Oct. 15, 1940. G. S. KNOX 2,217,986

WELL PIPE PLUG

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Fig. 1.

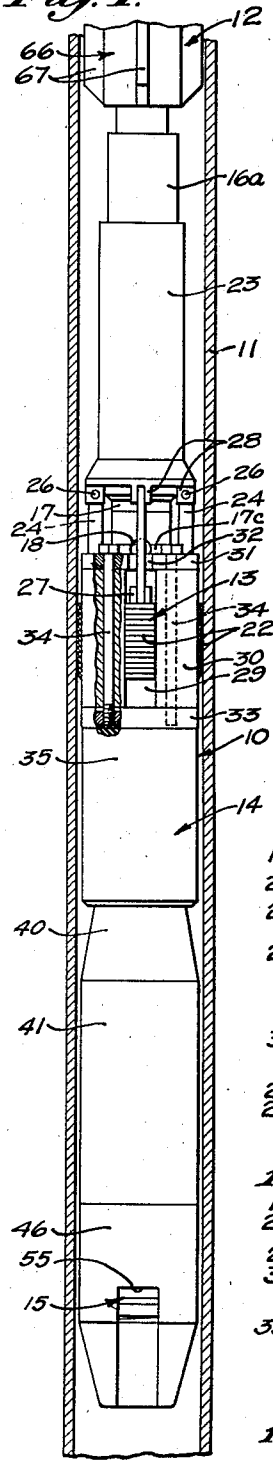


Fig. 2.

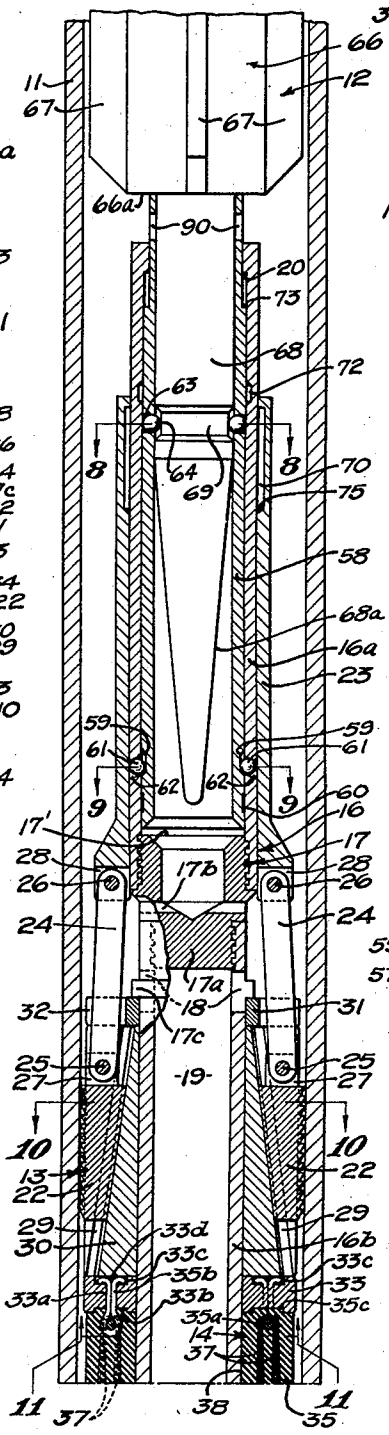
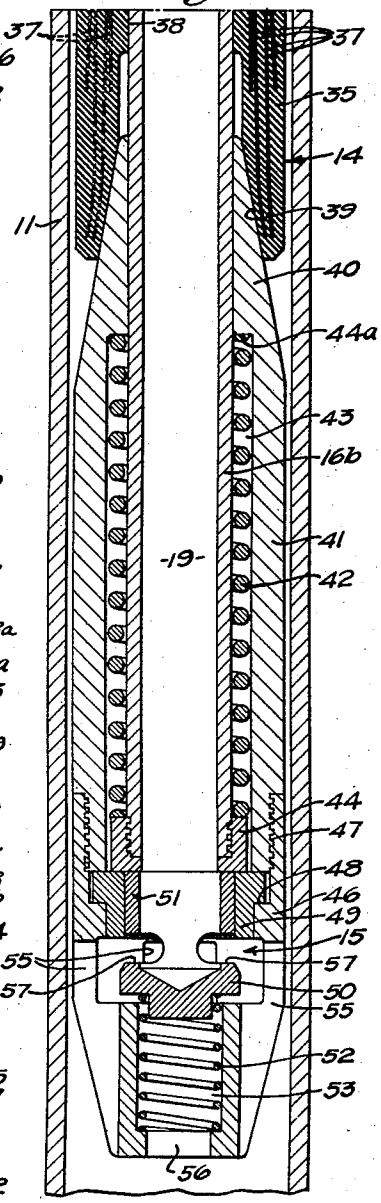


Fig. 3



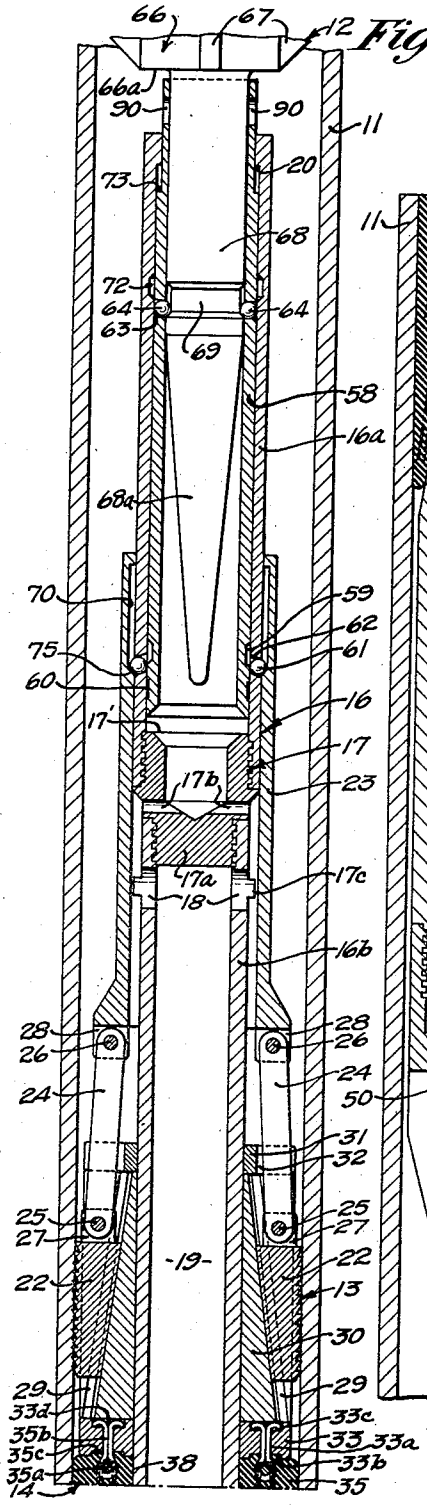
Inventor
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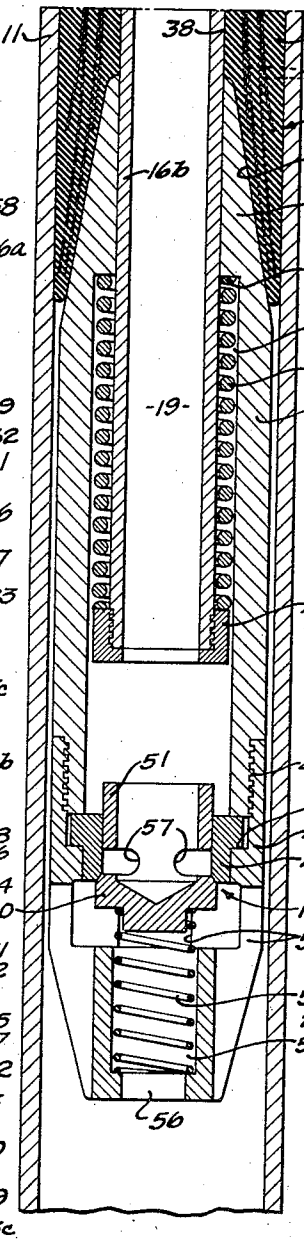
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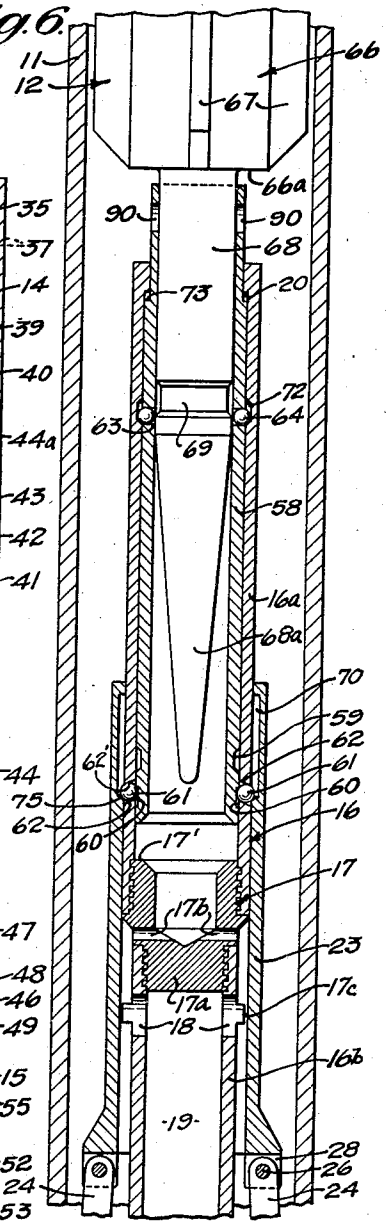
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Fig. 7.

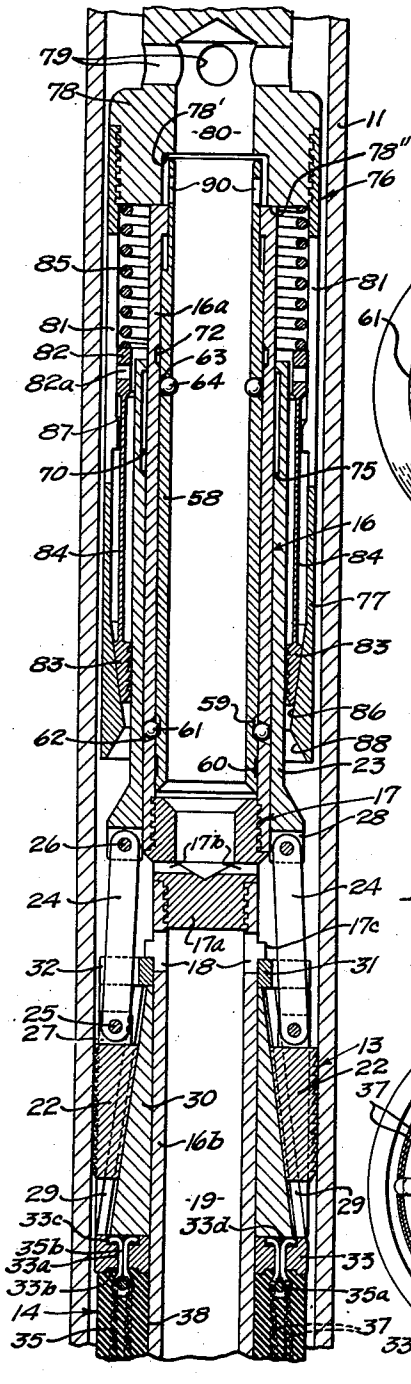


Fig. 8.

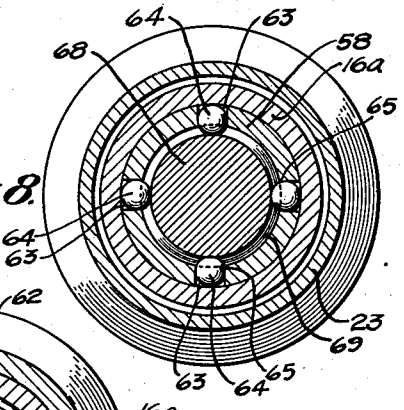


Fig. 9.

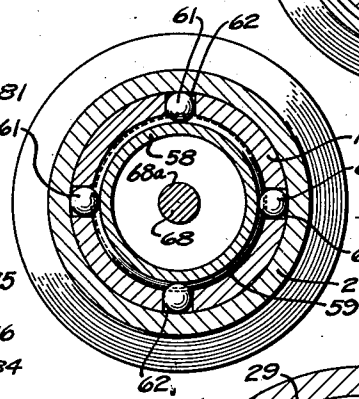


Fig. 10.

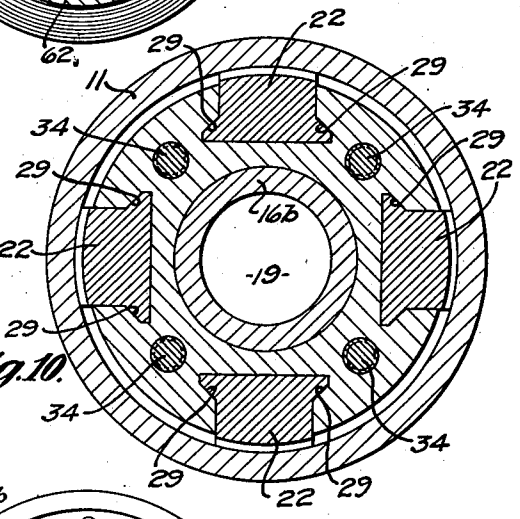
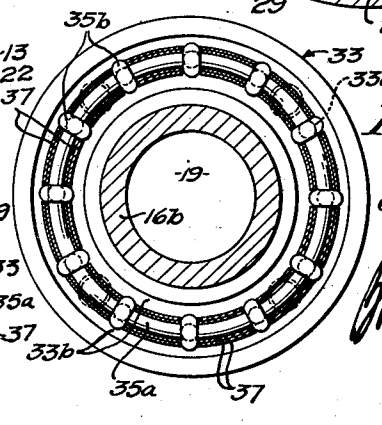


Fig. 11.



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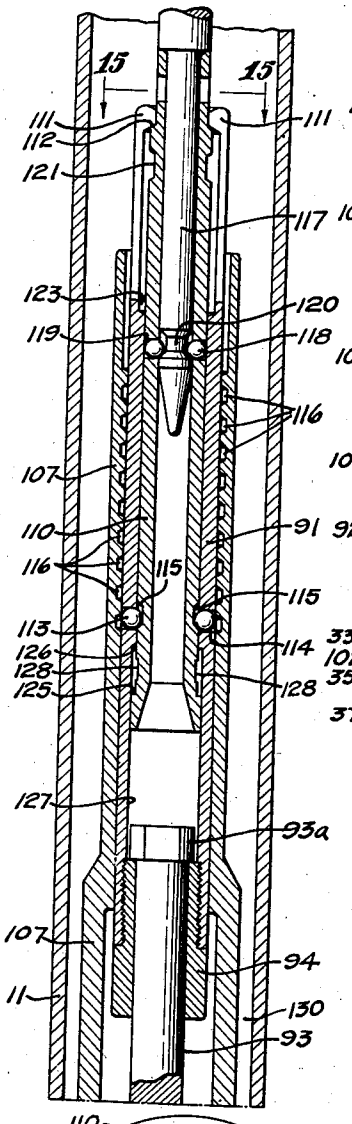
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WELL PIPE PLUG

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Fig. 12.



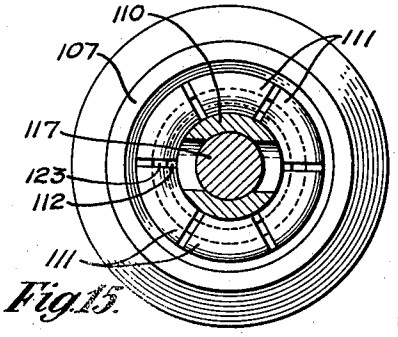


Fig. 15.

Fig. 13.

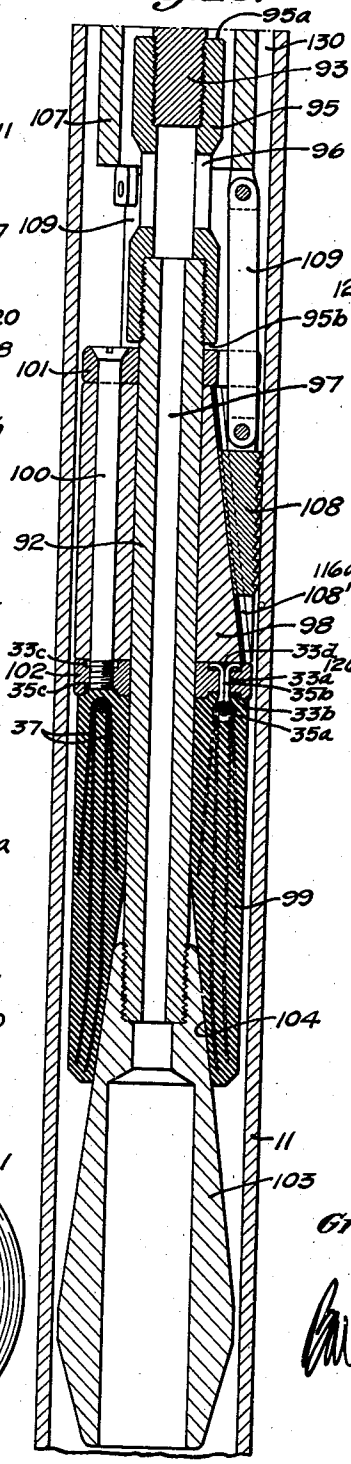
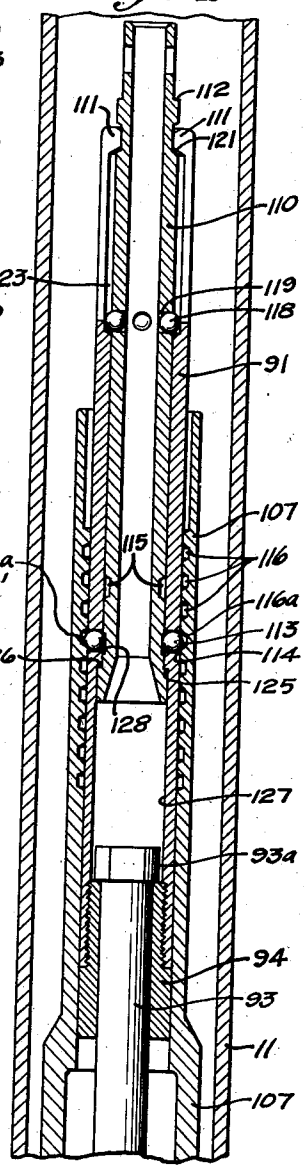


Fig. 14



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UNITED STATES PATENT OFFICE

2,217,986

WELL PIPE PLUG

Granville S. Knox, Los Angeles, Calif., assignor to Hydril Company, Los Angeles, Calif., a corporation of Nevada

Application April 29, 1940, Serial No. 332,231

26 Claims. (Cl. 166—13)

This invention relates generally to well pipe or casing plugs of the type adapted to be lowered into a well on a suspension means and set at any desired depth within the well pipe for sealing off fluid pressures from below. Certain aspects of the invention contemplate improvements in the type of plug disclosed in my copending application, Ser. No. 150,569, filed June 26, 1937, on Well pipe plug, now Patent No. 2,205,748, granted June 25, 1940.

The plug here described is of the "retrievable" type, that is, after once being set it may be released and withdrawn from the well pipe, in contra-distinction to plugs of the non-retrievable type which either are left in place permanently or are drilled out and thus destroyed in the event it is desired to unplug the well.

A retrievable plug is used, in the main, as a temporary plugging means to enable the operator to change surface fittings or to carry on other operations which require the shutting off of pressures at some lower point in the well pipe. Such plugs are seldom made of readily drillable material and, in any event, they are used primarily in well producing operations after all drilling equipment has been dismantled or removed from the well.

It follows that it is of utmost importance that the retrievable type of plug be readily and surely releasable from the well pipe after it has served its purpose, for a single failure has often resulted in tremendous loss of time and money due not only to the expense of setting up and operating heavy drilling or "well pulling" equipment, but also to the loss of producion which results from tying up the well.

It is therefore among the objects of my invention to provide a retrievable plug which not only serves its plugging purposes exceptionally well, but that can readily and surely be withdrawn when the time for that operation arrives.

And the invention fulfills the further object of providing a plug which may be surely and readily released even though the plug may be submerged in sand and debris, with such foreign matter having the natural tendency to lodge between working parts and thus interfere with their proper operation. How the device works even under the most disadvantageous conditions, how the resistance of the sand or other material is overcome, and how such foreign matter may be dislodged from between working parts, especially when the plug is used as a "bottom hole choke," will be made apparent in the detailed description.

In their general construction, plugs of this type comprise a tubular mandrel carrying expansible pipe gripping means and a packer, both adapted to be brought into tight engagement with the well pipe by vertical movement of the mandrel. Fluid flow through the mandrel may be controlled by a valve which, preferably, also is adapted to be opened and closed by operation of the mandrel. One of the principal features of the invention is the provision of means whereby the pipe gripping means, packer and valve may be operated in predetermined sequence by exerting a straight upward pull on the suspension means, thus permitting the plug to be run into the well and operated on a wire line or cable.

The invention has another outstanding feature of importance in the use of a locking mechanism operating after expansion of the packer and gripping means to hold the mandrel in its corresponding position, and releasable to cause contraction of the gripping means and packer and permit removal of the plug from the pipe. I provide in conjunction with the locking mechanism a setting tool releasably connected to the mandrel so as to be removable after the plug is set. In accordance with the invention, the setting tool is associated with the mandrel and locking mechanism in a manner such that the setting tool is not releasable from the mandrel until the latter has become locked in its packer expanding position, but is then disconnectible by continued straight upward pull on the suspension means. Thus in operating sequence, sustained pull on the suspension means first raises the mandrel to set the slips and packer, then actuates the locking mechanism to hold the mandrel in raised position, and finally causes the setting tool to be released from the plug.

The plug is removable from the well by lowering a retrieving tool adapted to be brought into engagement with the mandrel and jarred downwardly to release the mandrel from the locking mechanism and permit the gripping means and packer to contract. The retrieving tool attaches to a body or slip carrier section of the plug so as to permit the plug to be removed from the pipe by the retrieving tool, with the gripping means and packer maintained in contracted positions.

Or the plug may be adjusted to a new depth and reset—this in spite of the fact that the suspension means is in the form of a flexible cable. This feature is particularly valuable in connection with the use of a plug for locating leaks in a well pipe, where the plug is successively set and the pipe tested at spaced intervals down the pipe.

Because of the sometimes extreme differential

in pressures above and below the plug, it becomes difficult in the usual plug to set up the relative movement between body and mandrel sections required to disengage the pipe-gripping means and packer from the pipe wall. I overcome this difficulty by providing means for opening a valve of relatively small area, as compared to the cross-sectional area of the plug body and hence of the well-pipe, which allows the pressures above and below the plug to become balanced and thus relieve the wedging force which the initially predominant upward pressure exerts against the pipe gripping and sealing means.

The releasable locking means between setting or retrieving tool and the plug is of a nature to prevent accidental disconnection even under such conditions as when the plug has to be "jarred" downwardly through wax deposits or scale in the well pipe.

The invention embodies various additional features and novel structural details, but these will all be understood more clearly and to best advantage from the following description of the invention in one of its typical and illustrative forms. Throughout the description reference is had to the accompanying drawings, in which:

Fig. 1 is a general view showing the plug in elevation;

Fig. 2 is an enlarged sectional view showing the upper portion of the plug and its connection with the setting tool;

Fig. 3 is a lower continuation of Fig. 2;

Figs. 4 and 5 are views similar to Figs. 2 and 3, showing the plug parts in changed positions with the slips and packer expanded, and the valve closed;

Fig. 6 shows the positions of the mandrel locking sleeve at the point of releasing the setting tool;

Fig. 7 shows the upper end of the plug with an overshot type retrieving tool applied thereto;

Figs. 8, 9, and 10 are enlarged cross sections on lines 8—8, 9—9 and 10—10, respectively, of Fig. 2;

Fig. 11 is an enlarged cross section on line 11—11 of Fig. 2, but omitting a showing of the body of the packer;

Figs. 12 and 13 are views similar to Figs. 1 and 2, illustrating a variational form of the invention;

Fig. 14 shows the locking mechanism of Fig. 12 in changed position; and

Fig. 15 is an enlarged section on line 15—15 of Fig. 12.

Fig. 1 shows the plug, generally indicated at 10, lowered within a well pipe or casing 11 on a setting tool 12 which in turn may be connected to a suitable suspension means, preferably a wire line or cable, not shown. The plug may be generally described as comprising circularly arranged pipe gripping means indicated at 13, a packer 14, and a valve 15 for controlling the flow of fluid through the plug. As will later appear, while the plug is being lowered within the well pipe, the valve 15 remains open and the pipe gripping means 13 and packer 14 remain radially contracted to permit free passage of the plug through the pipe. After the plug has been lowered to the setting depth, an upward pull on the suspension means operates to expand the gripping means 13 into holding engagement with the pipe, also to close valve 15 and expand the packer 14, and finally to release the setting tool 12 from the plug.

The plug includes a mandrel, generally indicated at 16, having upper and lower sections 16a and 16b interconnected by threaded coupling 17 having a solid end or barrier 17a and a transverse, through passageway 17b above barrier 17a. Just below the barrier, the mandrel section 16b is provided with an external, annular flange 17c and a pair of diametrically opposite ports 18 which extend through the walls of the section and the corresponding parts of flange 17c.

Passageway 17b opens to the bore of coupling 17 above barriers 17a and hence to the bore of upper mandrel section 16a, so, under certain circumstances, well fluid may have free passage therethrough, both to act as a relief or discharge port when elements (to be described) are moved longitudinally through the mandrel bore, and to permit the flushing away of sand or other foreign matter which might otherwise lodge within the mandrel bore.

On the other hand, ports 18 permit well fluid passing upwardly through the bore 19 of section 16b to by-pass outwardly to the well-pipe as the plug is being lowered therethrough, it being noted that said ports are located above packer 14 so that the established fluid-bypass around the packer permits free movement of the plug down through the well fluid. Barrier 17a acts, of course, to divert the fluid outwardly through ports 18, rather than into the bore of coupling 17 or mandrel section 16a, the diverted fluid acting to wash sand or debris away from slips 13.

It will be noted that mandrel section 16b and the exteriorly exposed part of coupling 17 just above the upper end of that section are of less outside diameter than is mandrel section 16a, it following that the ends of passageway 17b and ports 18 are unobstructed and the described fluid-flow therethrough may continue, irrespective of the position to which sleeve 23 (to be later described) may be moved (see, for instance, Fig. 4).

The pipe gripping means 13 preferably comprise circularly arranged wedge slips 22 connected with and suspended from what may be termed a body section of the plug, or more specifically, a carrier sleeve 23 movable vertically on the upper mandrel section 16a. The slips are suitably attached to the lower end of the carrier sleeve, as by means of links 24 pivotally connected by pins 25 and 26 to lugs 27 and 28 formed integrally with the slips and carrier sleeve, respectively. The slips 22 are contained within outwardly inclined, dove tail ways 29 formed in the surface of a wedge ring or slips-supporting body 30 that is movable vertically with relation to the lower mandrel section 16b. Upward movement of the slip and carrier sleeve assembly is limited by engagement of the slips with a stop ring or slip-retainer plate 31 having circumferentially spaced notches 32 receiving the links 24, and attached to the packer supporting ring or anchor plate 33 by anchor bolts 34 (see Fig. 1) extending through the wedge sleeve 30. In turn, upward movement of the stop ring, wedge sleeve and packer assembly relative to the mandrel, is limited by the engagement of ring 31 with the lower end of coupling-flange 17c.

The packer 14 comprises a sleeve 35 of rubber, "Neoprene," or other suitable substance, attached to and suspended from ring 33 by suitable means. For instance, packer 35 may be molded about an assembly made up of a metal ring 35a (Fig. 11) upon which the eyes of circumferentially spaced cotter keys 35b are threaded, and the fabric reinforcing strips or hangers 37, pref-

erably of two plys of "Neoprene"—dipped cord, which are looped over ring 35a between the cotter keys in the manner clearly shown in Figs. 2 and 3. The ends of the cotter keys project beyond the upper end of sleeve 35 and are adapted to be extended through vertical openings 33a in ring 33, said openings extending upwardly from bottom groove 33b to top groove 33c, these grooves being provided in the horizontal faces of the ring. The sleeve 35 has an annular, upstanding rib 35c which fits in groove 33b, while, after the keys have been thrust through openings 33a, the key-legs are spread into groove 33c and tack-welded at 33d to anchor the sleeve assembly to the ring. The sleeve assembly may be replaced, if and when it becomes unduly worn, by breaking away the tack welds and freeing the keys from the ring, whereupon a new assembly may be substituted.

The packer has an upper cylindric bore 38 peripherally engaging mandrel section 16b, and a lower tapered bore 39 which receives the correspondingly tapered upper end 40 of the packer expanding sleeve 41. The latter surrounds mandrel section 16b and is vertically supported by a coil spring 42 received within the sleeve bore 43 and resting on removable flange-ring or retainer 44 at the lower end of the mandrel. The upper end of spring 42 engages the internal downwardly facing shoulder 44a on expander 41. In the normal position of the parts shown in Figs. 1 to 3, end 40 of the expander sleeve is withdrawn sufficiently from the packer bore 39 to permit the packer to assume its radially contracted condition. Upon upward movement of the mandrel relative to the packer, spring 42, then under compression, thrusts the wedge end 40 of the sleeve into the packer bore, radially expanding the packer and at the same time compressing it longitudinally, so as to bring the packer into sealing engagement with the pipe as shown in Fig. 5.

The valve means or assembly 15 comprises a valve cage 46 threaded at 47 on the lower end of expander sleeve 41 and having an internal shoulder 48, between which and the lower end of the sleeve is clamped the valve seat 49. The valve or stopper 50 has an integral, tubular guide portion 51 extending upwardly through the seat 49, and the valve is urged upwardly toward seating position by a coil spring 52 contained within bore 53 of cage 46. While the plug is being lowered within the well, the valve is held open in the position of Fig. 3 by engagement of the lower end of the mandrel with the upper end of guide 51. In this position of the parts, fluid is permitted to flow into the mandrel bore through openings 55 and 56 of the cage and ports 57 through guide 51, which ports are uncovered when the valve is depressed to open position.

I have provided a locking mechanism which is operable by a straight upward pull of the suspension means and setting tool to automatically lock the slips and packer in gripping and sealing engagement with the wall of the pipe. An added feature in this same connection is the capacity, by continued upward pull on the suspension means, for sequentially expanding the slips and packer, closing the valve, and disconnecting the setting tool from the plug, all in one simple and progressive operation.

In its preferred form, the locking mechanism comprises a locking sleeve 58 inserted within the upper mandrel section 16a and adjustable vertically with relation thereto for the purpose of connecting and releasing the setting tool from the plug, and also for locking the mandrel against movement with respect to the carrier sleeve 23 after expansion of the wedge slips and packer. Near its lower end, the locking sleeve 58 is provided with annular surface grooves 59 and 60 adapted to receive detents or locking elements in the form of steel balls 61 contained within downwardly and outwardly inclined openings 62 drilled through the wall of the mandrel. In the position of the parts shown in Fig. 2, balls 61, being confined against outward displacement by engagement with the defining wall of the lower bore of the carrier sleeve 23, lock the locking sleeve against upward movement relative to the mandrel. The assembly of balls 61 may be considered as both a locking-sleeve latch and as an expander latch. Toward its upper end, the locking sleeve is provided with openings 63 containing locking elements or detents in the form of steel balls 64 which, when the setting tool is released, are prevented from dropping into the sleeve bore by a slight reduction in the diameter of openings 63 at the inside of the sleeve, as indicated at 65 in Fig. 8. The assembly of balls 64 may be considered as the setting tool latch.

The setting tool 12 typically may comprise a body 66 having vertically extending guide ribs 67 and a tapered nose spindle or spear 68 which is adapted to be inserted within the locking sleeve and releasably connected with the plug by the projection of balls 64 into annular groove 69 in the spindle. A description of the method of engaging the setting tool within the locking sleeve can best be given after a more complete description of the operation of the locking sleeve and its associated parts. It will suffice to note at this point that the setting tool initially is attached to the plug as shown in Fig. 2, and the plug is lowered within the pipe with the packer maintained in contracted condition and the valve held open, the lowering being accomplished, for instance, by a cable (not shown) attached to the setting tool.

In operation, the plug is lowered to the desired depth with the slip and carrier sleeve assembly resting on the wedge ring 30, but without the slips being in gripping engagement with the pipe and therefore not interfering with the downward progress of the plug by reason of any upward displaceability of the slip and carrier assembly as irregularities on the surface of the pipe are encountered.

After the plug has been lowered to setting position, an upward pull is exerted through the lowering cable on the setting tool. Since the setting tool is locked to sleeve 58 by balls 64, and the sleeve is locked to mandrel 16 by balls 61, this upward pull is transmitted to the mandrel which acts, through spring 42, expander 41, sleeve 35 and wedge ring 30, to engage slips 22 with pipe 11 (it being evident that the slips and carrier are initially free for vertical movement relative to the mandrel and thus to hold the wedge ring, carrier sleeve and packer against further upward bodily movement.

Continued upward pull on the lowering cable causes the mandrel to move upwardly through the carrier sleeve 23, wedge ring 30 and the packer 35. As a result, the lower end of the mandrel is disengaged from the guide 51, permitting the valve 50 to seat (see Fig. 5) and at the same time the tapered end 40 of sleeve 41 is moved upwardly, through spring 42, into wedging and expanding engagement with the packer 35. The compressive strength of the spring and the extent of upward travel of the mandrel are such as to

cause the sleeve to expand the packer into fluid-tight engagement with the well pipe.

Upward movement of the mandrel continues until balls 61 reach the lower end of an annular recess 70 in the upper portion of the carrier sleeve 23, at which point, see Fig. 4, the balls are displaced out of the mandrel groove into recess 70 where they overlie shoulder 75 on sleeve 23, thus preventing the mandrel from dropping with relation to sleeve 23, so slips 22 may not be accidentally released. The displacement of balls 61 into recess 70 also permits the locking sleeve 58 to move upwardly with relation to the mandrel. Continued upward movement of the setting tool elevates the locking sleeve to a point at which the relatively shallow annular groove 60 at the lower end of the locking sleeve is brought opposite balls 61, and balls 64 are raised opposite an annular groove 72 in the carrier sleeve. Upward movement of the locking sleeve beyond this point is prevented by engagement of shoulder 73 on the locking sleeve, with the mandrel shoulder 20. With the parts thus brought to the position shown in Fig. 6, balls 64 are displaced radially outwardly within groove 72 to release the setting tool, and at the instant of release, balls 61 are thrust into the shallow mandrel groove 60 but they still overhang the downwardly inclined bottom surface or shoulder 75 in recess 70 to lock the mandrel against downward movement relative to the carrier sleeve, wedge ring and packer.

The shifting of balls 61 into groove 60 is accomplished by virtue of the camming effect of the top inclined surfaces 62' (Fig. 6) of openings 62, acting under the influence of spring 42, to displace the balls radially inwardly, said balls thus not only holding the mandrel up with relation to carrier 23 but also holding sleeve 58 from dropping with relation to the mandrel. Thus, after disconnection of the setting tool, the mandrel remains locked in its upper position with the valve 50 closed and spring 42 compressed to continuously maintain an expanding force against the packer 35. As will be apparent, if for any reason it is desired to maintain downward circulation through the plug, fluid pumped into the pipe 11 will flow into the mandrel bore above the packer through openings 18 and, by unseating the valve 50 against the resistance of spring 52, will flow outwardly through ports 57 into the pipe below the packer.

It will be noted that annular clearance exists between sleeve 23 and mandrel section 16b so neither openings 17b nor 18 are closed off, even though the sleeve is relatively depressed. By providing openings 17b and 18 intermediate the ends of the plug and approximately opposite the linkage and ways of the slips, it is assured that well fluid will be directed in a manner to flush the slips and their mountings clear of sand or debris.

It will thus be seen that balls 61 and 64 initially act together to lock certain parts of the mechanism against relative vertical movement so the upward pull on the setting tool sets the slips, allows the valve to close and expands the packer. Then, at one and the same time, balls 61 are shifted to positions which lock the slips and packer in expanded condition and free the locking sleeve for upward movement, so upon continued raising movement, balls 64 are unlocked to free the lowering tool from the plug. This same last movement of the locking sleeve shifts it to a position where balls 61 come into play (without effecting their slip-and-packer locking function) to hold the locking sleeve in elevated position after the lowering tool is freed therefrom.

It will be noted that the lowering tool cannot be freed from the plug until after the slips and packer have been locked in fully expanded and tight engagement with the well pipe, it following that there is no need of auxiliary provisions, usual to most retrievable plugs, to catch the plug in the event of premature release from the lowering line.

The plug may be removed from the well by the use of a retrieving tool of the type shown in Fig. 7, which is operable to release the mandrel from the locking device and thereby permit the mandrel to be returned to its lower position under the influence of spring 42, and also to maintain the wedge slips and carrier sleeve in elevated position relative to the mandrel, while the plug is being removed from the well. The retrieving tool, generally indicated at 76, may be of an overshot type comprising a tubular body 77 connected by a suitable coupling or sub 78 with the lowering cable (not shown). Sub 78 may be provided with fluid passages 79 and 80 communicating with the interior of the body 77. The circulation fluid may thus be discharged downwardly through the body 77, and also outwardly through slots 81 below the sub 78.

The body 77 contains an annular slip carrier 82 attached to wedge slips 83 by integral, depending flexible fingers 84. A coil spring 85 confined between sub 78 and the carrier 82 acts to radially contract the slips by thrusting them downwardly along conical wedge surface 86 at the lower end of the body, downward movement of the slip assembly being limited by engagement of the carrier with stop shoulders 87 on the body. The bottom of the body has an outwardly flaring mouth 88 to facilitate centering the tool about the upper end of the mandrel. Vertically extending slots 81 in the body permit insertion of a suitable tool within openings 82a in the carrier 82, for the purpose of releasing the slips after the plug has been removed from the well.

In removing the plug from the pipe, the retrieving tool 76 is lowered about the upper end of the mandrel and the carrier sleeve 23, the retrieving tool slip-assembly being upwardly displaceable against the resistance of spring 85 to permit the slips 83 to move down along the outside surface of the carrier sleeve. After the sub 78 has been lowered so its shoulder 78' is in engagement with the upper end of the locking sleeve 58 (the latter being in the position shown in Fig. 6) a light downward blow against the locking sleeve, applied for example by operation of a jar carried on the lowering cable above the sub 78, will displace balls 61 outwardly within recess 70 and return the locking sleeve to the position of Fig. 2 in which balls 61 enter the groove 59 to release the mandrel for downward movement relative to the carrier sleeve 23. A downward jarring blow on the upper end of the mandrel by sub-shoulder 78'', releases it against any restraint resulting from the upper portion of the packer being contracted about the mandrel. When released, the mandrel is returned by spring 42 to its lowermost position, opening the valve 50 and relieving the spring thrust against the packer expanding sleeve.

The ability to open the valve in the manner described is of importance in that it becomes possible to remove the plug from the pipe even

though the pressure above and below the plug are not balanced. Consequently, it generally is unnecessary to run water into the pipe for the purpose of balancing pressures above and below the plug. The relatively small cross-sectional area of the valve with respect to the cross sectional area of the bore of pipe 11, makes it comparatively easy to open the valve even against relatively high pressures below the plug. The engagement of slips 83 with the carrier sleeve retains the mandrel in its valve opening position so that the valve is held open against high pressures and fluid flow may continue through the plug until the pressures above and below are in balance. A final jar upon the mandrel drives the slip expanding ring 30 downward and relieves slips 22 from wedging engagement with the pipe, slips 83 having been set by wedge face 86 in gripping engagement with sleeve 23. The plug may now be removed from the well by elevating the retrieving tool, slips 22 being raised into engagement with the stop ring 31 and maintained in contracted condition.

It will be noted that since the plug is elevated through the slips carrier and ring 31 (rather than through a pull exerted directly on the mandrel) there is no relative vertical movement between the mandrel and packer during the pick-up operation and therefore no tendency for the packer (if, accidentally, it frictionally engages the pipe) to be dragged down over the larger diameter of the expanding member with a consequent danger of wedging the packer outwardly against the walls of the pipe.

It will also be noted that the slips 22 are forcibly moved to their contracted positions before the upward draft on the plug, proper, is applied, and, as the plug is being lifted, the carrier 23 and mandrel 16 are locked in such relative positions that slips 22 are also locked against accidental movement to expanded or pipe-engaging positions.

The setting tool 12 may be attached to the plug by first latching (with balls 61) the locking sleeve 58 in its upper position of Fig. 6. This may be done by holding the carrier sleeve 23 stationary and pulling out the locking sleeve by means of a handle through holes 90 in its upper end. The spindle end 68 of the lowering tool is then inserted in the bore of sleeve 58, balls 64 being cammed radially outward into groove 72 to permit the spindle to be depressed to a position where groove 69 lines up with those balls, and shoulder 66a of the setting tool engages the upper end of sleeve 58. A blow struck on the head of the lowering tool then drives sleeve 58 downward with relation to mandrel section 16a, this movement shifting balls 64 into locking association with spindle 68 (Fig. 4). Since groove 60 is relatively shallow, the balls 61 are cammed radially outward from that groove and more fully into recess 70, to allow the described downward movement of the locking sleeve.

The downward movement of the sleeve lines up relatively deep groove 59 with balls 61 so the latter may move to the position of Fig. 2, thus unlocking sleeve 58 from carrier 23, whereupon spring 42 is free to shift all parts to the positions of Fig. 2.

It is sometimes desirable to re-set the plug at a lower depth, particularly in locating leaks in well pipe, where the plug is successively set at lower depths with a test made between each setting. Ordinarily, this has required that the plug be fished from the hole after each test, re-connected to the lowering tool and re-lowered to the new depth. With my device this is unnecessary.

Assume the plug has been set and is in the condition of Fig. 6, except that the lowering tool has been entirely removed. It will be remembered that balls 61 are now holding sleeve 58 in the elevated position (with relation to mandrel 16) shown in this figure, so it is assured groove 72 is lined up with balls 64.

The setting tool 12 is then run in on a weighted lowering line, the conical nose 68a guiding spindle 68 into the bore of locking sleeve 58. Shoulder 66a strikes the upper end of sleeve 58 with sufficient force to drive it down, just as described immediately above in connection with the out-of-well attachment of the tool. With the lowering tool thus connected to the locking sleeve by balls 64 and with balls 61 lined up with groove 59 (the parts would then be approximately in the position of Fig. 4 but the groove 59 would be somewhat lower than there shown) balls 61 are free to clear shoulder 75, and spring 42, aided by gravity, is free to move the mandrel downwardly through sleeve 58, opening valve 15, engaging flange 17c with ring 31 and allowing the packer to contract. A continuation of the downward force imposed on sleeve 58 engages the lower end of the sleeve with the upper end 17' of coupling 17, thus jarring mandrel 16 downwardly, which, through flange 17c and ring 31, drives wedge ring 30 down, the latter, due to the dove-tail ways 29, thus radially contracting the slips assembly 13 and freeing the plug from the walls of the pipe.

All parts will now be in the condition of Figs. 2 and 3, it following that the plug may be lowered to a new depth, reset, and then freed from the lowering tool, all as has been previously described. This sequence of resetting at successively lower depths may be repeated as often as the depth of the well will allow.

Figs. 12 to 15 show a variational form of the invention similar in general to the previously described embodiment, but differing principally in the omission of the valve, and certain changes in the parts that permit substantial reduction in the required length of the plug. Here the mandrel comprises upper and lower relatively longitudinally movable sections 91 and 92 having a lost motion connection by way of bolt 93 extending through a tubular bushing 94 threaded into the lower end of the upper section 91. The lower end of bolt 93 is connected to mandrel section 92 by a tubular coupling 95 having ports 96 communicating with the mandrel bore 97. As in the first described form of the invention, the slip expanding wedge sleeve 98 and packer 99 are tied together by bolts 100 extending through the stop ring 101 and sleeve 98 and threaded into the packer supporting ring 102. The packer sleeve is internally reenforced and attached to the ring 102 in the manner described in connection with the first described form of the invention. I have applied the same reference numerals but will not repeat the description.

The mandrel carries on its lower end the upwardly tapered tubular packer expanding wedge 103, the upper end of which is received within the tapered portion 104 of the packer bore. As will be understood, the packer is radially expansible and contractible by upward and downward movement, respectively, of the lower mandrel section and wedge member 103 within the wedge sleeve and packer assembly.

The slip carrier sleeve 107 is vertically movable on the upper mandrel section 91, and is attached

to the slips 108 by the pivoted links 109. The slips are adapted to slide through dove-tail ways 108' in member 98. The locking sleeve 110 contained within the upper mandrel section bore normally is releasably held against upward movement relative to the mandrel by detents 111 engaging the locking sleeve shoulder 112, the detents being formed by vertically slotting the upper end of the mandrel at suitable circularly spaced intervals, which gives the detents a desired degree of radial resilience. The mandrel and locking sleeve are releasably interlocked in their normal positions of Fig. 12 by circumferentially arranged balls 113 contained within openings 114 in the mandrel and projecting into an annular recess 115 in the locking sleeve. The carrier sleeve 107 is provided with a series of vertically spaced, internal annular grooves 116 adapted to receive the balls 113 to prevent downward movement of the mandrel relative to the locking sleeve under conditions later described. The setting tool 117 is releasably locked within sleeve 110 by balls 118 (corresponding to balls 64 in Fig. 2) contained within openings 119 in the locking sleeve and projecting within the recessed portion 120 of the setting tool.

In operation, the plug is lowered on the suspension cable with the parts positioned as shown in Figs. 12 and 13. When the desired depth has been reached, an upward pull on the setting tool first causes the wedge sleeve 98 to bring the slips 108 into gripping engagement with the pipe. Continued upward pull, transmitted to the lower mandrel section by the engagement of bushing 94 with the head 93*a* of bolt 93, causes the wedge member 103 to expand the packer sleeve into fluid tight engagement with the casing. During this time, the upper mandrel section 91 will have become raised within the carrier sleeve a distance depending upon the length of mandrel travel required to fully expand the packer.

At the point at which further upward movement of the mandrel is prevented by the engagement of the wedge member 103 within the packer, the pull on the locking sleeve 110 overcomes the resistance of detents 111, causing shoulder 112 to be pulled upwardly past the detents to the point at which they spring back into the annular groove 121 in the locking sleeve. Upward movement of the locking sleeve within the mandrel during this operation, is limited by engagement of the sleeve shoulder 125 with shoulder 126 at the upper end of the counterbore 127. As a result of such upward movement of the locking sleeve, balls 113 are displaced outwardly within the particular carrier sleeve groove 116 opposite which they happen to be positioned, and balls 113 are moved upwardly to the point of outward displacement into recess 123, releasing the setting tool 117, see Fig. 14. Immediately upon release of the setting tool, balls 113 lock the mandrel against downward movement relative to the slip carrier, wedge sleeve and packer, by reason of the balls being retained within the groove 116*a* by engagement within the recessed portion 128 of the locking sleeve. By seating the balls within the relatively shallow recess 128, the locking sleeve is prevented from becoming accidentally moved downward to the point of releasing the mandrel.

The plug may be removed from the well by an overshot type retrieving tool as previously described. By lowering the retrieving tool around and into engagement with the upper end of the locking sleeve, positioned as shown in Fig. 14, and then jarring down on the retrieving tool, shoulder 112 is returned past the detents 111 to the position of Fig. 12, in which the locking sleeve will be moved downward to the point of accommodating balls 113 within recess 115, thereby releasing the balls from locking engagement with the carrier sleeve. The upper mandrel section is jarred downward to the point of engaging bushing 94 with shoulder 95*a* formed by the upper end of coupling 95, with the result that the lower mandrel section is driven downward sufficiently to permit contraction of the packer 99 to releasing position. With the over-shot slips now engaging the carrier sleeve 107, the plug may be removed from the well, the slips 108 being raised into contracted position and into engagement with the ring 101, which in turn, engages the coupling shoulder 95*b* to support and elevate the mandrel assembly.

The lost motion connection between the mandrel sections permits upward movement of the lower section and expansion of the packer after the plug has been set in the well, without in any way interfering with the upper section and locking sleeve assembly. Thus, should increased well pressure tend to force the lower mandrel section upwardly and thus more tightly expand the packer, bolt 93 will move upward within bushing 94 without producing movement of the upper mandrel section, sufficient space being provided between the bolt head 93*a* and the lower end of the locking sleeve 110 to accommodate possible upward movement of the lower mandrel section.

Well fluid flowing upwardly through the mandrel bore 97 is discharged outwardly through openings 96 and upwardly around the carrier sleeve 107. This feature of maintaining upward flow around the carrier sleeve is of importance in that the well flow washes away and removes from the annular space 130 between the carrier sleeve and well pipe, sand or other solid particles that otherwise might accumulate therein and obstruct lowering the retrieving tool down about the carrier sleeve. Here the well fluid continuously washes the space 130 above openings 96, free from settling sands.

Another important feature of the invention is the adaptability of the lower mandrel section 92 for replacement by other mandrel sections having different bore diameters. In addition to its function as a mandrel, section 92 may also serve as a choke for restricting the flow of well fluid through the plug, the degree to which the fluid is restricted being determined by the size of the mandrel bore 97. In case it is desired to restrict flow through the plug to a greater or lesser degree, the lower mandrel section 92 may be disconnected from coupling 95 and wedge member 103, and replaced by another section having a larger or smaller size bore, as the case may be.

I claim:

1. In a plug adapted to be lowered in a well pipe on suspension means, the combination comprising relatively vertically movable body and mandrel sections, a packer encircling the mandrel section and being expansible into tight engagement with said pipe, a vertically slidable packer expander supported on the mandrel and engaging the packer, a spring engaging and adapted to exert packer-expanding force against said packer expander, means whereby relative vertical movement of said sections in one direction compresses the spring and, through the packer expander, expands the packer, and a lock carried by one section and engaging the other section, said lock being adapted to hold said

sections against relative vertical movement in an opposite direction after expansion of the packer.

2. In a plug adapted to be lowered in a well pipe on suspension means, the combination comprising relatively vertically movable body and mandrel sections, a tubular packer encircling the mandrel section and being expansible into tight engagement with said pipe, a packer expanding wedge member slidable vertically on the mandrel and extending into the bore of the packer, a spring acting between the mandrel and wedge member and adapted to exert a packer expanding force against said wedge member, and means whereby relative movement of said sections in one direction compresses the spring and, through the packer expander, expands the packer.

3. In a plug adapted to be lowered in a well pipe on a suspension means, the combination comprising a mandrel, a carrier sleeve mounted directly on and movable vertically along the mandrel, pipe gripping means suspended from said sleeve, a packer encircling the mandrel, both said gripping means and packer being expansible into tight engagement with the pipe by upward movement of the mandrel within the sleeve, and means inside said sleeve for releasably locking the mandrel against downward movement relative to the carrier sleeve after expansion of the gripping means and packer.

4. In a plug adapted to be lowered in a well pipe on a suspension means, the combination comprising a mandrel having a tubular portion, a carrier sleeve movable vertically on the mandrel, pipe gripping means suspended from said sleeve, a packer encircling the mandrel, both said gripping means and packer being expansible into tight engagement with the pipe by upward movement of the mandrel within the sleeve, and means including a locking sleeve movable vertically within the bore of the tubular portion of said mandrel for releasably locking the mandrel against downward movement relative to the carrier sleeve after expansion of the gripping means and packer.

5. The combination including a plug adapted to be lowered in a well pipe on a suspension means, said plug including a vertically movable member, pipe gripping means on said plug and expansible into gripping position by upward movement of said member; a setting tool carried by said suspension means and inserted within a bore in the upper end of said member, latch means within said bore and releasably connecting said setting tool and member, and a lock for said latch means, all in a manner whereby upward movement of the suspension means first expands the gripping means and subsequently releases said lock and actuates the latch to release the setting tool from said member.

6. The combination comprising a plug adapted to be lowered in a well pipe on a suspension means, said plug including a mandrel, a carrier sleeve movable vertically on the mandrel, wedge slips suspended from said sleeve, a slip expanding wedge ring on the mandrel, a packer on the mandrel below said wedge ring, means connecting said ring and packer and holding them against relative bodily movement, a packer expanding sleeve on the mandrel below the packer, the mandrel being vertically movable relative to said wedge ring, packer and the packer expanding sleeve, a pair of vertically spaced, opposed shoulders, one on the mandrel and the other on the last mentioned sleeve, and a spring about the mandrel and extending between said shoulders whereby upward movement of the mandrel causes the spring to exert an expanding force against the packer.

7. The combination comprising a plug adapted to be lowered in a well pipe on a suspension means, said plug including a mandrel containing a fluid passage, a carrier sleeve movable vertically on the mandrel, wedge slips suspended from said sleeve, a slip expanding wedge ring on the mandrel, a packer on the mandrel below said wedge ring, means connecting said ring and packer and holding them against relative bodily movement, a packer expanding sleeve on the mandrel below the packer, the mandrel being vertically movable relative to said wedge ring, packer and the packer expanding sleeve, a pair of vertically spaced, opposed shoulders, one on the mandrel and the other on the last mentioned sleeve, and a spring about the mandrel and extending between said shoulders whereby upward movement of the mandrel causes the spring to exert an expanding force against the packer, a spring loaded valve carried by said packer expanding sleeve, and means on the mandrel adapted releasably to hold the valve open against its spring-load.

8. The combination comprising a plug adapted to be lowered in a well pipe on a suspension means, said plug including a mandrel, a carrier sleeve movable vertically on the mandrel, wedge slips suspended from said sleeve, a slip expanding wedge ring on the mandrel, a packer on the mandrel below said wedge ring, means connecting said ring and packer and holding them against relative bodily movement, a packer expanding sleeve on the mandrel below the packer, the mandrel being vertically movable relative to said wedge ring, packer and the packer expanding sleeve, a pair of vertically spaced, opposed shoulders, one on the mandrel and the other on the last mentioned sleeve, a spring about the mandrel and extending between said shoulders whereby upward movement of the mandrel causes the spring to exert an expanding force against the packer, and means for releasably locking the mandrel against downward movement relative to the carrier sleeve.

9. In well pipe plug, a mandrel comprising upper and lower sections, pipe gripping means associated with the mandrel and expansible into holding engagement with the well pipe by upward movement of the mandrel with respect thereto, a carrier for said gripping means movable vertically on the upper section of the mandrel, a packer carried by the lower mandrel section, there being a well-fluid passage through the lower mandrel section and opening to the exterior of the plug at a point below the packer and at a point near the lower end of the carrier but above the packer.

10. In well pipe plug, a mandrel comprising upper and lower relatively vertically movable sections, pipe gripping means associated with the mandrel and expansible into holding engagement with the well pipe by upward movement of the mandrel with respect thereto, a carrier for said gripping means movable vertically on the upper section of the mandrel, a packer carried by the lower mandrel section, there being a well-fluid passage through the lower mandrel section and opening to the exterior of the plug at a point below the packer and at a point near the lower end of the carrier but above the packer.

11. In well pipe plug, a mandrel comprising an upper and lower relatively vertically movable section, pipe gripping means associated with the

mandrel and expansible into holding engagement with the well pipe by upward movement of the mandrel with respect thereto, a carrier connected to said gripping means and movable vertically on the upper section of the mandrel, a packer carried by the lower mandrel section, there being a well-fluid passage through the lower mandrel section and opening to the exterior of the plug at a point below the packer and at a point near the lower end of the carrier but above the packer, said lower mandrel section being movable upwardly relative to the upper mandrel section by well pressure to cause the packer to expand.

12. In well pipe plug, a mandrel comprising upper and lower sections, pipe gripping means associated with the mandrel and expansible into holding engagement with the well pipe by upward movement of the mandrel with respect thereto, a carrier for said gripping means movable vertically on the upper section of the mandrel, a packer carried by the lower mandrel section, said lower mandrel section having an open fluid passing bore for passing well fluid upwardly through the plug past the packer, and means detachably connecting said mandrel sections whereby the lower section may be replaced by a section of different bore size.

13. In well pipe plug, a mandrel comprising upper and lower sections, pipe gripping means associated with the mandrel and expansible into holding engagement with the well pipe by upward movement of the mandrel with respect thereto, a carrier for said gripping means movable vertically on the upper section of the mandrel, a packer carried by the lower mandrel section, said lower mandrel section having an open fluid passing bore opening at its lower end to the exterior of the plug for passing well fluid upwardly through the plug past the packer, there being a side port in the lower mandrel section near its upper end for discharging fluid from said bore through the side of the mandrel at a point intermediate its ends and above the packer, and means detachably connecting said mandrel sections whereby the lower section may be replaced by a section of different bore size.

14. In well pipe plug, a mandrel comprising upper and lower sections, pipe gripping means associated with the mandrel and expansible into holding engagement with the well pipe by upward movement of the mandrel with respect thereto, a carrier for said gripping means movable vertically on the upper section of the mandrel, a packer carried by the lower mandrel section, and there being a passage through the lower mandrel section and through which well liquid flows upwardly within the lower mandrel section and is discharged into the well pipe through an opening in the side of the mandrel at a point above the packer, and a barrier in the passage above the opening and adapted to divert fluid flow through said opening.

15. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug including relatively vertically movable body and mandrel sections, a releasable connection between the setting tool and one of the sections, pipe gripping means expansible into holding engagement with the pipe by relative vertical movement of said sections in one direction, means for locking said sections against relative movement in an opposite direction after expansion of said gripping means and means positively locking said releasable connection until said sections have been locked.

16. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug including relatively vertically movable body and mandrel sections, a releasable connection between the setting tool and one of the sections, pipe gripping means expansible into holding engagement with the pipe by relative vertical movement of said sections in one direction, means for locking said sections against relative movement in an opposite direction after expansion of said gripping means, means positively locking said releasable connection until said sections have been locked, and means acting to release said last mentioned locking means and to free the setting tool from said one section upon upward movement of the setting tool after said sections have been locked.

17. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug including relatively vertically movable body and mandrel sections, a releasable connection between the setting tool and one of the sections, pipe gripping means expansible into holding engagement with the pipe by relative vertical movement of said sections in one direction, means for locking said sections against relative movement in an opposite direction after expansion of said gripping means, means positively locking said releasable connection until said sections have been locked, and means acting to release said last mentioned locking means and to free the setting tool from said one section upon upward movement of the setting tool after said sections have been locked; said setting tool being subsequently re-engageable with said one section, while the plug is still in the pipe, to restore the releasable connection, and to unlock the sections, all by a direct lowering movement of the suspension means.

18. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug including relatively vertically movable body and mandrel sections, a releasable connection between the setting tool and one of the sections, pipe gripping means expansible into holding engagement with the pipe by relative vertical movement of said sections in one direction, means for locking said sections against relative movement in an opposite direction after expansion of said gripping means, means positively locking said releasable connection until said sections have been locked, and means acting to release said last mentioned locking means and to free the setting tool from said one section upon upward movement of the setting tool after said sections have been locked; said setting tool being subsequently re-engageable with said one section, while the plug is still in the pipe, to restore the releasable connection, to unlock the sections, and to release the gripping means, all by a direct lowering movement of the suspension means.

19. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug including relatively vertically movable body and mandrel sections, a releasable connection between the setting tool and one of the sections, a packer expansible into holding engagement with the pipe by relative vertical movement of said sections in one direction, means for locking said sections against relative movement in an opposite direction after expansion of said packer, and means positively locking said releasable connection until said sections have been locked.

20. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspen-

sion means, a plug including relatively vertically movable body and mandrel sections, a releasable connection between the setting tool and one of the sections, a packer expansible into holding engagement with the pipe by relative vertical movement of said sections in one direction, means for locking said sections against relative movement in an opposite direction after expansion of said packer, means positively locking said releasable connection until said sections have been locked, and means acting to release said last mentioned locking means and to free the setting tool from said one section upon upward movement of the setting tool after said sections have been locked.

21. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug including relatively vertically movable body and mandrel sections, a releasable connection between the setting tool and one of the sections, a packer expansible into holding engagement with the pipe by relative vertical movement of said sections in one direction, means for locking said sections against relative movement in an opposite direction after expansion of said packer, means positively locking said releasable connection until said sections have been locked, and means acting to release said last mentioned locking means and to free the setting tool from said one section upon upward movement of the setting tool after said sections have been locked; said setting tool being subsequently re-engageable with said one section, while the plug is still in the pipe, to restore the releasable connection and to unlock the sections, and to release the packer all by a direct lowering movement of the suspension means.

22. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug embodying a pair of members associated in a manner adapting them for relative vertical movement, pipe gripping means and a packer associated with said members and adapted to be operated into and out of tight engagement with said pipe by virtue of relative vertical movement of said members in opposite directions, a locking element associated with said members and movable, at times, vertically with respect thereto, a pair of latches, one acting between the lowering tool and said element, and the other acting between said element and, at times, both said members, said latches initially locking the lowering tool and one of said members against relative vertical movement whereby, after the plug is lowered to a predetermined position, the raising of the lowering tool sets up relative vertical movement of the members in a direction to operate the gripping means and packer into tight engagement with the pipe, means effective by continued upward movement of the lowering tool to operate said other latch to lock the members against opposite relative movement and to release said locking element whereby it is moved, by a continuation of the upward movement of the lowering means, to a position releasing said one latch, all in a manner whereby a continued upward movement of the lowering tool lifts the lowering tool clear of the plug.

23. The combination comprising a setting tool adapted to be lowered in a well pipe on a suspension means, a plug embodying a pair of members associated in a manner adapting them for relative vertical movement, pipe gripping means and a packer associated with said members and adapted to be operated into and out of tight engagement with said pipe by virtue of relative vertical movement of said members in opposite directions, a locking element associated with said members and movable, at times, vertically with respect thereto, a pair of latches, one acting between the lowering tool and said element, and the other acting between said element and, at times, both said members, said latches initially locking the lowering tool and one of said members against relative vertical movement whereby, after the plug is lowered to a predetermined position, the raising of the lowering tool sets up relative vertical movement of the members in a direction to operate the gripping means and packer into tight engagement with the pipe, means effective by continued upward movement of the lowering tool to operate said other latch to lock the members against opposite relative movement and to release said locking element whereby it is moved, by a continuation of the upward movement of the lowering means, to a position releasing said one latch, all in a manner whereby a continued upward movement of the lowering tool lifts the lowering tool clear of the plug; said lowering tool being subsequently re-engageable with the plug while it remains in the pipe to successively move said latching element downwardly to relock said one latch, release said other latch, set up relative vertical movement between the members in an opposite direction to free the gripping means and packer from the pipe, and relock said other latch.

25. In a well pipe plug, a mandrel, pipe gripping means associated with the mandrel intermediate the ends thereof, said means being expansible into holding engagement with the pipe by vertical movement of the mandrel with respect thereto, there being a well fluid passage in said mandrel and opening to one end thereof, and there being an opening from said passage to the exterior of the plug at a point adjacent said gripping means.

26. In a well pipe plug, a mandrel, pipe gripping means associated with the mandrel intermediate the ends thereof, said means being expansible into holding engagement with the pipe by vertical movement of the mandrel with respect thereto, a packer on the mandrel below the pipe gripping means, there being a well fluid passage in said mandrel opening to the exterior of the plug at a point below the packer and at a point adjacent said gripping means and above the packer.

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