first step may be to remove lower body section 16 from the rest of the body, and to then slip plug 24 axially upwardly into the lower end of body section 16, with lower nose member 25 removed from section 16. During such insertion, the disc 28 and its retaining nut 88 are not attached to plug 24, and the fingers 65 and 66, as well as parts 58 and 59 of cup structure 53, are all manually held in their inwardly retracted or collapsed positions of Fig. 3 as they are slipped into body section 16. When the plug has reached the Fig. 3 position in section 16, disc 28 is inserted downwardly into section 16 to engage shoulder 31, and nut 88 is then tightened downwardly on shaft 52 and against disc 28 to clamp shoulder 31 between elements 28 and 67, and thus secure plug 24 in fixed position within section 16. Nose member 25 is then attached to section 16, and section 16 is threaded onto the lower end of section 17. Gas gun 21 is then removed from the upper end of the tool as permitted by the threaded mounting of bushing 49, and cement is filled into the tool body through its open upper end to a proper predetermined level. Sufficient cement will normally be poured into the body to substantially fill its tubular portion 17. A gas producing propellant or explosive charge 22 is slipped into the firing gun 21 through its open lower end, and the gun and contained charge are then connected into the tool body as seen in Fig. 1.

The tool is lowered into the well to the zone to be cemented, and the electrical switch 41 is then closed at ground level to admit current from battery 40 to a fuse contained within charge 22. The resulting ignition of charge 22 produces a large quantity of high temperature gases under pressure, which gases are directed downwardly by gun 21 against the body of cement 20. The increase of pressure within the tool forces packer sleeve 23 outwardly to its Fig. 2 position to seal off the casing against upward fluid flow, and this pressure simultaneously exerts a downward force against cement 20. Until the pressure within the tool body and above cement 20 reaches the predetermined ejection pressure for which disc 28 is designed, the disc 28 supports the cement and prevents its downward movement within the tool body. However, when that critical pressure is reached, typically 150 p.s.i. (after expansion of packer 23 to its sealing position), the peripheral relatively thin portion 30 of disc 28 suddenly ruptures along an annular line just inwardly of shoulder 31, so that the gas pressure may then very suddenly eject the cement and plug 24 downwardly and from the tool body. Because the pressure has built up before rupture of disc 28, the plug movement downwardly to the Fig. 2 position is very rapid, and assures movement of the plug to a position spaced somewhat below body section 16 before fingers 65 can stop its downward movement. The cement flows downwardly from the tool body behind the plug, to form the desired cement closure across the well above cup structure 53. Preferably, the body section 16 contains side openings at 190 near its upper end, but beneath shoulder 31, through which openings some of the cement and the gas force can be bled laterally as soon as disc 28 has ruptured, to thus prevent

the development of an excessive force against the plug which might otherwise damage cup structure 53 or other portions of the plug. The initial force of the gases causes upward recoiling movement of the gas gun, which movement is abruptly stopped at the Fig. 2 position of the gun in a manner setting up a shock wave in the gases which may assist in rupturing disc 28 assuming that approximately the critical predetermined pressure has been reached.

Nose member 25, after being disconnected from the body of the tool by downward movement of the plug, may fall downwardly to the bottom of the well. The high temperature of the gases which are generated above cement 20 causes the cement to set much more rapidly than would be possible in the absence of such heat. Also, the pressure exerted against the cement by the gases assists in squeezing out all of the excess moisture from the cement, to thus further assure its rapid setting. As the pressure within the tool diminishes after an operation, packer sleeve 23 resiliently returns to its normal position of Fig. 1, permitting removal of the tool from the well, and check valves 33 permit inward passage of well fluid into the tool to equalize the pressures at the opposite sides of the tool body. When the tool is withdrawn upwardly from the well, plug 24 and the cement remain in the well, and may be subsequently very easily drilled out to again provide access to the lower portion of the well. It will of course be apparent that all of the various body parts and other parts of the apparatus, with the exception of the purposely shearable element 28, must be strong enough to withstand the force of the gases generated by the charge 22 upon firing. It is noted that, in the completed well closure formed by plug 24 and the cement, the fingers 65 and other portions of the plug which are positioned above cup structure 53 act as metal reinforcing elements within the cement, to thus maximize the strength of the reinforced cement combination. It is also pointed out that in some instances, the plug and cement can be effectively set without the necessity for the upper packer element 23, in which case upper body section 19 would of course be imperforate rather than contain the apertures 36. This variational form of the invention is shown fragmentarily in Fig. 11, in which the body section 19a corresponds to body section 19 of Fig. 1, but is imperforate. Otherwise, the Fig. 11 arrangement would be identical with that of Figs. 1 to 7.

Figs. 8 and 9 represent fragmentarily a variational form of the invention, which may be considered as essentially identical with that of Figs. 1 to 7 except for the substitution of a different type of plug 24b for the plug 24 of the first form of the invention. This plug 24b is contained within a lower section 90 of the body corresponding to section 16 of Fig. 1, section 90 being vertically elongated to accommodate the rather elongated plug 24b. Plug 24b includes a vertically extending body 91 about which is carried an outer tubular body 92 carrying a number of resiliently deformable sealing cups or discs 93 typically formed of rubber. These sealing cups 93 may be initially held in constricted condition within body section 90, and are adapted to resiliently expand outwardly into engagement with liner 13b when the plug is ejected downwardly from the lower end of the tool body. The carrier element 91 of plug 24b has an upper series of circularly spaced downwardly flaring fingers 94 which are pivotally connected to carrier 91 as at 95, and which are initially held in their retracted positions of Fig. 8 by reception of the plug within body section 90.

A second but upwardly flaring series of gripping fingers 96 pivoted at 97 to carrier 91 are provided at the lower end of carrier 91. A pair of collapsible springs 98 and 99 urge rings 100 and 101 axially against fingers 94 and 96, to yieldingly urge those fingers radially outwardly, so that when plug 24b is ejected downwardly from the tool body by the gas force, fingers 94 and 96 expand into gripping engagement with liner 13b, and then act to

positively hold plug 24b in a fixed position somewhat beneath the lower end of the tool body. Thus, when the tool is fired, plug 24b serves essentially the same function as plug 24 of the first form of the invention, that is, plug 24b closes off the well bore at a location spaced beneath the tool body, and thereby requires that the displaced cement accumulate above the plug and form a closure across the well bore. As in the first form of the invention, the cement 20b is contained within the tool body above a frangible disc 28b, which is adapted to be ruptured by the force of the generated gases when the propellant charge is fired, to thus allow the cement to be forced downwardly through the tool body and out its lower end, with the plug 24b of course being pushed downwardly in advance of and by the cement. Frangible horizontal wall 28b may be retained in its illustrated Fig. 8 position by reception of the circular peripheral edge of element 28b between a downwardly facing shoulder formed in the upper end of body section 90 and a clamping ring 104 which is threadedly connected into body section 90 and against disc 28b. The disc 28b may typically be formed of a suitable frangible resinous plastic material, a thin sheet of aluminum, or other suitable material.

If desired, plug 24b may have a shaft 102 extending downwardly through tubular carrier 91 and having an annular recess at 103 within which inner projections on fingers 96 are movably receivable so that downward movement of shaft 102 relative to the rest of the plug will swing fingers 96 laterally inwardly to retracted positions in which the plug may be withdrawn upwardly from the well. Such downward movement of shaft 102 may be effected by a suitable fishing tool, which can simultaneously exert an upward pulling force on the upper portion 104 of the plug. Obviously such removal of the plug from the well by a fishing tool would be effected only under very unusual circumstances, in which for some reason the cement after displacement would not cover the upper end of the tool (as where the cement might virtually all be lost in the formation), and to remove the plug without further attempt at cementing. As in the first form of the invention, the fingers 94 and 96 are so designed that they will not grip tube 90 in holding relation, but will positively grip casing 13b in a holding engagement preventing vertical movement of the plug within the casing, after the fingers have been allowed to expand outwardly into engagement with the casing.

Fig. 10 shows still another form of the invention, in which all parts of the tool may be essentially identical with the device of Fig. 1 except that a different form of plug 24c is substituted for the plug 24. This plug 24c includes a vertically extending shaft-like carrier member 106, on which are removably carried a pair of oppositely directed annular sealing cups 107 and 108 formed of resiliently flexible elastomeric material such as rubber. These cups 107 and 108 are initially retained in a radially retracted condition within portion 109 of the tool body, and normally tend to laterally expand to a diameter to which the peripheral sealing edges or lips of cups 107 and 108 will annularly engage the inner wall of liner 13c in fluid tight sealing relation. The two sealing cups 107 and 108 are carried by individual rigid preferably metal rings 110 and 111, having an annular groove 112 within which the inner edges of cups 107 and 108 are received, with the material of the cups being vulcanized or otherwise tightly bonded to rings 110 and 111 within these grooves.

The upper ring 110 is initially held upwardly by an upper series of gripping fingers 113 and bears upwardly against a nut 114 which is threadedly connected onto carrier 106. The lower ring 111 is initially held downwardly by a lower series of fingers 115 and bears against a bottom nut 116. Rings 110 and 111 are sufficiently loose fits on carrier 106 to be displaced relatively together axially along carrier 106 by the force generated by the

propellant charge, such displacement of rings 110 and 111 being limited by engagement of these rings with the upper and lower sides of an annular enlargement 117 on carrier 106. In the positions in which rings 110 and 111 are in substantial contact with enlargement 117, the rings are retained against returning movement away from enlargement 117 by means of spring detent elements 118 contained in radial bores in rings 110 and 111 and receivable within annular grooves or recesses 119 in carrier 106.

In the initial inactive condition of plug 24c, fingers 113 and 115 are held stationarily relative to carrier 106 in the full line positions of Fig. 10. In these positions, the fingers 113 of the upper set of fingers are arranged as a series of circularly spaced elongated elements which flare upwardly from their lower ends 120 (attached to carrier 106), to their upper ends 121 (which bear against ring 110). The lower ends 120 of fingers 113 are mounted within individual circularly spaced bores 122 formed in the peripheral portion of an upper part 123 of carrier enlargement 117. The radially outer surface 124 of portion 123 of the carrier may flare upwardly at approximately the same angle as fingers 113.

The finger mounting bores 122 in the carrier enlargement are positioned so that the bore walls intersect or are interrupted by the outer surface 124 of that part of the carrier, so that each of the finger mounting bores 122 is opened along its outer side, but for a width narrower than the diameter of the bore and contained finger (the fingers preferably being of circular transverse section). Thus, the material of carrier 106 acts to only partially embrace the outer side of each of the fingers 113, to initially hold the fingers in fixed relation to carrier 106, through the material which retains fingers 113 at their outer sides is sufficiently thin to be sheared or deformed by the fingers upon firing of the propellant charge, to thereby allow the fingers to swing outwardly to the broken line positions of Fig. 10. The lower ends of fingers 113 bear against an annular flange 125 formed on carrier enlargement 117, so that those lower ends of the fingers are contained in a manner guiding fingers 113 for the desired outward swinging movement. The lower set of fingers 115 are identical with upper fingers 113, except that fingers 115 flare downwardly, and swing outwardly in a direction the reverse of fingers 113. The upper ends 126 of fingers 115 are confined within individual bores 127 formed in the periphery of a lower portion 128 of enlargement 117, which portion of the enlargement has a downwardly flaring radially outer surface 129 of a diameter such that the outer sides of bores 127 are interrupted in the same manner as bores 122, to allow outward swinging movement of fingers 115 when the propellant charge is fired.

The outward swinging movement of fingers 113 and 115 is effected by a camming engagement of rings 110 and 111 with the fingers. More particularly, the ends 121 and 130 of fingers 113 and 115 are received within individual notches or guide recesses 131 in rings 110 and 111, which notches have inner walls 132 extending at an angle relative to the axis of carrier 106, such that movement of rings 110 and 111 relatively together along carrier 106 acts to cam the engaged ends of the fingers 113 and 115 radially outwardly. When this camming action proceeds to an extent such that the ends of the fingers 113 and 115 move out of notches 131, the inner sides of fingers 113 and 115 then move into engagement with points 133 on rings 110 and 111, and this engagement serves to further cam the fingers radially outwardly until their pointed ends 121 and 130 bite into the inner surface of liner 13b, so that the upper fingers 113 very positively retain plug 24c against upward displacement, while lower fingers 115 positively retain the plug against downward displacement. As previously brought out, rings 110 and 111 are retained in this locked position by detents 118, so that the plug is then positively locked in

a fixed position within the liner. In this condition, fingers 113 and 115 preferably act as backing elements for backing up cups 107 and 108 to prevent undue flexure of these cups.

As in the previous forms of the invention, the cement in Fig. 10 may be initially supported by a frangible disc 28c, which may be identical with the disc 28b of Figs. 8 and 9. Also, the lower end of section 109 in Fig. 10 may removably carry a bottom nose member 25c which is frictionally or otherwise attached to the bottom of section 109 in a manner such that the nose member can be easily blown downwardly by the explosive force.

When the tool of Fig. 10 is fired, the operation is the same as in the previous forms of the invention except as to the manner in which the plug 24c is locked in position in the well. As this plug 24c is ejected downwardly, the lower downwardly facing seal cup 108 of this plug engages the liquid contained in the well, and the resistance offered by this liquid causes pressurized cement to actuate the seal cups 107 and 108 relatively together, to progressively cam fingers 113 and 115 radially outwardly into gripping engagement with liner 13c. Cups 107 and 108 of course resiliently expand into sealing engagement with the liner or casing 13c, to close off the well bore and support the cement in the well. By the time the gripping fingers 113 and 115 of plug 24c have been actuated to their holding positions of engagement with casing 13c, the plug has moved downwardly to a position somewhat below the lower end of the tubular body of the tool, to thus allow an annular space between the body and the upper seal cup through which cement may flow from the tool. The plug of Fig. 10 is, in any suitable manner, so designed as to assure against gripping engagement of fingers 113 and 115 with the interior of the tool section 109. For this purpose, the outer pointed ends 130 of fingers 113 and 115 may have surfaces 135 adjacent their points which engage section 109 and hold the points out of gripping engagement with that section, but with these surfaces 135 being so formed as to allow gripping engagement of the points with the greater diameter casing 13c after further radial expansion of the fingers. Also, the fingers 113 and 115 and the rings 110 and 111, are all so formed as to allow enough clearance between the fingers and the cups 107 and 108 to prevent the fingers from biting into the cups as the fingers swing outwardly.

I claim:

1. Apparatus for forming a closure in a well bore, comprising a hollow vertically extending body adapted to be lowered to a zone within the well, a mass of cementitious material in the body adapted to be ejected from the lower end of the body by gas pressure acting downwardly against the material, a plug carried by the body in an inactive position beneath said cementitious material and adapted to be ejected downwardly from the body with said cementitious material and to an active bore plugging position, said plug including holding means engageable with the side wall of the well after said downward ejection and operable to hold the plug against further downward movement in the well, said plug including closure means engageable with the bore wall after said downward ejection and operable to close the bore against downward flow of the cementitious material past the plug, a gas producing propellant charge carried by the body and adapted and positioned to produce a large quantity of high temperature and high pressure gases above said cementitious material at such a location and in such quantity as to rapidly force the cementitious material and plug downwardly relative to and from the body by the fluid pressure of said gases to thereby close the bore, said cementitious material being positioned to be highly pressurized by the gas force after the plug has been ejected so that said material, being retained by the plug against further downward movement, is forced to be rapidly set by the high pressure and high temperature

of the gases, a packer carried by the body and adapted outwardly against the well bore wall by the gases, and to close the bore at a location spaced above said active position of the plug to thereby confine the pressurized cementitious material and gases vertically between the plug and packer, said body being constructed to be free for withdrawal upwardly from the well without the plug and cement after firing of the propellant charge, and a seal structure supported in the body vertically between the cementitious material and said plug and preventing flow of said material downwardly into contact with the plug and constructed to shear under the force of said gases to allow downward movement of the material relative to the body.

2. Apparatus for forming a closure in a well bore, comprising a hollow vertically extending body adapted to be lowered to a zone within the well, a mass of cementitious material in the body adapted to be ejected from the lower end of the body by gas pressure acting downwardly against the material, a plug carried by the body in an inactive position beneath said cementitious material and adapted to be ejected downwardly from the body with said cementitious material and to an active bore plugging position, said plug including holding means engageable with the side wall of the well after said downward ejection and operable to hold the plug against further downward movement in the well, said plug including closure means engageable with the bore wall after said downward ejection and operable to close the bore against downward flow of the cementitious material past the plug, a gas producing propellant charge carried by the body and adapted and positioned to produce a large quantity of high temperature and high pressure gases above said cementitious material at such a location and in such quantity as to rapidly force the cementitious material and plug downwardly relative to and from the body by the fluid pressure of said gases to thereby close the bore, said cementitious material being positioned to be highly pressurized by the gas force after the plug has been ejected so that said material, being retained by the plug against further downward movement, is forced outwardly against the well bore wall by the gases, and is rapidly set by the high pressure and high temperature of the gases, a packer carried by the body and adapted to close the bore at a location spaced above said active position of the plug to thereby confine the pressurized cementitious material and gases vertically between the plug and packer, said body being constructed to be free for withdrawal upwardly from the well without the plug and cement after firing of the propellant charge, a seal structure supported in the body vertically between the cementitious material and said plug and preventing flow of said material downwardly into contact with the plug and constructed to shear under the force of said gases to allow downward movement of the material relative to the body, and means attaching said shearable seal structure to the upper end of said plug.

3. Apparatus as recited in claim 2, in which said body has a lower tubular portion beneath said seal structure and containing said plug and having an apertured side wall through which the cementitious material can bleed laterally from the body during downward movement of the plug to prevent the exertion of excessive force against the plug.

4. Apparatus for forming a closure in a well bore, comprising a hollow vertically extending body adapted to be lowered to a zone within the well, a mass of cementitious material in the body adapted to be ejected from the lower end of the body by gas pressure acting downwardly against the material, a plug carried by the body in an inactive position beneath said cementitious material and adapted to be ejected downwardly from the body with said cementitious material and to an active bore plugging position, said plug including holding means engageable with the side wall of the well after said downward ejection

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and operable to hold the plug against further downward movement in the well, said plug including closure means engageable with the bore wall after said downward ejection and operable to close the bore against downward flow of the cementitious material past the plug, a gas producing propellant charge carried by the body and adapted and positioned to produce a large quantity of high temperature and high pressure gases above said cementitious material at such a location and in such quantity as to rapidly force the cementitious material and plug downwardly relative to and from the body by the fluid pressure of said gases to thereby close the bore, said cementitious material being positioned to be highly pressurized by the gas force after the plug has been ejected so that said material, being retained by the plug against further downward movement, is forced outwardly against the well bore wall by the gases, and is rapidly set by the high pressure and high temperature of the gases, and a packer carried by the body and adapted to close the bore at a location spaced above said active position of the plug to

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thereby confine the pressurized cementitious material and gases vertically between the plug and packer, said body being constructed to be free for withdrawal upwardly from the well without the plug and cement after firing of the propellant charge, said body having a lower tubular portion containing said plug and having an apertured side wall through which the cementitious material can bleed laterally from the body during downward movement of the plug to prevent the exertion of excessive force against the plug.

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