United States Patent

[11] 3,580,332

[72] Inventors **Michael R. Dean; Luis F. Castro, Houston, Tex.; John V. Salerni, Whittier, Calif.**

[21] Appl. No. **15,403**
[22] Filed **Mar. 2, 1970**
[45] Patented **May 25, 1971**
[73] Assignee **Baker Oil Tools, Inc. Commerce, Calif.**

[54] **APPARATUS FOR CONTROLLING FLUID FLOW FROM GAS STORAGE WELLS AND RESERVOIRS**
23 Claims, 49 Drawing Figs.

[52] **U.S. Cl.** **166/184,** 166/151
[51] **Int. Cl.** **E21b 33/12**
[50] **Field of Search** 166/131, 151, 184, 224

[56] **References Cited**

UNITED STATES PATENTS

3,310,114	3/1967	Dollison	166/224
3,356,145	12/1967	Fredd	166/224
3,361,212	1/1968	Page, Jr.	166/224
3,433,303	3/1969	Clark, Jr. et al.	166/184

Primary Examiner—James A. Leppink
Attorney—Bernard Kriegel

ABSTRACT: A retrievable packer with a large passage area and control valve connected thereto are run and set in a cased well bore. A plug is set in the valve, after which a tubing is connected to the plug and fluid pressure applied thereto to open the valve so that gas from the well or reservoir can flow through the packer and opened valve into the tubing-casing annulus and into a gas delivery line at the top of the well bore. The valve is tapered to provide a greater annular area between it and the well casing to allow unrestricted flow of gas from the well at a very high rate. In the event of damage to the surface equipment, the well pressure automatically closes the control valve. The valve can be closed whenever desired and the tubing string removed, after which the plug and control valve and packer are removable from the well casing through use of wireline equipment, and without the necessity for "killing" the well.

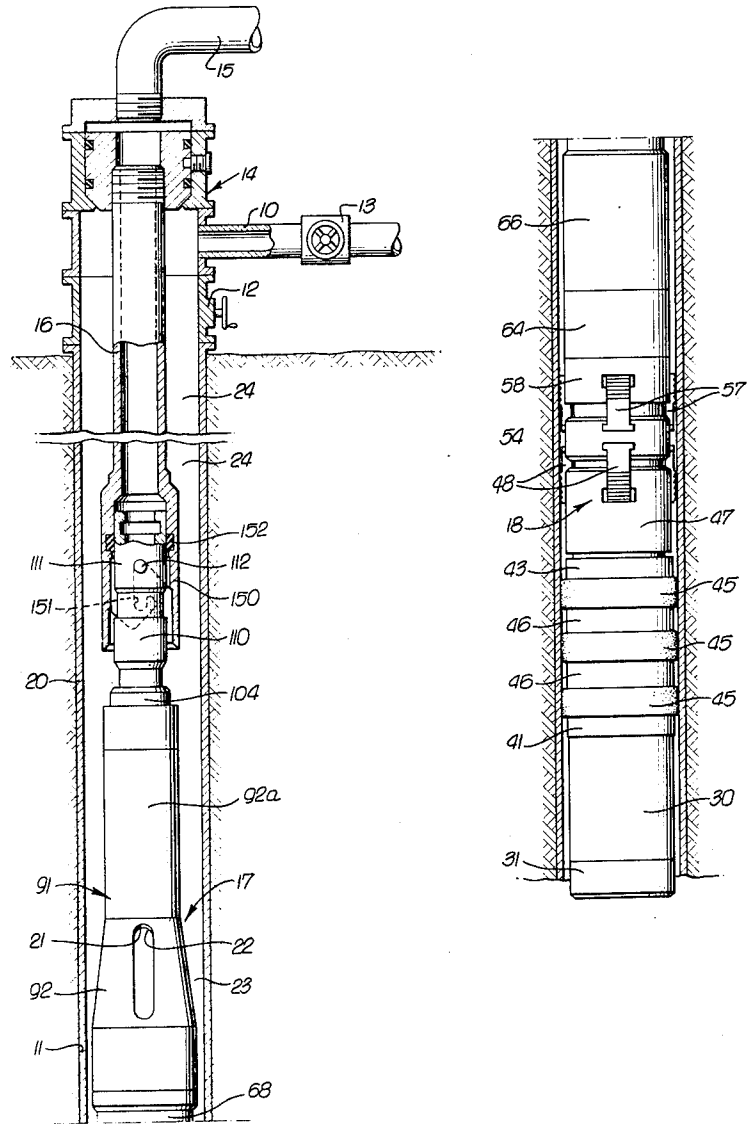

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FIG. 1a.

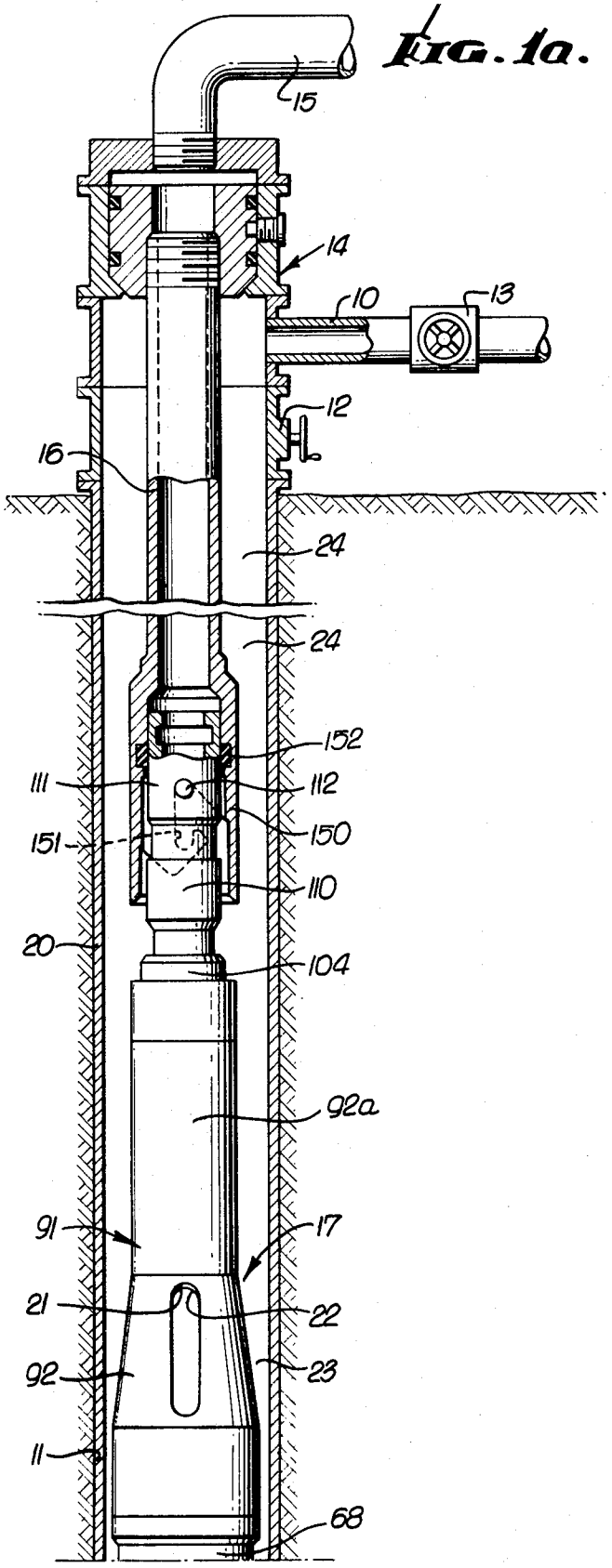

FIG. 1b.

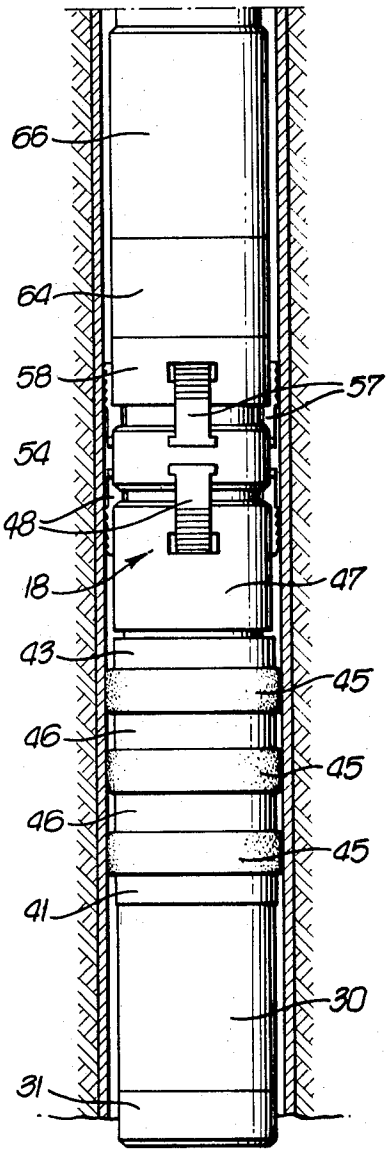

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FIG. 2.

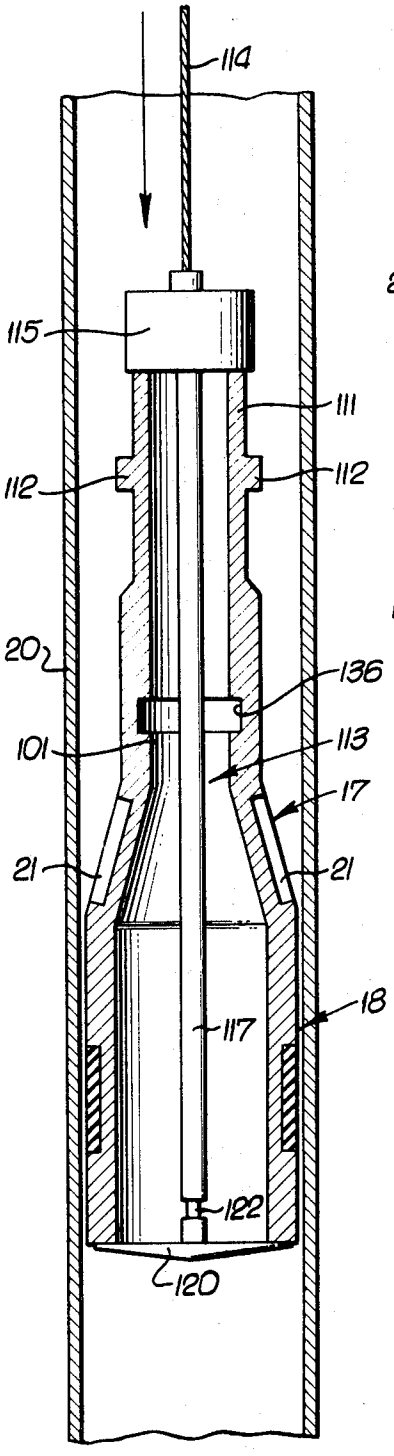

FIG. 3.

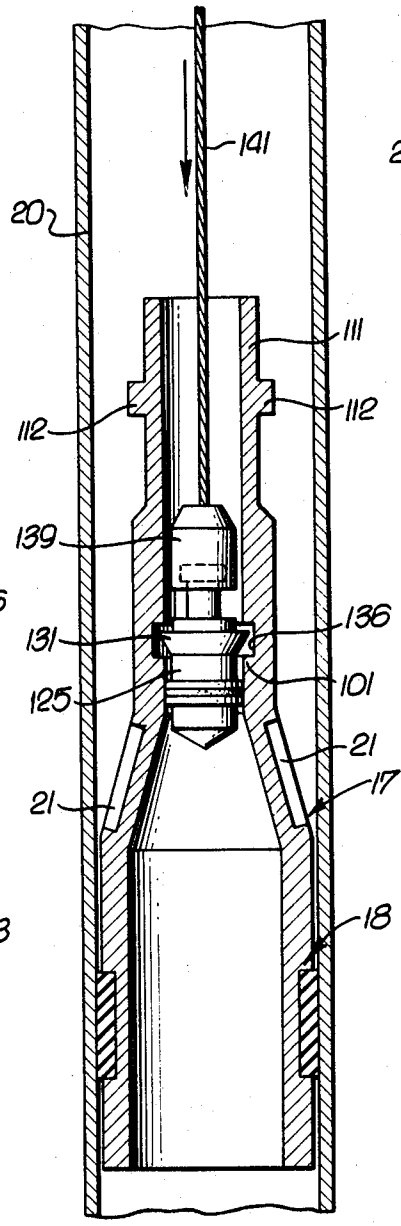

FIG. 4.

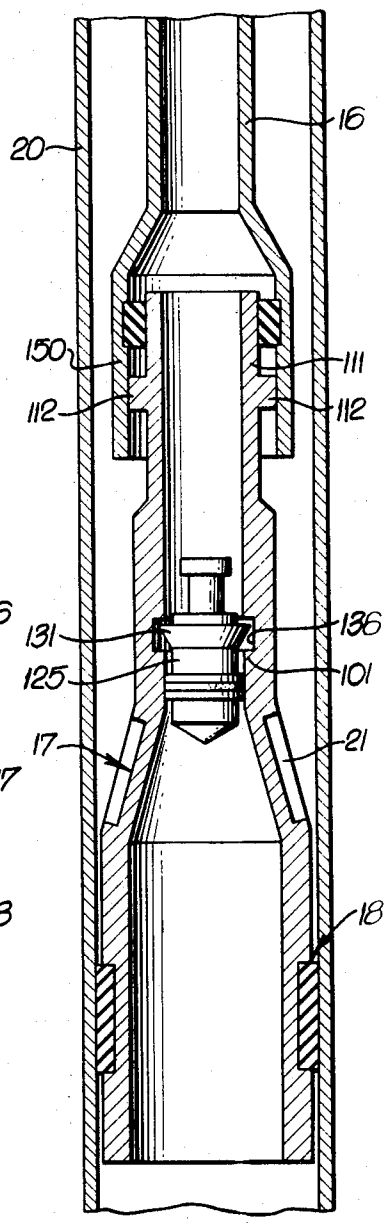

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FIG. 5.

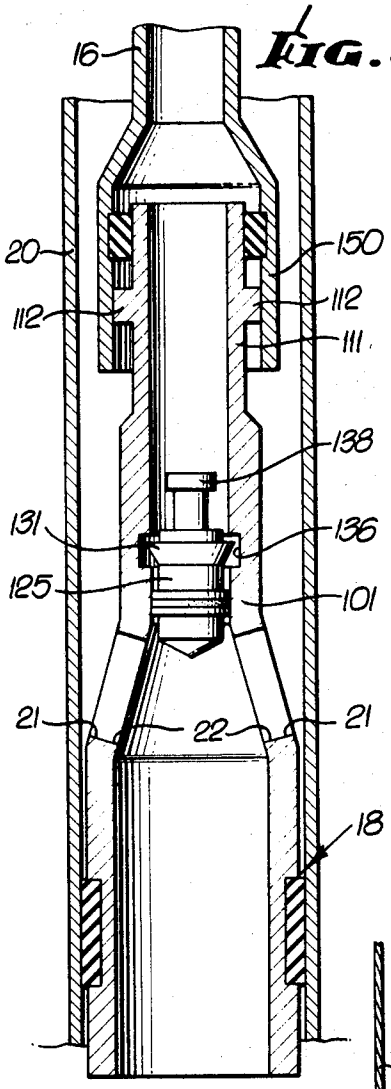

FIG. 6.

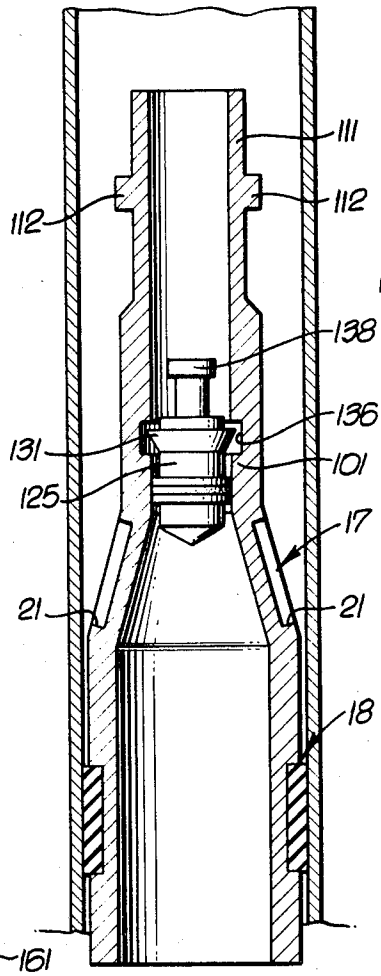

FIG. 8.

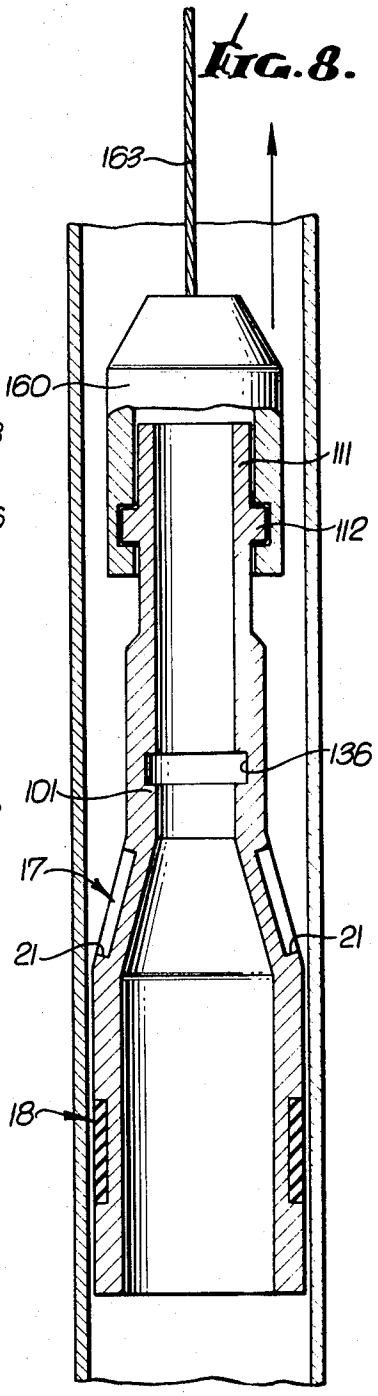

FIG. 7.

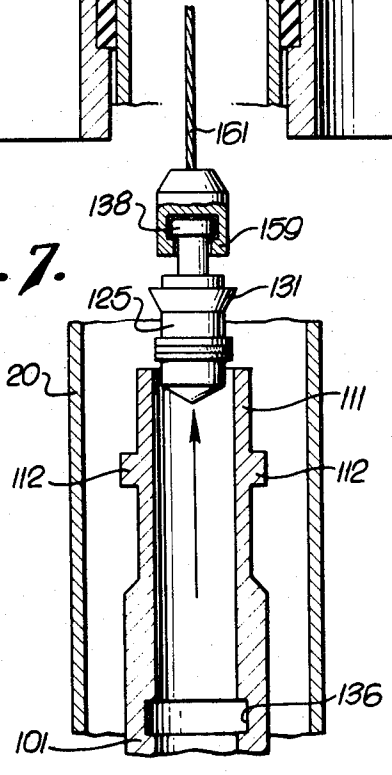

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FIG. 9a.

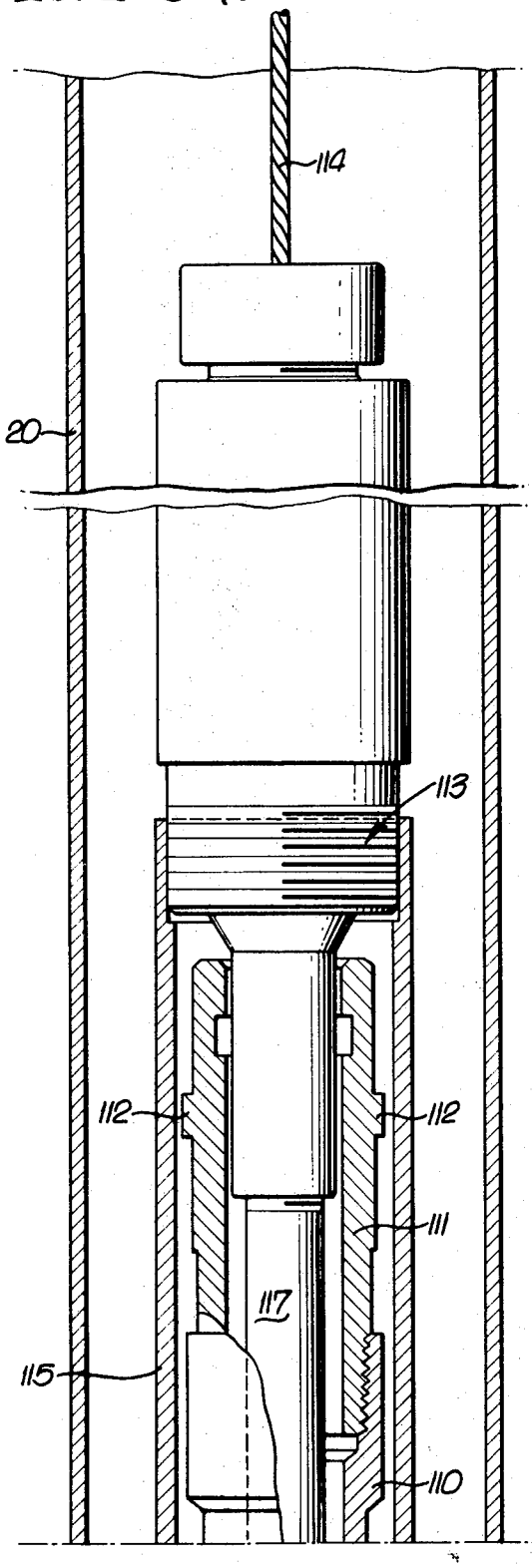

FIG. 9b.

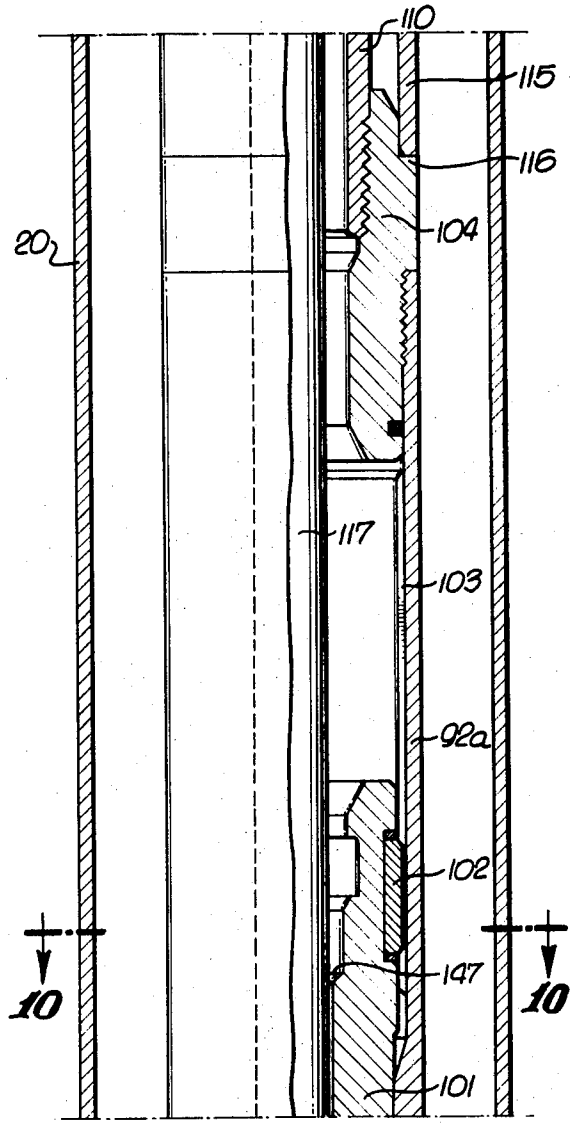

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FIG. 9c.

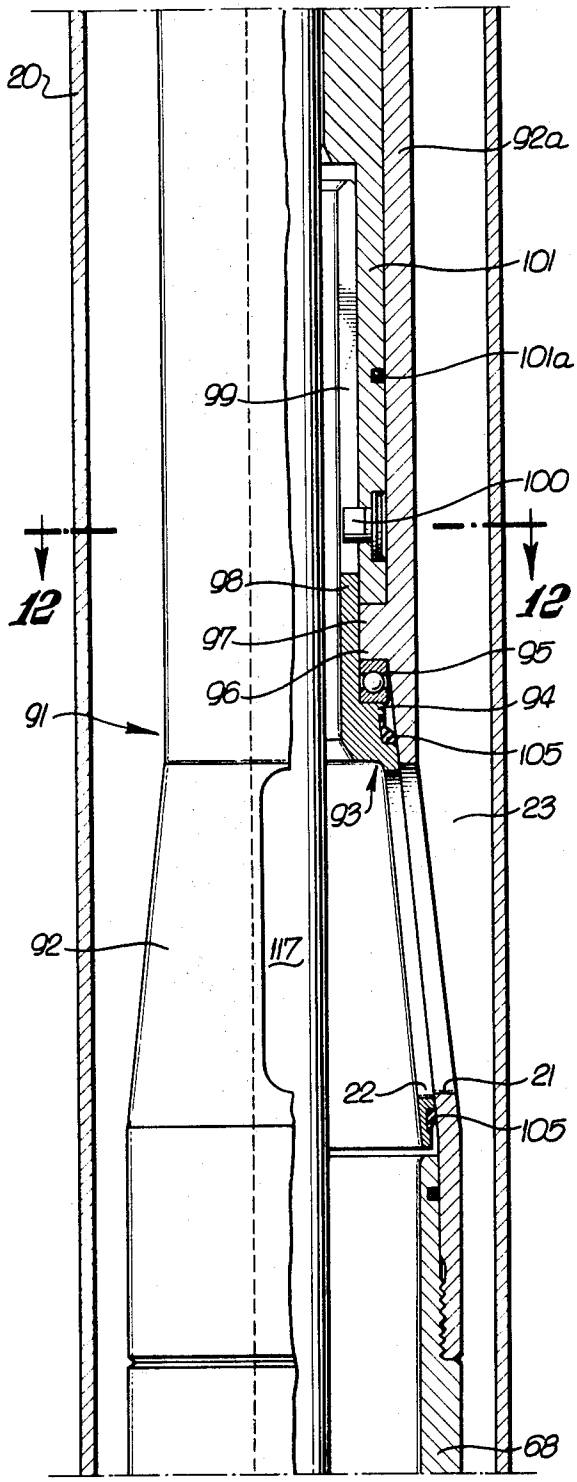


FIG. 10.

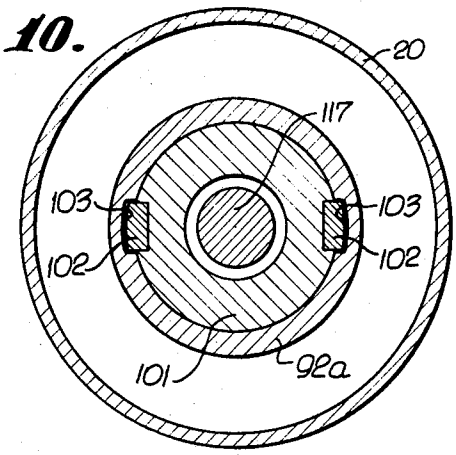
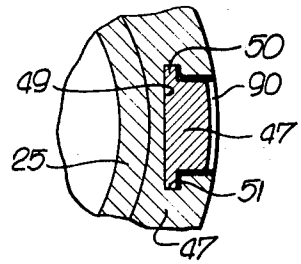


FIG. 11.



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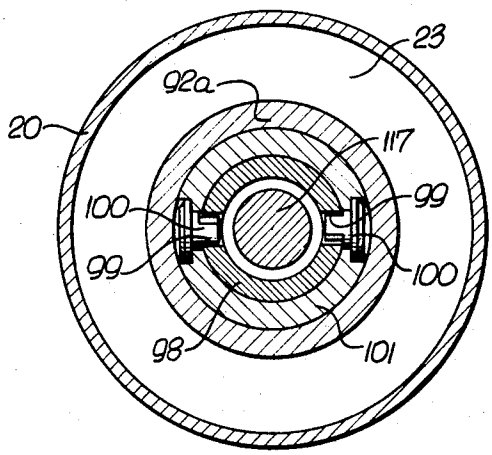

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FIG. 9d.

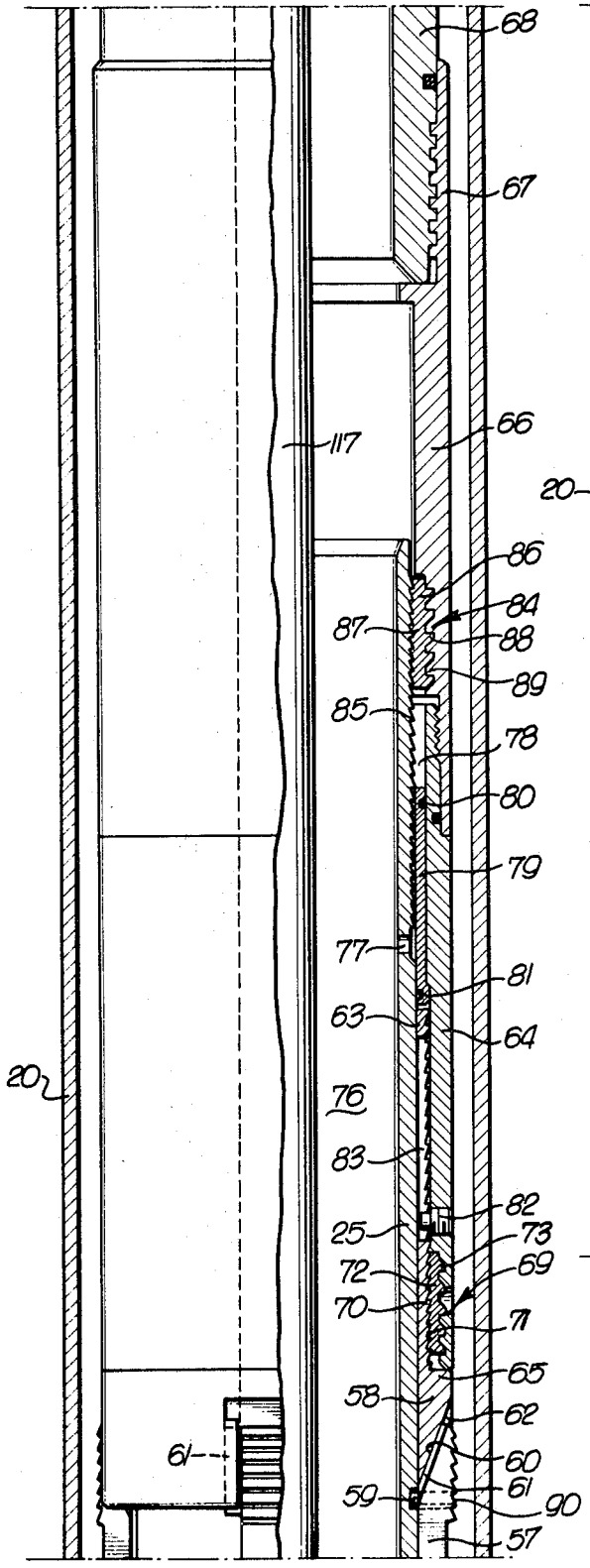

FIG. 9e.

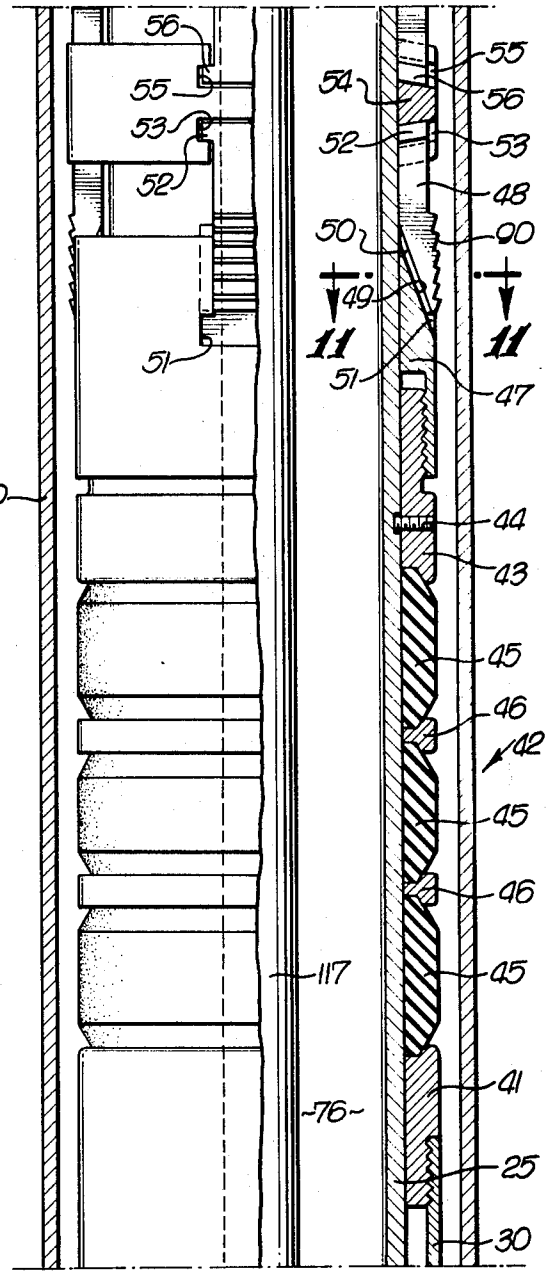

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FIG. 9f.

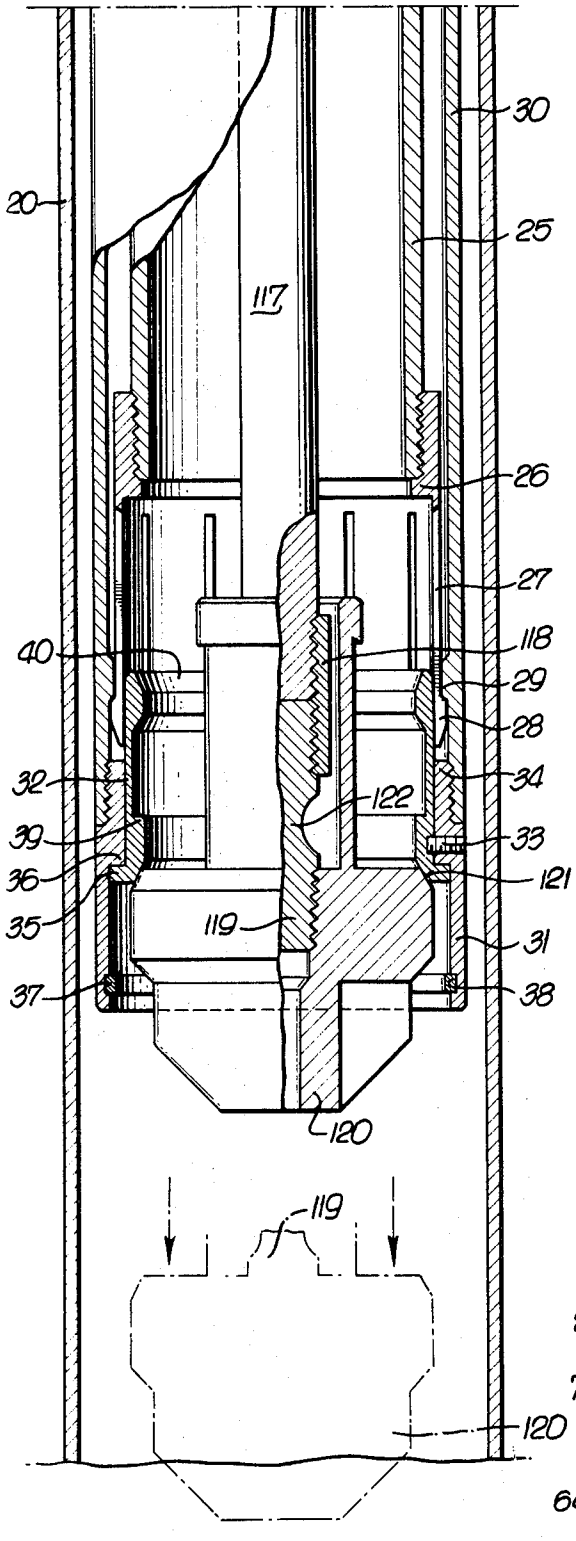

FIG. 13a.

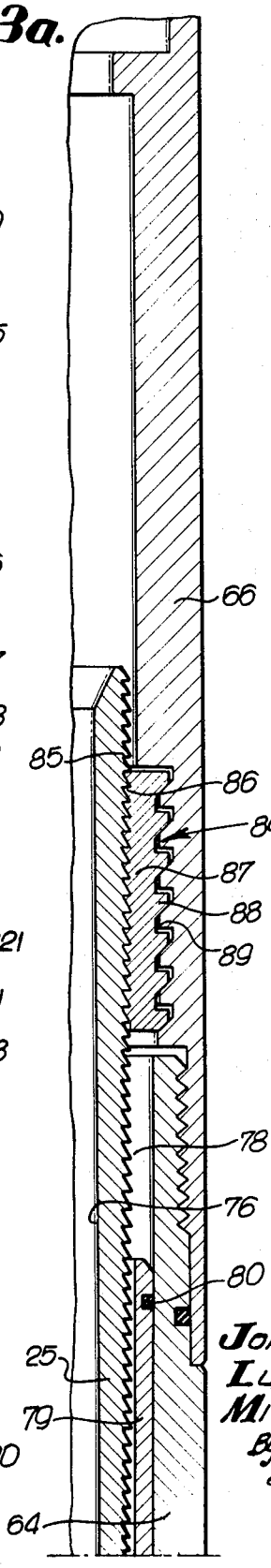

FIG. 13b.

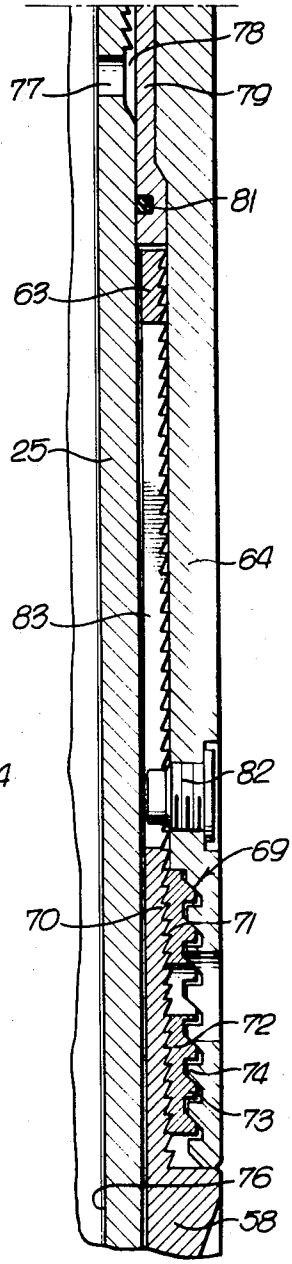

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FIG. 14a.

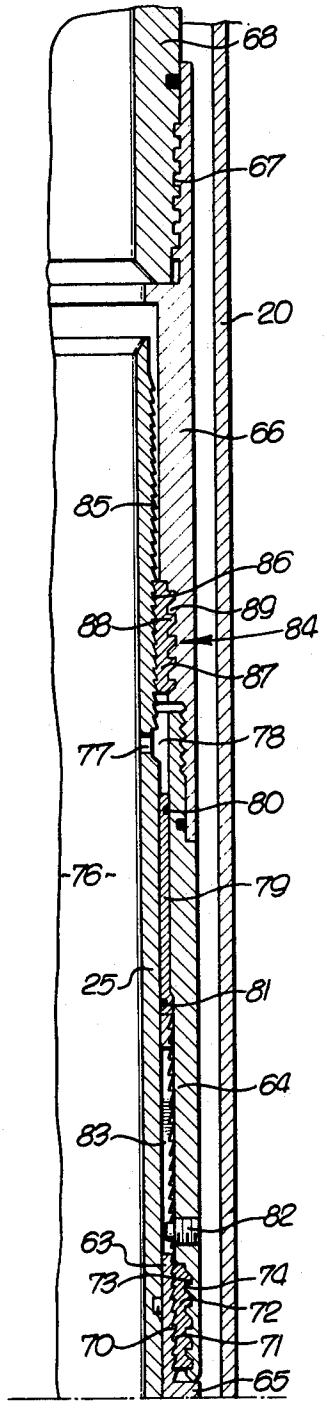

FIG. 14b.

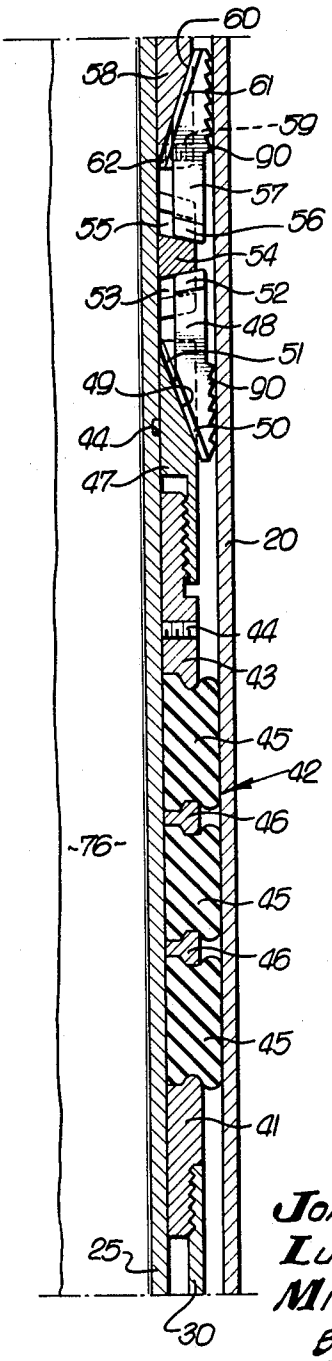

FIG. 14c.

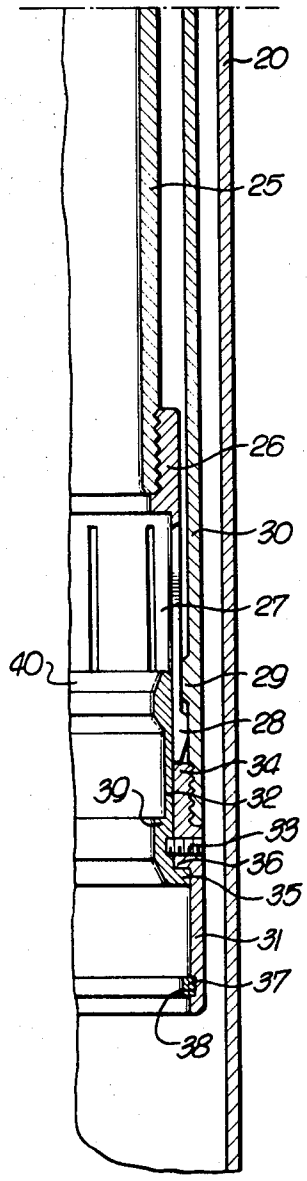

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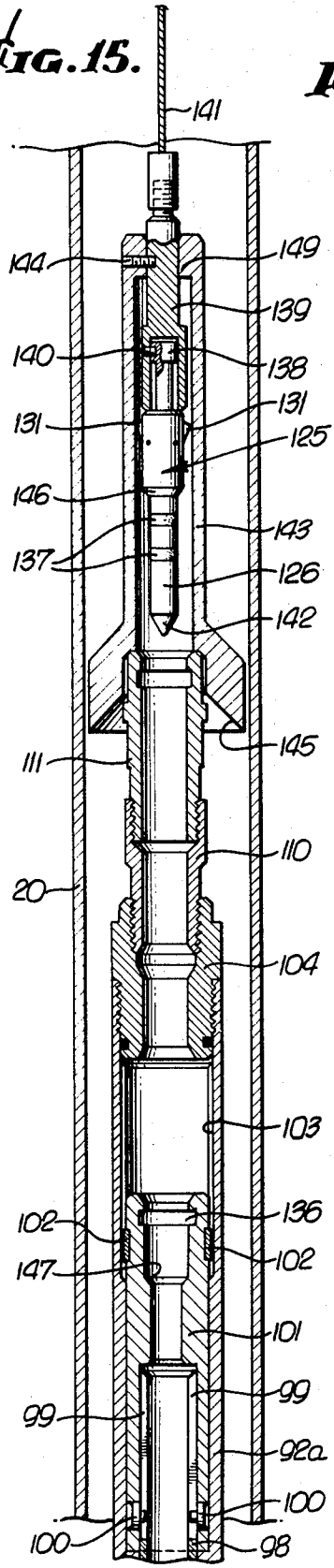
FIG. 15.



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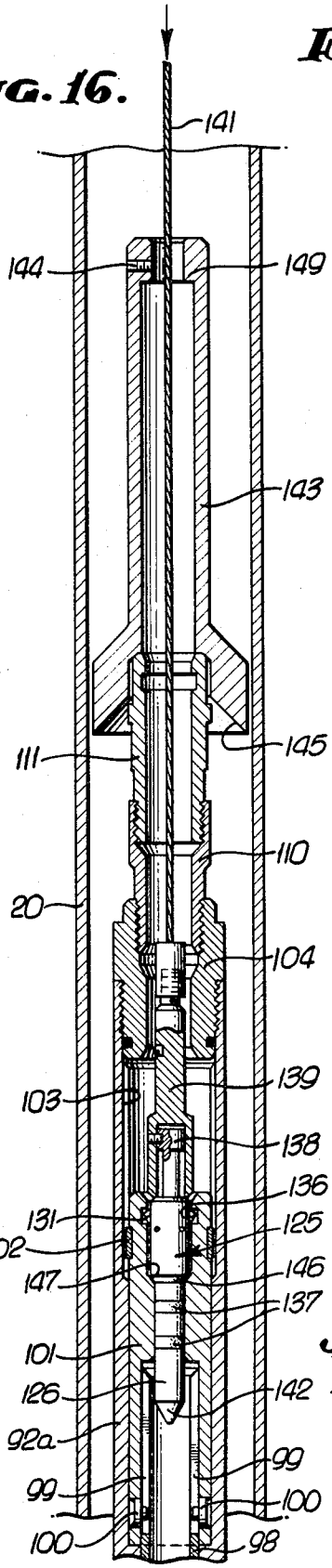

FIG. 17.

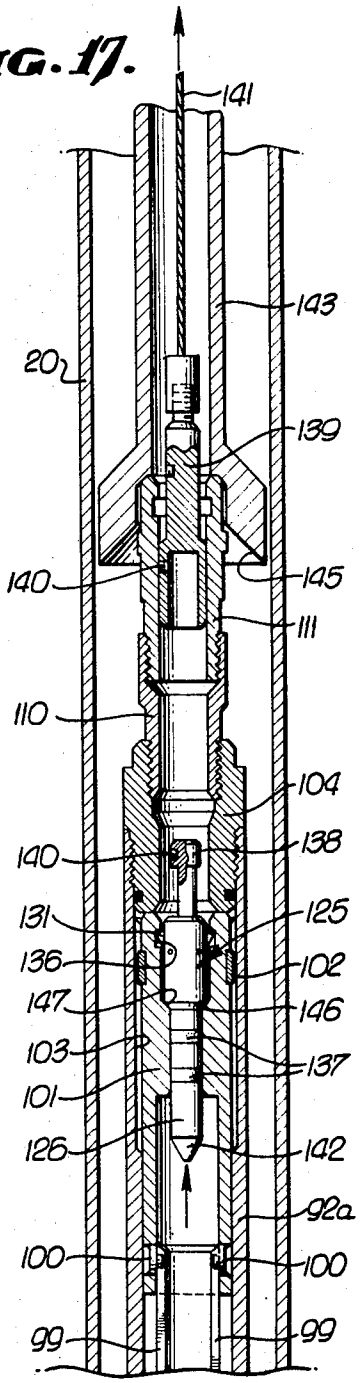

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FIG. 18a.

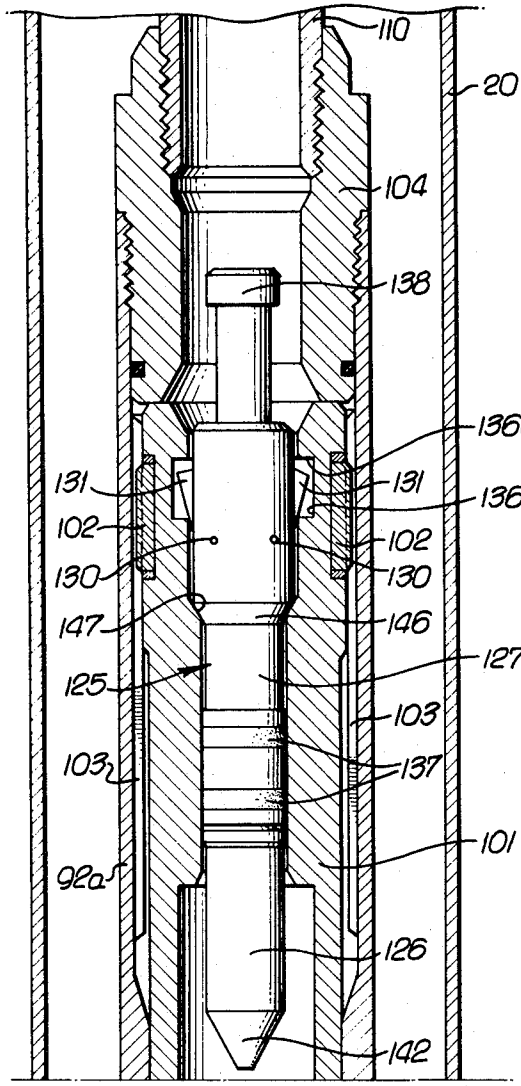
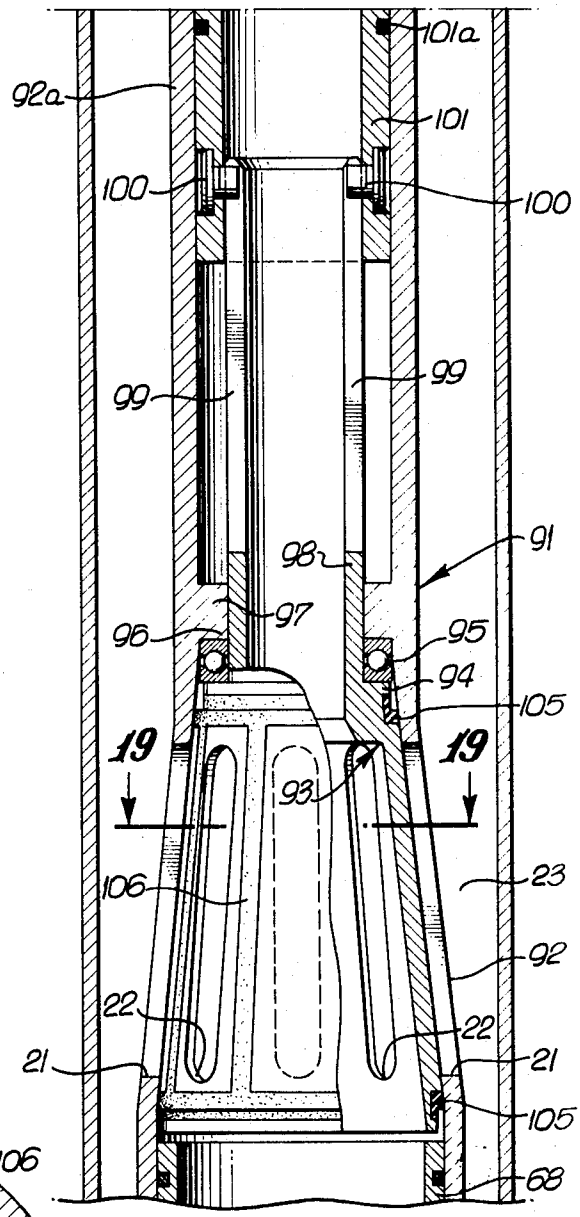


FIG. 18b.



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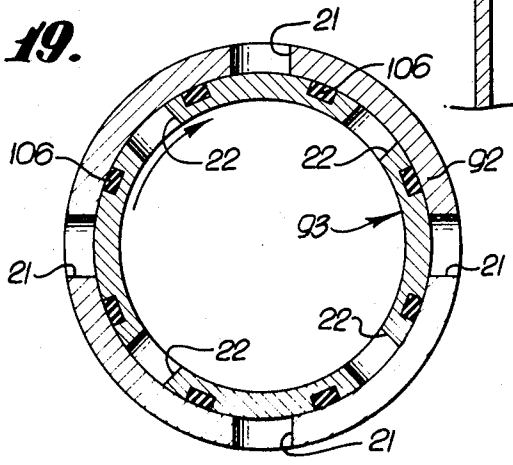

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FIG. 20a.

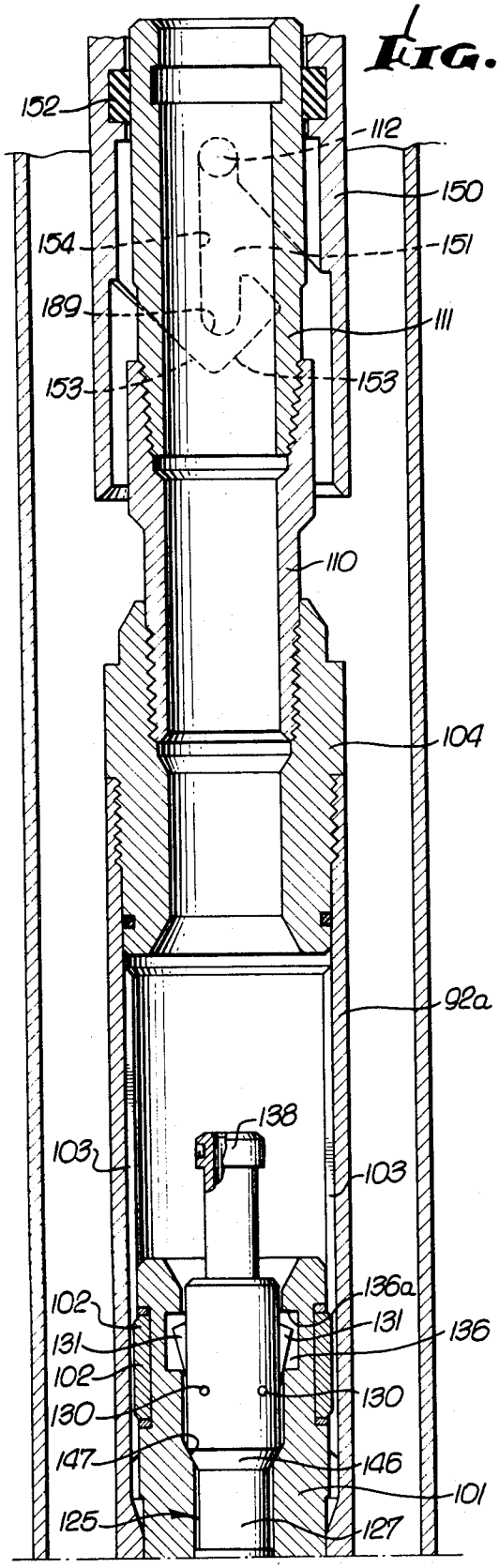

FIG. 20b.

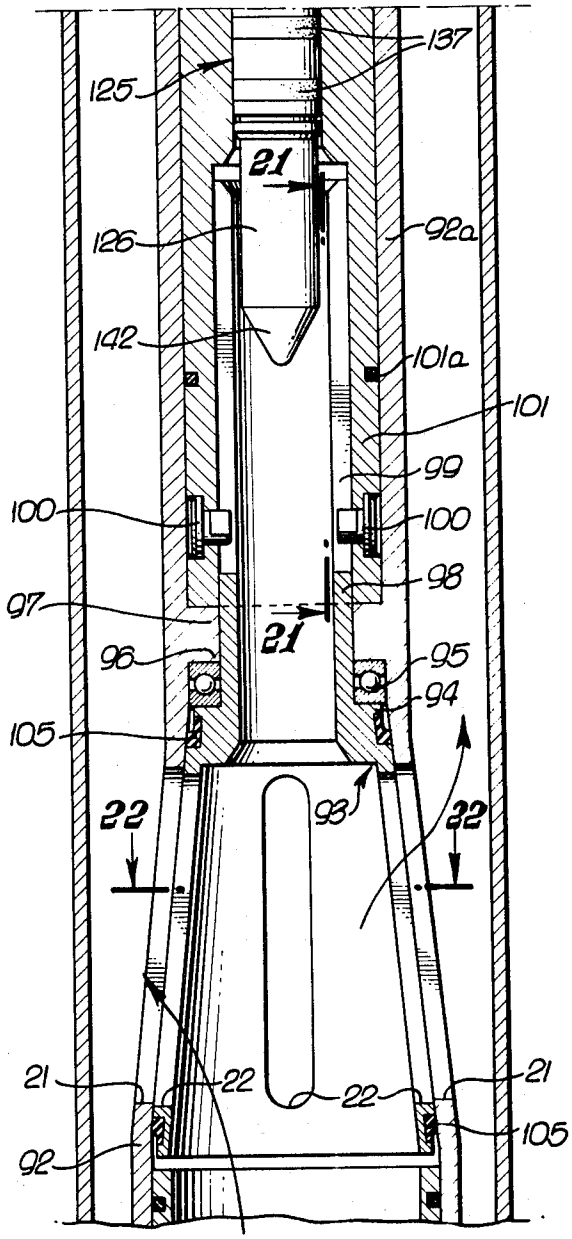

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FIG. 23.

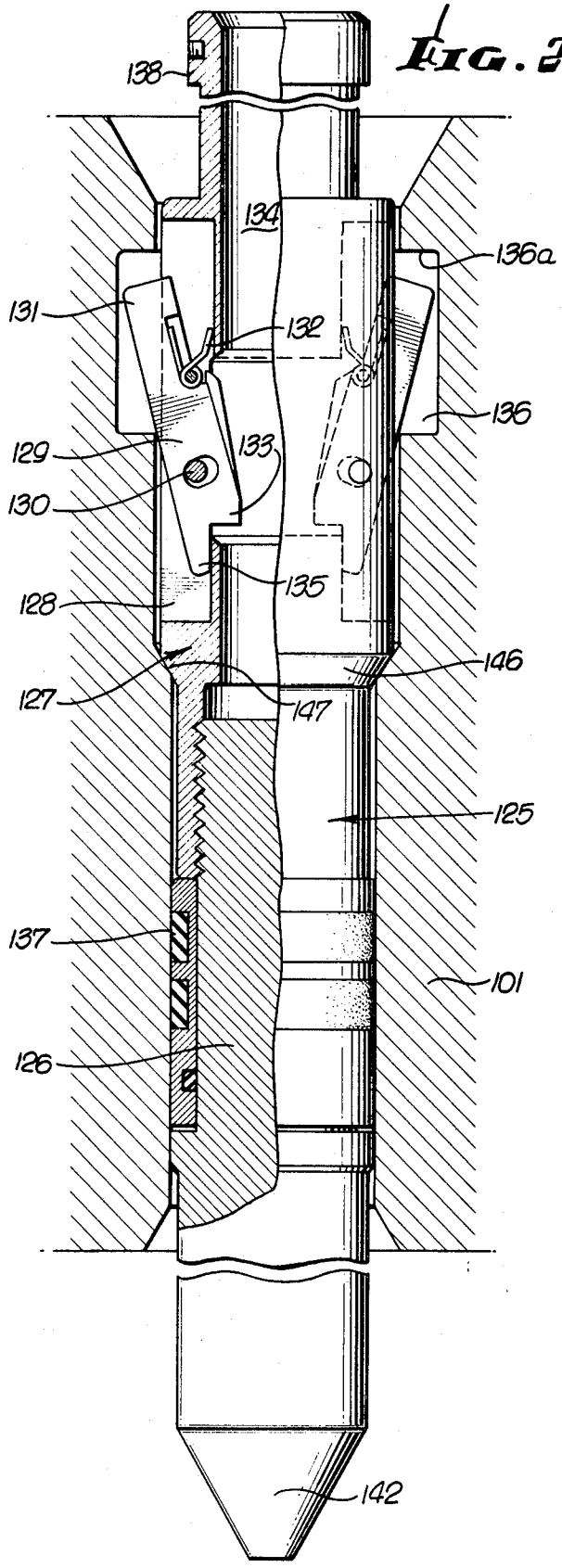

FIG. 21.

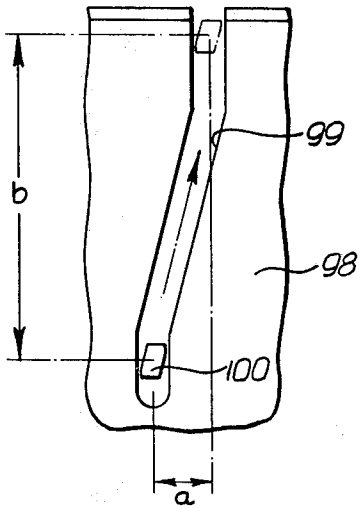

FIG. 22.

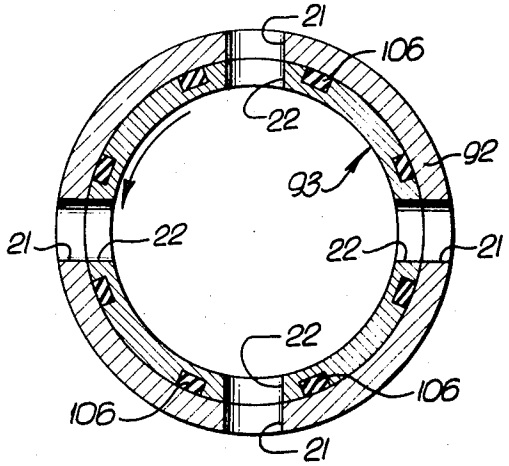

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FIG. 24.

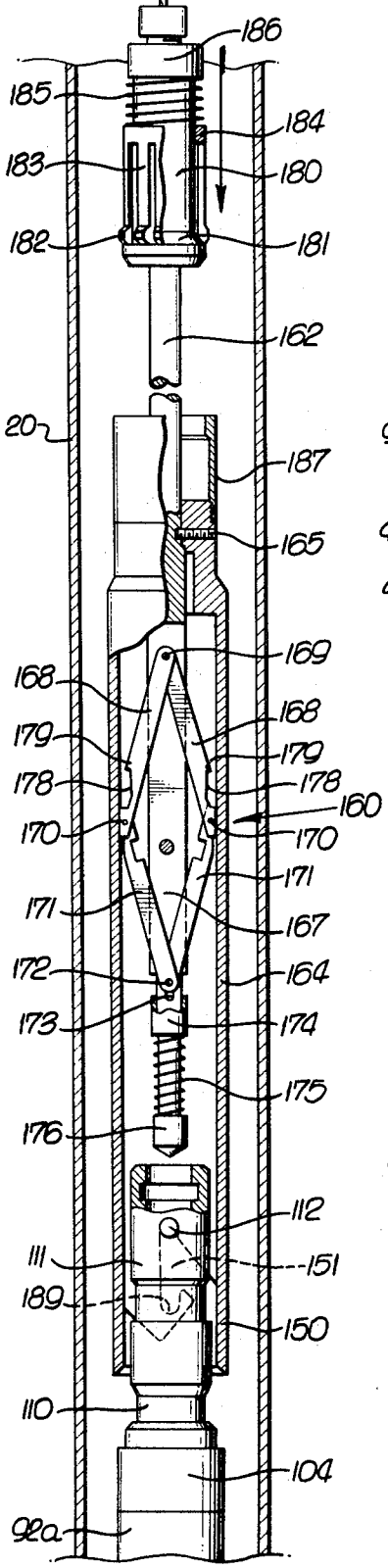

FIG. 29.

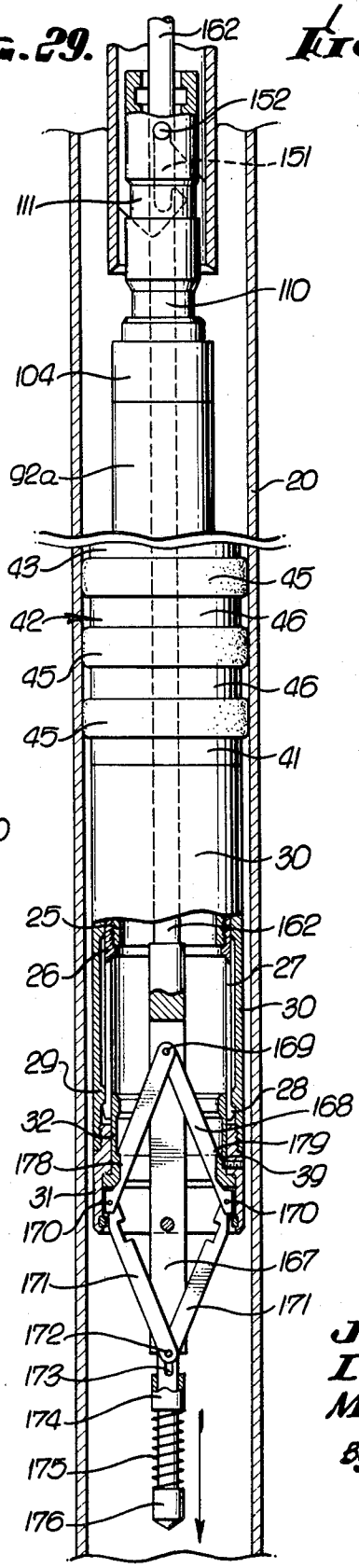

FIG. 31.

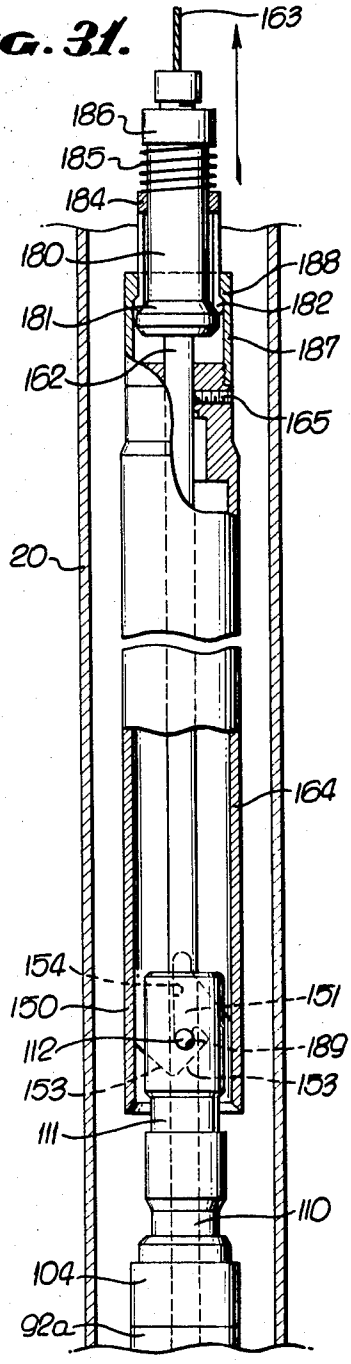

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FIG. 25.

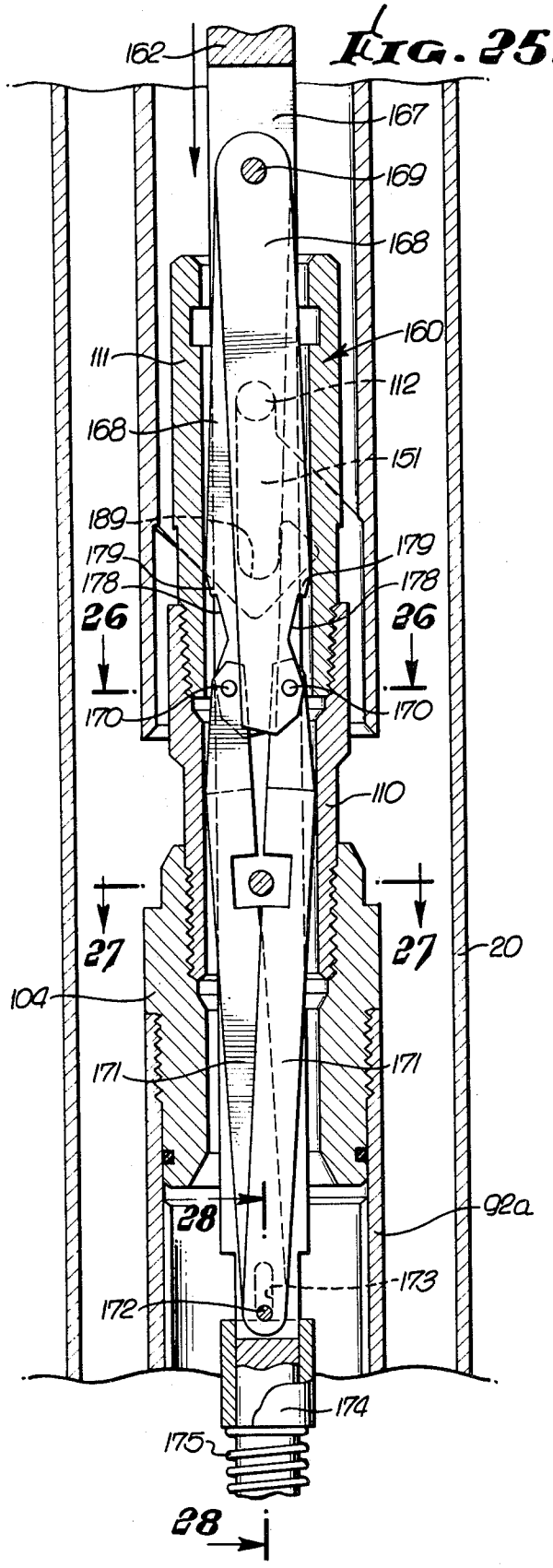

FIG. 26.

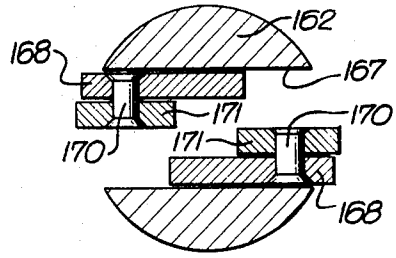

FIG. 27.

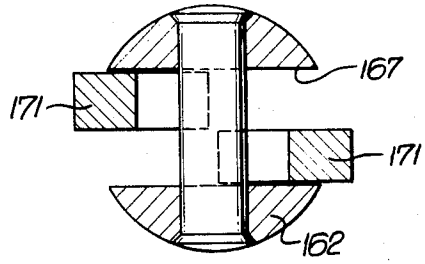

FIG. 28.

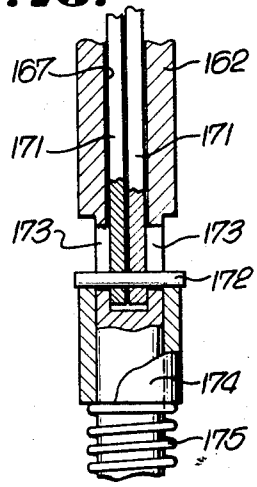

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FIG. 30a.

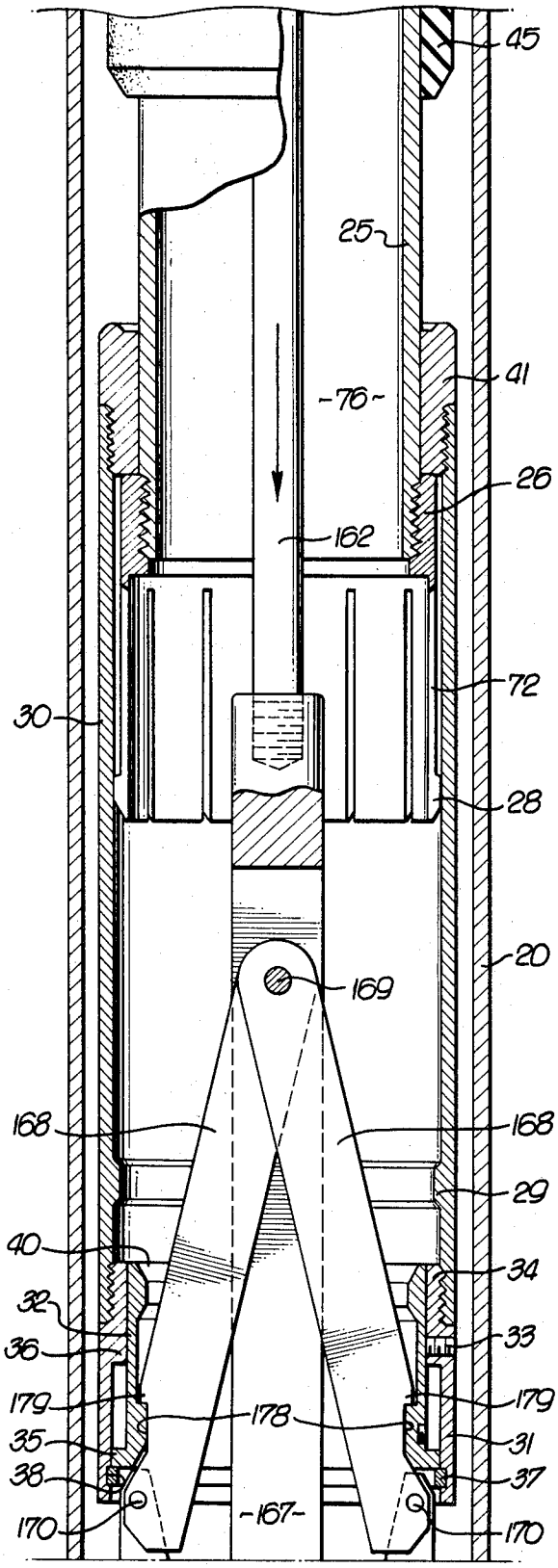

FIG. 30b.

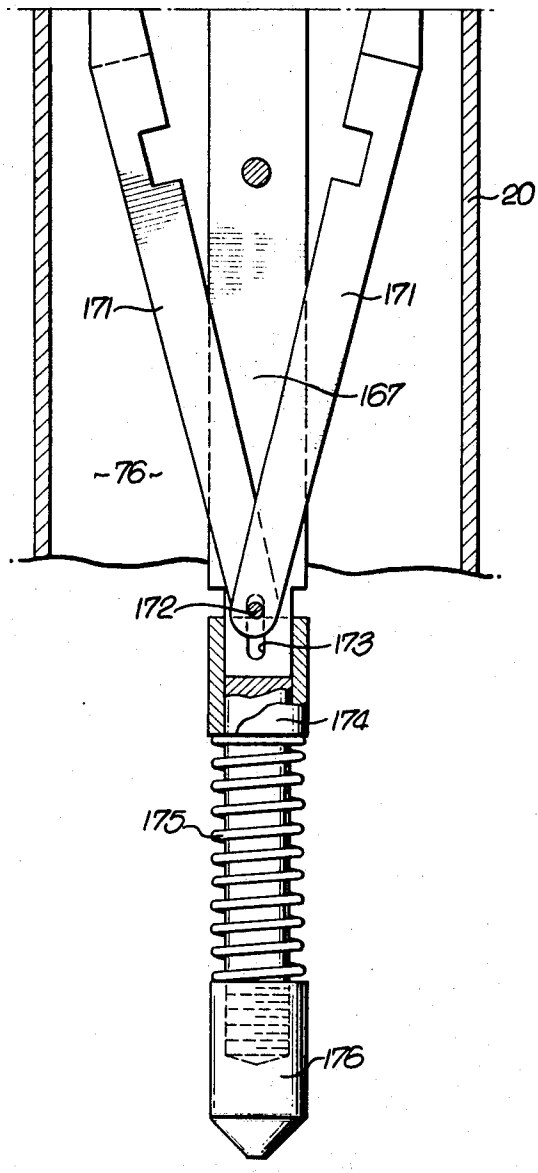

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FIG. 32a.

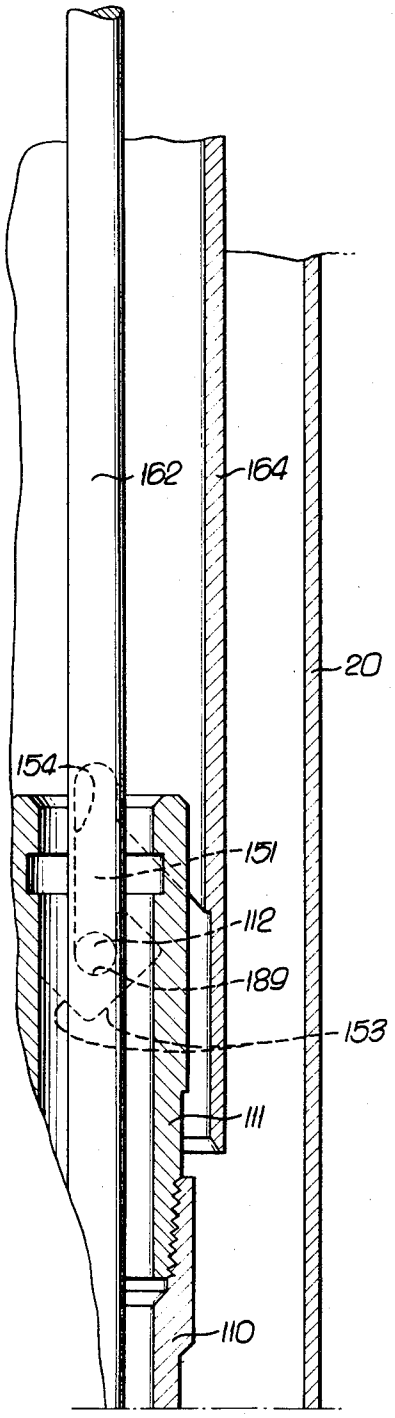

FIG. 32b.

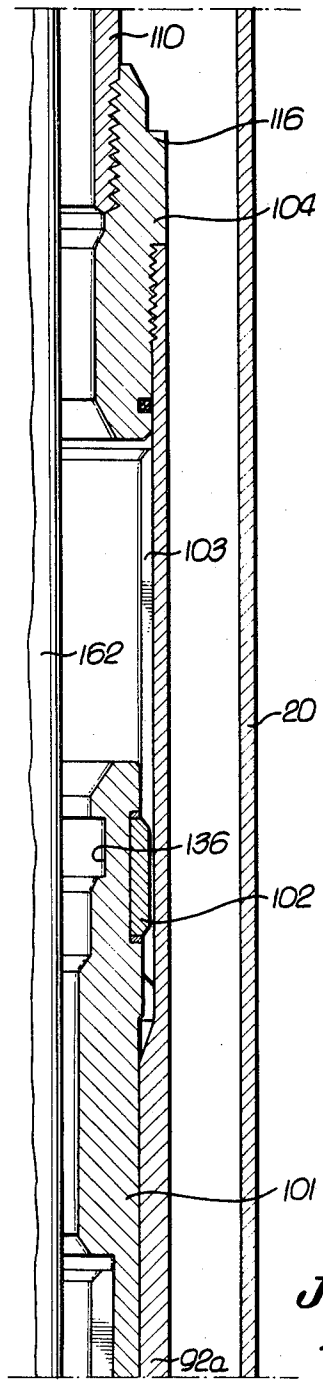

FIG. 32c.

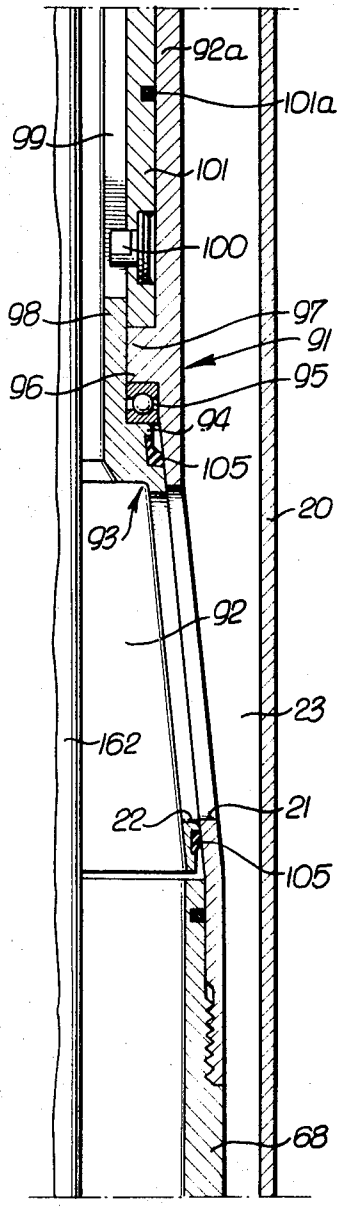

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FIG. 32d.

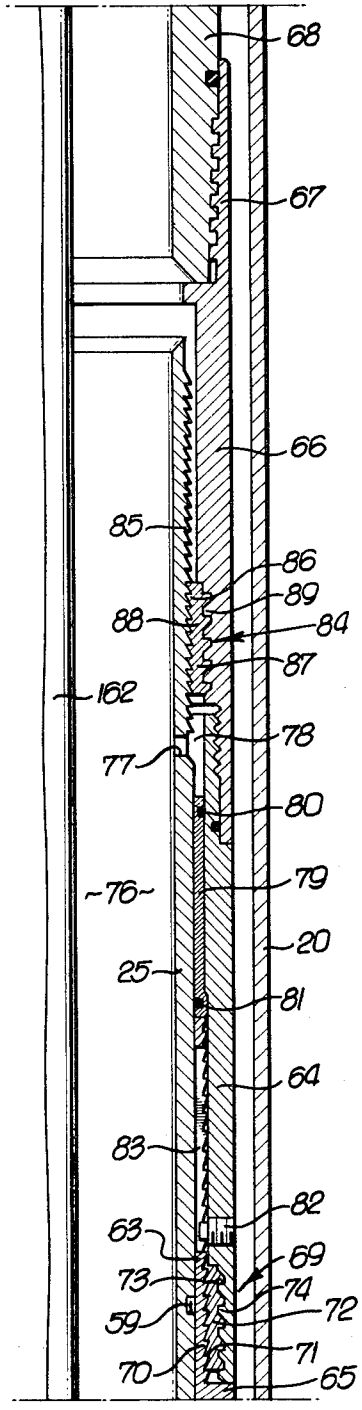


FIG. 32e.

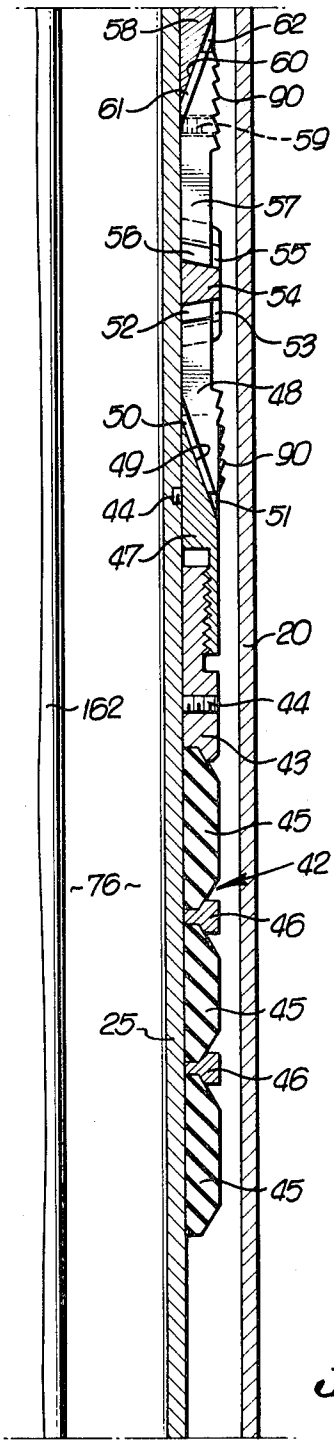
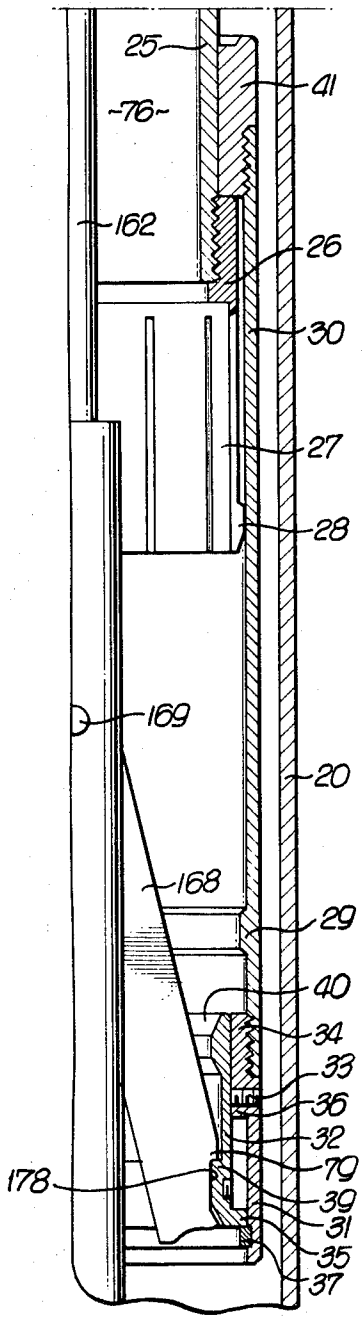


FIG. 32f.



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APPARATUS FOR CONTROLLING FLUID FLOW FROM GAS STORAGE WELLS AND RESERVOIRS

The present invention relates to well bore apparatus, and more particularly to subsurface apparatus for controlling the flow of fluid between the well bore and reservoir communicating therewith and the top of the well bore.

Prior devices are known for automatically shutting off fluid flow from a well bore in the event of damage to the surface connections, as, for example, to the wellhead or to a delivery pipe line. If gas is being produced from a gas well or underground gas storage reservoir, disruption of the surface connections will be accompanied by a substantial drop in gas pressure and thereby effect automatic closure of a safety valve disposed in the well bore. In connection with gas storage wells, it is necessary to withdraw gas at a very high rate during peak demand periods. However, prior devices embodying subsurface safety shutoff valves have had insufficient flow area therethrough, and between such devices and the well casing in which they are located, imposing severe restrictions on the rate at which the gas can flow. As an example, in the U.S. Pat. application of Gonzalo Vasquez and John V. Salerni, Ser. No. 752,366, filed Aug. 13, 1968, for "Disaster Valve," a sleeve valve is disclosed to which a plug can be latched for the purpose of closing the passage therethrough, such that a predetermined gas pressure differential can shift the sleeve valve longitudinally of an associated valve housing for the purpose of shutting off the valve. However, the valve housing or body is comparatively close to the wall of the surrounding well casing, reducing the annular area through which the gas can flow, such gas proceeding upwardly through a tubing-casing annulus to the delivery line at the top of the well bore.

In prior equipment, such as that exemplified in the above-identified patent application, it is desirable to employ a well packer having a maximum flow passage therethrough. However, the advantages of a large flow passage through the packer are nullified to some extent by the restriction that the safety shutoff valve offers to the flow of fluid into the tubing-casing annulus. Moreover, in the prior devices it has not been possible to run the well packer and safety valve in the well casing, or to retrieve such parts from the well casing, without "killing" the well; that is, filling the well bore with heavy drilling mud, or the like. The "killing" of a well is costly, and is associated with the possibility of damage to the well bore and the reservoir.

By virtue of apparatus embodying the present invention, the well packer and safety valve can be both run in and retrieved from the well casing without "killing" the well, and under safe conditions. Accordingly, expense and possible damage to the well bore and reservoir are avoided. In addition, the safety valve employed has a large port area through which the gas, or other fluids, can flow, the safety valve being such that the annulus into which the gas flows from the ports has a much greater area than was heretofore possible to provide, thereby permitting the gas to flow through a large diameter packer passage, ports with large areas, and a large tubing-casing annulus to the top of the well bore, and without restrictions. Accordingly, during peak operating periods, gas can be withdrawn from the gas storage well or reservoir at very high rates. In the event of damage or failure to the equipment, the safety valve automatically shuts in the well. Closing of the safety valve is also effected whenever desired from a remote point. More specifically, a predetermined pressure drop in the tubing string connected to the apparatus and extending to the top of the well bore will cause the gas, or other fluid, pressure below the valve to automatically effect its closing.

In connection with running the apparatus into and retrieving it from the well casing, the packer, safety valve, and all accessories can be lowered and removed through use of wire line equipment, such as an electric wire line, piano wire line, or a sand line, such equipment being lowered into the well casing through use of a known type of lubricator, such that the operations can take place under pressure and without the necessity for "killing" the well. The well packer employed is capable of being anchored to the casing in packed-off condition against movement in both longitudinal directions and of being released and retrieved at the well casing through use of wire line operated equipment.

This invention possesses many other advantages, and has other purposes which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense.

Referring to the drawings:

FIGS. **1***a* and **1***b* together constitute a side elevational view, portions being disclosed in section and diagrammatically, of an apparatus embodying the invention, with parts in condition for delivering well bore fluid to the top thereof;

FIGS. **2**, **3**, **4**, **5**, **6**, **7** and **8** are diagrammatic views illustrating different conditions relating to the operation of the well bore equipment illustrated in FIGS. **1***a and 1b;*

FIGS. **9***a*, **9***b*, **9***c*, **9***d*, **9***e*, and **9***f* together constitute a combined side elevational view and longitudinal section through the safety valve and well packer portions of the apparatus, being lowered in a casing on a wire line, and with the packer parts in their initial retracted positions, FIGS. **9***b*, **9***c*, **9***d*, **9***e* and **9***f* being lower continuations of FIGS. **9***a*, **9***b*, **9***c*, **9***d* and **9***e*, respectively;

FIG. **10** is a cross section taken along the line **10–10** on FIG. **9***b*;

FIG. **11** is a fragmentary cross section taken along the line **11–11** on FIG. **9***e*;

FIG. **12** is a cross section taken along the line **12–12** on FIG. **9***c*;

FIGS. **13***a* and **13***b* together constitute a partial longitudinal section through the upper portion of the packer apparatus on an enlarged scale, primarily illustrating the ratchet-type lock mechanisms embodied in the well packer, FIG. **13***b* being a lower continuation of FIG. **13***a;*

FIGS. **14***a*, **14***b* and **14***c* together constitute a quarter longitudinal section through the lower packer portion of the apparatus, illustrated as anchored in packed-off condition in the well casing, FIGS. **14***b* and **14***c* being lower continuations of FIGS. **14***a* and **14***b*, respectively;

FIGS. **15** is a longitudinal section through the upper portion of the apparatus, illustrating the lowering of a blanking plug to the region of the safety valve therebelow;

FIG. **16** is a view similar to FIG. **15**, showing the blanking plug landed in place;

FIG. **17** is a view similar to FIGS. **15** and **16**, illustrating the running tool released from the blanking plug;

FIGS. **18***a* and **18***b* together constitute a longitudinal section through the safety valve portion of the apparatus, with the valve in closed condition, FIG. **18***b* being a lower continuation of FIG. **18***a*;

FIG. **19** is a cross section taken along the line **19–19** on FIG. **18***b*;

FIGS. **20***a* and **20***b* together constitute a longitudinal section through the safety valve in opened condition, FIG. **20***b* being a lower continuation of FIG. **20***a*;

FIG. **21** is a view taken along the line **21–21** on FIG. **20***b*;

FIG. **22** is a cross section taken along the line **22–22** on FIG. **20***b*;

FIG. **23** is an enlarged, combined sectional and side elevational view illustrating the blanketing plug latched into the valve operating member;

FIG. **24** is a view of the apparatus with a packer releasing and retrieving tool lowered into engagement with the apparatus;

FIG. **25** is an enlarged longitudinal section of the packer releasing portion of the releasing and retrieving tool, with its releasing dogs in contracted condition and passing through the upper portion of the apparatus;

FIG. **26** is an enlarged cross section taken along the line **26–26** on FIG. **25**;

FIG. 27 is an enlarged cross section taken along the line 27–27 on FIG. 25;

FIG. 28 is a fragmentary section taken on the line 28–28 on FIG. 25;

FIG. 29 is a combined side elevational view and longitudinal section illustrating the releasing mechanism in condition for releasing the well packer;

FIGS. 30*a* and 30*b* together constitute an enlarged longitudinal section, with parts shown in side elevation, of the releasing mechanism after having released the well packer parts, FIG. 30*b* being a lower continuation of FIG. 30*a*;

FIG. 31 is a longitudinal section, with parts shown in side elevation, of the upper portion of the retrieving tool in condition for retrieving the well packer and safety valve from the well casing;

FIGS. 32*a*, 32*b*, 32*c*, 32*d*, 32*e* and 32*f* are quarter longitudinal sections through the well packer and safety valve, with the well packer parts retracted from the well casing and with the entire apparatus in condition for elevation through and from the wall casing, FIGS. 32*b*, 32*c*, 32*d*, 32*e* and 32*f* being lower continuations of FIGS. 32*a*, 32*b*, 32*c*, 32*d* and 32*e*, respectively.

In FIGS. 1*a* and 1*b*, a somewhat diagrammatic illustration of a portion of the apparatus embodying the invention is disclosed, with the parts in position for delivering gas from an underground reservoir (not shown) to a gas delivery line 10. A well bore 11 extends downwardly from the ground surface to the location of the gas reservoir, there being a suitable master valve 12 at the top of a casing 20, the gas delivery line 10 controlled by a valve 13, and a suitable head 14 communicating with a fluid pressure line 15, from which fluid under pressure can pass into a tubing string 16 connected to the head and extending downwardly in the well casing to operative connection with a safety valve 17 secured to a well packer 18 depending therefrom, which is illustrated as having been anchored in packed-off condition in the well casing 20. The gas will flow from the reservoir into the packer 18 and out through ports 21, 22 in the safety valve above the packer into an annulus 23 surrounding the safety valve, flowing upwardly through the tubing-casing annulus 24 to the gas delivery line 10.

The well packer can be lowered in the well casing and anchored therein in packed-off condition against movement in both longitudinal directions. It includes a main or tubular body 25 (FIGS. 9*d*, 9*e*, 9*f*) the lower end of which is threadedly secured to a body latch sleeve 26 having a plurality of depending springlike arms 27 terminating in lateral outward directed latch fingers 28 adapted to be disposed under an inwardly directed circumferential shoulder or flange 29 integral with a thrust sleeve 30, the lower end of which is threadedly secured, below the latch fingers, to a lower thrust sleeve section 31 (FIG. 9*f*). A retainer sleeve 32 is disposed within the upper portion of the extension 31, being held initially in a position closely behind the latch fingers 28 be a shear screw 33, in order to retain the latch fingers under the thrust sleeve shoulder 29. The body latch sleeve 26 can only move to a limited distance downwardly along the thrust sleeve 30 by engagement of its latch fingers with the upper end 34 of the thrust sleeve extension 31. Upward force imposed upon the retainer sleeve 32 is transmitted from its lower flange 35 to a downwardly facing shoulder 36 on the extension sleeve 31, with which it is in engagement when the shear screw 33 is intact. The upper ends of the latch fingers 28 and their companion shoulder 29 are inclined in a downward and outward direction so that an upward pull taken on the body 25 and its latch sleeve 26 will tend to cam the latch fingers 28 laterally inwardly from engagement with the shoulder or flange 29. However, such action cannot occur so long as the retainer sleeve 32 is located behind the latch fingers.

Shearing of the screw 33 by imposing a downward force on the retainer sleeve 32 will enable the latter to shift downwardly to a position below the latch fingers 28, allowing the latter to shift laterally inwardly. The extent of downward movement of the retainer sleeve 32 is limited by its engagement with a split stop ring 37 confined within an internal groove 38 in the extension member 31. Such downward movement is obtained as a result of engagement of a tool part, described hereinbelow, with an upwardly facing shoulder 39 in the retainer sleeve, the tool being guided into the sleeve by a downwardly tapering upper surface 40 on the retainer sleeve.

The upper end of the thrust sleeve 30 is threadedly secured to a lower abutment ring 41 slidably mounted on the periphery of the body 25 (FIG. 9*e*). This abutment ring engages the lower end of a packing assembly 42, the upper end of which contacts an upper abutment ring 43 initially secured to the body 25 by a shear screw 44. As specifically illustrated, the packing assembly 42 includes a plurality of elastomer packing elements 45 engaging the upper and lower abutments 43, 41 and separated by metallic spacer sleeves 46. Relative movement of the upper and lower abutments 43, 41 toward each other will compress the packing elements 45 and expand them outwardly into firm sealing engagement with the wall of the well casing 20 and the periphery of the body 25.

The upper abutment 43 is threadedly secured to a lower expander 47 engaging initially retracted lower slips 48 adapted to be expanded outwardly upon relative downward movement of the lower slips along the lower expander, by virtue of slidable engagement of the inner downwardly and outwardly inclined inner surfaces 49 on the slips with companion tapered surfaces on the lower expander. Relative separating movement between the lower slips 48 and lower expander 47 will cause retraction of the lower slips because of opposed side tongues 50 on the lower slips engaging in companion grooves 51 in the lower expander (FIG. 11), the tongues and grooves being inclined in the same direction and to the same extent as the expander surfaces 49. The upper ends of the lower slips 48 are formed as T-shaped heads 52 radially slidable in companion slots 53 in a slip ring 54.

The upper end of the slipring 54 has similar T-shaped slots 55 receiving the lower T-shaped heads 56 of a plurality of circumferentially spaced upper slips 57 engageable with an upper expander 58 initially secured to the body by a shear screw 59 when the slips 48, 57 and packing assembly 42 are in retracted position (FIG. 9*d*). The inner surfaces 60 of the slips 57 are inclined in an upward and outward direction, engaging companion surfaces in the upper expander 58, such that relative longitudinal movement toward each other between the upper expander and upper slips will effect radial outward expansion of the upper slips against the well casing 20. Similarly, relative longitudinal separating movement between the upper expander and upper slips will effect retraction of the upper slips toward the packer body 25 because of the inclined side tongues 61 on the upper slips received with companion grooves 62 in the upper expander, the tongues and grooves being inclined to the same extent as the expander surfaces 60 on the upper expander and slips.

The expander 58 has an extension sleeve 63 integral therewith and extending upwardly therefrom, which is slidable along the periphery of the body 25. This extension sleeve is connected to a connector sleeve 64 extending upwardly from the expander 58 and encompassing the extension sleeve, the lower end of the connector sleeve engaging an upwardly facing shoulder 65 on the upper expander. The upper end of the connector sleeve is threadedly secured to a connector sub 66 having an upper left-hand threaded box 67 threadedly secured to a valve body section 68 disposed therewithin. The upper expander 58, although initially engaged by the lower end of the connector sleeve 64, is movable downwardly to a small extent relative to the latter by virtue of a one-way or ratchet interconnection 69 therebetween (FIGS. 9*e*, 13*b*). Thus, the expander extension sleeve 63 has a plurality of upwardly facing ratchet teeth 70 on its periphery engaging companion downwardly facing ratchet teeth 71 on a split lockring 72 having external cam teeth 73 thereon engaging companion internal cam teeth 74 in the connector sleeve 64. Thus, the extension sleeve 63 and upper expander 58 can move downwardly

relative to the connector sleeve 64 by virtue of ratcheting of the extension sleeve through the lockring 72. However, the teeth 70, 71 will coengage to prevent upward or return movement of the extension sleeve and upper expander relative to the connector sleeve 64, the cam teeth 73, 74 on the exterior of the lockring 72 and the connector sleeve 64 forcing the internal ratchet teeth 71 of the lockring laterally inwardly to retain them meshed with the external ratchet teeth 70 on the extension sleeve. The specific one-way connection between the connector sleeve 63 and extension sleeve 64 forms no part of the present invention, being illustrated and described in U.S. Pat. No. 3,311,171, to which attention is directed.

The extension sleeve 63 and upper expander 58 are urged in a downward direction by fluid pressure internally of the central passage 76 through the body 25, the fluid passing through side ports 77 in the body into an annular space 78 between the body and the connector sleeve, acting upon the upper end of an annular piston 79 disposed in such space, this piston having an upper side seal ring 80 engaging the inner wall of the connector sleeve 64 and a lower internal side seal ring 81 engaging the periphery of the body 25 below the port 77. Thus, fluid under pressure will act over the upper end area of the piston 79 and urge it in a downward direction against the extension sleeve 63, urging the upper expander 58 downwardly of the body 25 and the connector sleeve 64. Relative rotation between the connector sleeve 64 and the expander extension sleeve 63 is prevented by a torque pin 82 threaded in the connector sleeve and received within a longitudinal slot 83 in the extension sleeve.

As described hereinbelow, the packing assembly 42 and the upper and lower slips 48, 57 are expanded outwardly to set the well packer as a result of moving the packer body 25 upwardly and the connector sub 66 and connector sleeve 64 downwardly. Such relative movement is permitted by a one-way or ratchet device 84, but return relative movement is prevented (FIGS. 9*d*, 13*a*). As disclosed, the upper portion of the body 25 above its port 77 is provided with circumferential ratchet teeth 85 extending therealong that face in a downward direction, which are adapted to mesh with companion upwardly facing ratchet teeth 86 on a split upper lockring 87 having external circumferential cam teeth 88 engaging companion cam teeth 89 in the connector sub 66. Thus, the body 25 can move upwardly and ratchet through the lockring 87, but its downward movement is prevented by coengagement of the ratchet teeth 85, 86 and the bearing of the inclined faces of the cam teeth 88, 89 against one another, urging and retaining the lockring 87 in its lateral inward direction to hold the ratchet teeth fully meshed.

The well packer 18 is lowered to its desired setting location in the casing 20, whereupon, as described hereinbelow, a downward force is imposed on the connector sub 66 and connector sleeve 64, the body 25 being shifted in an upward direction, such upward movement being transmitted to the thrust sleeve 30. Such upwardly and downwardly directed forces will shear the pin 59 securing the upper expander 58 to the body and the upper abutment 43 to the body, the upper expander 58 being shifted downwardly and the lower abutment 43 being shifted upwardly. This action effects downward movement of the upper expander within the upper slips 57 and relative upward movement of the lower expander 47 within the lower slips 48 to expand both upper and lower slips radially outwardly until their wickers or teeth 90 engage and are embedded firmly in the well casing 20. Upon anchoring of the upper slips 57 against the casing, the upper expander 58 cannot move downwardly to any further extent, which is also true of the anchoring of the lower slips 48 against the well casing preventing further upward movement of the lower expander 47. Accordingly, the lower packing abutment 41 then moves upwardly toward the upper packer abutment 43 to shorten the packing assembly 42 and expand the packing elements 45 outwardly into sealing engagement with the wall of the well casing 20 and periphery of the packer body 25. During setting of the tool, the body 25 ratchets relatively upwardly through the upper lockring 87. However, when full setting has been achieved, the body cannot shift downwardly and thereby release the slips and packing assembly, because of the interengagement between the ratchet teeth 85, 86, which lock the body to the connector sub 66 against downward movement with respect thereto.

The packer 18 is attached through the left-hand threaded interconnection 67 to the lower valve body section 68, the upper end of which is threadedly secured to an upper valve body section 91 having a plurality of elongate, circumferentially spaced ports 21 through an upwardly tapering or converging section 92 thereof (FIG. 9*c*). The small diameter portion of the tapered valve body section is laterally spaced from the wall of the casing 20 to a considerable extent, providing a large annular space 23 therebetween, the valve body portion 92*a* being of cylindrical form above the small end of its frustoconical or tapered portion. A plug valve 93 is rotatably mounted within the frustoconical portion 92 of the valve body, having elongate ports 22 extending therethrough conforming in number, shape and spacing with the body ports 21 so that the alignment between the plug valve ports 22 and the body ports 21 provides a large flow area for gas therethrough from the packer body 25, through the lower valve body section 68 and into the relatively large area annulus 23 between the upper cylindrical body portion 92*a* and the well casing 20. Downward movement of the plug valve 93 is limited by its engagement with the upper end of the lower valve body section 68; whereas, its upward movement is prevented by its upwardly facing shoulder 94 bearing against the lower end of a suitable thrust bearing 95 that engages a downwardly facing shoulder 96 on an internal flange 97 provided in the cylindrical valve body portion 92. A cylindrical plug valve extension 98 extends upwardly from its tapered portion, such extension having a pair of opposed inclined cam slots 99 therein in which pins 100 are received carried by and extending inwardly from a longitudinally slidable sleeve 101 which is prevented from rotating by one or a plurality of keys 102 thereon riding in longitudinal keyways 103 within the upper portion of the cylindrical valve body extension 92*a* (FIG. 9*b*). The slidable sleeve 101 is adapted to occupy a lower position in engagement with the flange 97, at which time its cam pins or followers 100 are disposed in the lower portions of the inclined cam slots 99, the plug body 93 then being disposed in the position in which its ports 22 are aligned with the body ports 21. Upward shifting of the slidable sleeve 101, which is prevented from rotating by reception of its keys 102 within the keyways 103, carries the follower pins 100 upwardly in the inclined cam slots 99 and turns or rotates the plug valve body 93 so that, when the slidable sleeve 101 is in its uppermost position in engagement with a top sub 104 threadedly secured to the upper end of the valve body 92, the plug valve ports 22 are completely out of alignment with the body ports 21, the valve 17 then being in a closed position. A side seal ring 101*a* on the sleeve 101 engages the body portion 92*a* to prevent leakage therebetween.

As specifically illustrated by way of example, the cam slots 99 are inclines so that a full stroke of the slidable sleeve 101 from its lowermost to its uppermost position will turn the valve body 93 45°, since there are four ports 22 and 21 in the plug valve member 93 and in the surrounding body portion 92 (FIGS. 19 and 22). As disclosed in FIGS. 20*b*, 22, the ports 22, 21 are aligned and the valve is in a fully opened condition; whereas, FIGS. 18*b*, 19 illustrate the plug valve member 93 having been turned 45° so that the ports are fully disaligned, the valve then being in a closed condition.

To prevent fluid leakage between the plug valve 93 and the surrounding body 92, the plug valve has upper and lower circumferential seal rings 105 mounted thereon above and below its ports 22 sealingly engaging the inner wall of the plug body portion 92 above and below its ports 21. The plug body also has longitudinal seals 106 (FIGS. 18*b*, 19) mounted thereon between its ports 22 and extending from the upper to the lower seals 105, so as to provide a seal completely around

each plug body port 22, to prevent fluid from flowing through the plug body ports 22 and around the plug body exterior into the valve body ports 21 when the valve 17 is in the closed condition, such as disclosed in FIGS. 18*b*, 19.

The valve body 91, 68 may be considered as forming an upper extension of the connector sub 66 and connector sleeve 64, for the purpose of running the well packer 18 in the casing, setting the packer therein, and releasing and withdrawing the well packer from the well casing. The top sub 104 secured to the upper valve body section 92*a* is threadedly secured to a coupling 110, which is, in turn, threadedly attached to a seal nipple 111 having a pair of opposed radial lock pins 112 projecting therefrom. As specifically illustrated, the well packer and valve mechanism connected thereto is run in the well casing by means of a setting tool 113 secured to a wireline 114 extending to the top of the well bore. The setting tool is of a known type, for example, being of the specific type illustrated in U.S. Pat. No. 2,640,546, in which its upper end is secured to the wireline. The setting tool includes a setting sleeve 115 surrounding the seal nipple 111 and coupling 110, with its lower end engaging an upwardly facing shoulder 116 on the top sub 104. This setting sleeve is shifted downwardly as a result of operation of the setting tool 113. The setting tool also includes a tension rod 117 that extends through a seal nipple 111, coupling 110, top sub 104, slidable sleeve 101, plug body 93, valve body 91, 63 and packer body 25, its lower end being threaded to a coupling 118, which is, in turn, threaded onto a tension release stud 119 threadedly secured to an abutment 120 underlying and engaging a downwardly facing shoulder 121 of the retainer sleeve 32. The release stud 119 has a weakened section 122 at which it can pull apart when a certain predetermined setting force has been imposed on the well packer.

In a known manner, described in the above U.S. Pat. No. 2,640,546, the setting tool 113 is actuated, after lowering of the packer and valve apparatus to the position in which the well packer is to be set within the casing. The setting force developed in the tool shifts the setting sleeve 115 downwardly and pulls upwardly on the tension rod 117. Downward force on the setting sleeve is then transmitted through the top sub 104 and valve body 91, 68 to the connector sub 66 and the connector sleeve 64, shearing the screw 59 and shifting the upper expander 58 downwardly. At the same time, the upward motion and force on the tension rod 117 is being exerted through the release stud 119, abutment 120, and retainer sleeve 32 on the thrust member 31, 30, shifting the thrust sleeve 30 upwardly and causing the upper end 34 of the sleeve extension 31 to engage the latch fingers 28 and shift the sleeve 26 and the body 25 upwardly. Upward movement of the thrust sleeve 30 and downward movement of the connector sleeve 64 effect outward expansion of the upper and lower slips 57, 48 and of the elastomer packing elements 45 against the well casing 20, in the manner described above, the packer then being in its set condition as illustrated in FIGS. 14*a*, 14*b* and 14*c*. As the force developed in the setting tool increases, the slips are anchored more firmly against the well casing and the packing elements 45 are forced to a greater extent into sealed relation against the casing 20 and the packer body 25. The force eventually exceeds the strength of the release stud 119 at its weakened section 122, pulling the stud apart at that point, which allows the lower portion of the stud and the abutment 120 to drop down in the well bore. The wireline 114 can now be elevated to remove the setting tool 113 from the anchored packer 18 and valve mechanism 17 thereabove, leaving the bore of the packer and of the valve body unobstructed, the packer then being in the condition shown in FIGS. 14*a*, 14*b*, 14*c*.

A blanking plug 125 is then run into the well casing and set within the slidable sleeve 101 of the flow control valve 17. This blanking plug (see FIG. 23 particularly) includes a seal body 126 threadedly secured to a latch body 127 having slots 128 therein in which locking dogs 129 are mounted on pivot pins 130. The upper portions 131 of the dogs are biased outwardly by springs 132, which swing their lower nose portions 133 inwardly of the passage 134 through the mandrel to the extent limited by engagement of the lower foot portions 135 of the dogs with the bottoms of the slots 128. The upper dogs or fingers 131 are adapted to spring outwardly into a lock groove 136 in the slidable sleeve 101, the plug carrying side seals 137 for sealing with the inner wall of the sleeve to close the passage therethrough. The mandrel 127 has an upper head 138 releasably secured to a running tool 139 by a shear pin 140, the running tool being attached to the lower end of a wireline 141 adapted to extend to the top of the well bore.

The blanking plug 125 is of a much lesser diameter than the inside diameter of the well casing 20, in view of its being required to pass through the aligned passages through the seal nipple 111, coupling 110, top sub 104 and into the slidable sleeve 101. It is desirable to approximately center the blanking plug for entry of its lower tapered nose or guide portion 142 into the passage in the seal nipple 111. Accordingly, a tubular guide member 143 of a maximum outside diameter slightly less than the inside diameter of the casing is releasably secured to the running tool 139 by a shear pin 144, with the guide member surrounding the blanking plug 125 and terminating a short distance below its lower end 142. This guide member has a downwardly flaring mouth 145 for guiding it over the upper end of the seal nipple 111 and to center it with respect thereto.

When the blanking plug 125, with the guide member 143 secured thereto, is lowered through the well casing 20, the guide member will land upon the seal nipple 111 (FIG. 15), whereupon a downward jarring force is imposed on the running tool 139 to shear the pin 144, thus freeing the running tool from the guide member. At this time, the lower end 142 of the blanking plug 25 is adjacent to the seal nipple 111 and can readily enter its passage upon lowering of the wireline running tool 139 and blanking plug 125 attached thereto. Such lowering action occurs until a shoulder 146 on the latch body 127 engages a companion upwardly facing shoulder 147 in the slidable sleeve 101, at which time the upper dogs or fingers 131 of the latches are disposed opposite the groove 136, the fingers being forced outwardly by the springs 132 into such groove, as disclosed in FIGS. 16, 20*a*, 20*b*, 23. An upward pull can now be taken on the wireline 141, the dogs 131 engaging the upper side 136*a* of the groove 136, enabling an upward drawing force to be taken on the wireline and running tool 139 to shear the pin 140 and thereby release the running tool from the latch body 127. The wire line 141 is elevated to carry the running tool 139 upwardly with it, which will engage the upper end 149 of the guide 143, the entire combination then being elevated to the top of the well bore.

During the taking of the upward pull on the wire line 141 and running tool 139 to release the latter from the latch body, the latch body 127 and dogs 131 pull the slidable sleeve upwardly within the upper valve body portion 92*a*, causing its follower pins 100 to slide upwardly along the inclined guide slots 99 and turn the plug valve body 93 to the closed position in which its ports 22 are out of alignment with the valve body ports 21 (FIGS. 18*a*, 18*b*). As described above, the wire line with the running tool and guide 143 are then removed from the well casing 20.

A tubing string 16 is now lowered in the well casing (FIG. 1*a*), this tubing string having a lower head 150 adapted to slide over the seal nipple 111 and also having a J-slot arrangement 151 cooperable with the lock pins 112 to releasably secure the head to the seal nipple. The head 150 carries an internal seal 152 for sealingly engaging the periphery of the nipple 111 above the pins 112. As the head moves over the seal nipple, the inclined surface portion 153 of the J-slot will engage the lock pins 112 and turn the head to a position in which the pins are disposed in the vertical locking portions 154 of the J-slots, as disclosed in FIGS. 1*a* and 20*a*. The engagement of the upper ends of such slots 154 with the pins will prevent further downward movement of the tubing string 16 along the seal nipple 111; whereas, upward movement of the tubing string will cause the lower ends of the J-slot portions 154 to engage the pins.

The connections at the top of the well can now be completed. Thus, the head **14** is secured to the upper end of the tubing string, the fluid pressure line **15** extending from this head and communicating with the interior of the tubing string. The gas delivery line **10** is connected to communicate with the tubing-casing annulus **24**.

The valve **17** is in its closed position during lowering of the tubing string **16** in the casing, the connection of the tubing string to the seal nipple **111**, and the completion of the connections at the top of the well bore. Pressure from a suitable source is now directed through the line **15** into the interior of the tubing string **16**, this pressure acting downwardly on the slidable sleeve **101** and blanking plug **125** sealed therewithin, which function as a piston, shifting the slidable sleeve **101** downwardly and rotating the plug valve **93** to its open position (FIGS. **20***a*, **20***b*, **22**). The gas or other fluid can now flow upwardly through the packer **18** into the plug valve **17** and through the aligned ports **22**, **21** into the annulus **23** surrounding the valve, for continued upward movement through the tubing-casing annulus **24** to the gas delivery line **10**.

In the event of relieving of the pressure in the tubing **16** to a predetermined value below the gas pressure within the well packer **18**, the pressure differential will act upon the blanking plug **25** and the slidable sleeve valve **101**, shifting them upwardly, the follower pins **100** sliding upwardly in the inclined cam slots **99** to rotate the plug valve **93** to its closed position, thereby shutting off the flow through the ports **21** and into the tubing-casing annulus **24** (FIGS. a, a, **18***b*, **19**). This action will occur in the event of damage to the surface connections, such as a break in the gas delivery line **10** or the pressure line **15** leading to the tubing string **16**. The delivery line and line leading to the tubing string are interconnected by a known mechanism (not shown) so that reduction of pressure in the gas delivery line **10**, as by a break therein, will relieve or dump the pressure in the tubing string, causing the well or reservoir pressure to effect automatic closing of the plug valve.

In the event is is desired to retrieve the shutoff valve and well packer combination **17**, **18** from the well casing **20**, the tubing string **16** is first removed from the well casing by appropriately turning the tubing string and its head **150**, which will effect rotation of the J-slot **151** relative to the lock pins **112**, enabling the head to be pulled off the seal nipple **111**. Following removal of the tubing string from the well casing, a suitable retrieving tool **159** (FIG. 7) is lowered on a wire line **161** through the casing, this tool being of a known type (see U.S. Pat. No. 2,885,007) and being capable of latching onto the retrieving head **138** of the latch body **127**, while a probe (not shown) enters the passage **134** and engages the inwardly directed latch noses **133** to shift them outwardly and the upper dog or finger portions **131** inwardly from the groove **136**. An upward pull on the wire line **161**, the retrieving tool **159** and the blanking plug assembly **125** will now remove the latter from the slidable sleeve **101**, allowing the blanking plug to be elevated to the top of the well bore.

The passages through the safety valve **17** and packer **18** are now open and capable of receiving a packer releasing and retrieving mechanism as disclosed in FIGS. **24** to **32**, inclusive. This mechanism includes an elongate mandrel **162**, the upper end of which is secured to a wire line running string **163**, by means of which the packer releasing and retrieving mechanism is lowered in the well casing **20**. A housing **164** surrounds the mandrel, its lower end being provided with J-slots **151** of the same configuration as the tubing string J-slots, so that the lower portion of the housing can be piloted over the seal nipple **111** and become coupled thereto. This housing is releasably secured to the mandrel **162** by a shear pin **165**, such that engagement of the upper end of the housing slots with the lock pins **112** will allow a downward jarring force to be imposed on the extension mandrel **162** to shear the pin **165** and release the mandrel from the housing **164**, permitting the mandrel to move downwardly therethrough.

The extension mandrel **162** has an elongate slot **167** extending therethrough in which a scissors-type linkage is received. An upper pair of links **168** is disposed in the mandrel slot, being pivotally mounted on the mandrel by a hinge pin **169**. The lower ends of these upper links are connected by pins **170** to the upper ends of a pair of lower links **171**, whose lower ends are pivoted together by a hinge pin **172** extending through an elongate slot **173** in the mandrel. A ring **174** is slidably mounted on the lower portion of the mandrel **162**, engaging the pin **172** and being urged upwardly of the mandrel by a compression spring **175** surrounding the mandrel and bearing against a lower guide **176** secured to the mandrel. The spring forces the sleeve **174** upwardly, urging the lower ends of the lower links **171** upwardly, and, because of the pin connection **170** with the upper links **168**, tends to separate such pin connections **170** of the upper and lower links with respect to one another. Such separating action is prevented initially by the encompassing retrieving tool housing **164**. However, after shearing of the pin **165** and lowering of the mandrel **162** within the housing, the links **168**, **171** are removed therefrom, collapsing together in passing through the seal nipple **111**, coupling **110**, top sub **104**, slidable sleeve **101** and rotary plug valve **93** into the packer body **25**, which is of a much larger inside diameter than the parts thereabove. Accordingly, the spring **175** then shifts the lower ends of the lower links upwardly and spreads out their pin connected portions **170**, as shown in FIG. **29**.

The upper links **168** have recesses **178** therein above their pin connections **170** with the lower links **171**, the upper ends of the recesses providing downwardly facing dogs **179** which are adapted to engage the upwardly facing shoulder **39** of the retainer sleeve **32**, for the purpose of releasing the latter from the thrust sleeve extension **31**, as described below.

To the upper end of the extension mandrel **162** is secured a retrieving body **180** having a downwardly and outwardly inclined holding surface **181** adapted to engage the lower ends of fingers **182** at the bottom end of springlike arms **183** forming part of a collet latch sleeve **184** surrounding the body. A compression spring **185** surrounds the body **180** and engages an upper stop ring **186** on the body and the latch sleeve **184**, tending to urge the collet latch sleeve downwardly so as to slide its fingers **182** downwardly along the holding surface **181**. The retrieving latch mechanism is adapted to pass into an upper extension sleeve **187** secured to the retrieving tool housing **164**, the fingers **182** and holding portion **181** of the body moving into the extension, with the fingers disposed under an extension shoulder **188**. Accordingly, upward movement of the extension mandrel **162** and its body **180** will bring the holding surface **181** behind the fingers **182** and urge and hold them outwardly in position under the shoulder **188**, whereby upward movement of the wire line **163** will exert an upward pull on the housing **164**, and, through the lower ends **189** of the J-slots **151** at the lower portion of the housing, pull upwardly upon the seal nipple **111**, coupling **110**, top sub **104**, valve body **91**, connector sub **66**, connector sleeve **64** and upper expander **58**.

With the tubing string **16** having been removed from the well casing **20**, as well as the blanking plug **125**, the packer releasing and retrieving tool **160** is lowered on the wire line **163** in the well casing. The lower housing portion **164** of the retrieving tool moves over the seal nipple **111** and the inclined walls **153** of the J-slots **151** will cause the J-slots to assume an appropriate retrieving position, as determined by engagement of the upper ends of the inclined J-slot walls with the release studs or pins **112**, as disclosed in FIG. **24**. A downward jarring force is now imposed on the wire line to shear the pin **165**, which will cause the mandrel **162** to move downwardly through the housing **164**, carrying its linkage **168—170** with it, the linkage and mandrel passing through the seal nipple **111**, top sub **110**, slidable sleeve **101**, plug body **93**, lower portion **68** of the valve body, and connector sub **66** into the passage **76** through the main body **25**, the scissorslike links **168**, **171** then being expanded outwardly by the spring **175**, the lower links **171** shifting through the packer retainer sleeve **32**, but the dogs **179** expanding outwardly into the retainer sleeve above its shoulder **39** and coming to a stop in engage-

ment with such shoulder, as disclosed in FIG. 29. A downward jarring force is now imposed through the wire line 163 on the extension mandrel 162, which will act through the links 168 and their dog portions 179 on the retainer sleeve 32 to shear the pin 33 securing it to the thrust sleeve extension 31, driving the retainer sleeve downwardly until it engages the stop ring 37, at which time the upper end of the retainer sleeve is disposed below the latch fingers 28, freeing the latch sleeve 26 from the thrust sleeve 30. Downward movement of the extension mandrel 162 moves the body 180 at its upper portion and the fingers 182 of the collet latch 184 into the housing extension 187, at which the extension mandrel 162 becomes coupled to the housing 164. At this time, the dogs 179 will have driven the thrust sleeve shoulder 29 past the latch fingers 28, the lower abutment 41 on the thrust sleeve engaging the upper end of the body latch sleeve 26, as disclosed in FIGS. 30*a*, 30*b*.

An upward pull can now be taken on the wire line 163, which, through the body 180 and upper collet sleeve 184, will exert an upward pull on the housing 164 and seal nipple 111 connected thereto by engagement of the lower ends of the J-slot portions 154 with the lock pins 112 (FIG. 31). The upward force and pull is transmitted from the seal nipple through the coupling 111, top sub 110 and valve body 91 to the connector sub 66 and connector sleeve 64, pulling the upper expander 58 upwardly and effecting retraction of the upper slips 57, because of the tongue and groove interconnection 61, 62 therebetween. Upon dropping away of the lower abutment 41 from the packing assembly 42, the latter will inherently contract from the casing, relieving the upwardly directed force on the lower expander 47. Accordingly, retraction of the upper expander 58 and the upper slips 57 will then cause their upward movement and upward movement of the slipring 54 and of the lower slips 48 relative to the lower expander 47, effecting retraction of the lower slips because of their tongue and groove interconnection 50, 51 with the lower expander. During such retracting movement as a result of upward shifting of the upper expander 58 with respect to the lower expander 47, the body 25 is moving upwardly with the connector sub 66 because of the ratchet lock 84. However, such upward movement of the body 25 does not adversely effect the retraction of the packing elements 45 and of the upper and lower slips 57, 48, since the body is free to move upwardly with respect thereto because of the large longitudinal space that existed between the lower abutment 41 and the lowermost packing element 45 upon release of the thrust sleeve 30 from the collet latch 26 and its dropping down to place the lower abutment 41 upon the upper end of the collet sleeve (FIG. 30*a*). The safety valve 17 and packing assembly 18 can now be elevated by the wire line 163 and removed from the casing to the top of the well bore, the parts being in the relative positions shown in FIGS. 31 to 32*f*, inclusive.

The foregoing sequence of operation can take place without "killing" the well. The tubing string 16 is run in the well casing and connected to the apparatus, and is also removed from the well casing, only when the packer 18 is set and the safety valve 17 is in its closed condition. The packer and valve combination is run in the well casing and removed therefrom under pressure-controlled conditions, as through use of a lubricator (not shown) of a known arrangement at the top of the well, which is readily permitted because of the use of wire lines. The same is true of the lowering of the blanking plug 125 in the casing to its locked position within the actuating slidable sleeve 101 of the safety valve, as well as during the removal of the blanking plug from the apparatus.

The sequence of operation of the equipment is illustrated diagrammatically in FIGS. 2 to 8, inclusive. FIG. 2 discloses the lowering of the packer and safety valve combination 18, 17 on the wire line operated setting equipment 113 in the well casing 20. When the setting location is reached, the packer 18 is set and the release stud disrupted at its weakened section 122, permitting the retaining abutment 120 to drop down into the well bore. The setting tool 113 and wire line 114 are then removed from the casing. This operation occurs through use of a lubricator at the top of the well bore, to confine the well or reservoir pressure within the casing.

In FIG. 3, the packer 18 has been set and the blanking plug 125 has been lowered on the wire line 141 into the apparatus for latching connection with the slidable actuating sleeve. Here again, the blanking plug is run in through a lubricator. As a result of release of the running tool 139 from the blanking plug 125, the actuating sleeve 101 is shifted upwardly to close the safety valve, a condition depicted in FIG. 3.

In FIG. 4, the safety valve 17 is still in its closed condition, the tubing string 16 having been lowered through the well casing and connected to the seal nipple 111. The surface connections at the top of the well bore are then completed, as disclosed in FIG. 1*a*, pressure being applied to the fluid in the tubing string to shift the safety valve 17 to its opened condition, as shown in FIG. 5.

As disclosed in FIG. 6, the pressure in the tubing string has been relieved so that the reservoir or well pressure will have shifted the blanking plug 125 and actuating sleeve 101 upwardly to close the safety valve, whereupon the tubing string 16 has been disconnected from the seal nipple 111 and removed from the well casing 20. After this has occurred, the retrieving tool 159 can be lowered on a wire line 161, through use of a lubricator at the top of the well bore, to latch on to the blanking plug 125 and release it from the actuating sleeve 101 and remove it from the well casing to the top of the well bore (FIG. 7).

The packer releasing and retrieving tool 160 is now lowered on the wire line 163 through use of a lubricator, the retrieving tool 160 being coupled to the seal nipple 111 so that the well packer 18 can be released and removed from the well casing (FIG. 8). In the interest of simplicity, the linkage mechanism for driving the retainer sleeve 32 downwardly from its holding position behind the latch fingers 28 has been omitted.

Thus, it is apparent that all necessary operations can be carried out without the necessity for "killing" the well, since the valve 17 is only in its opened condition when the tubing string 16 is in place, with the well packer 18 anchored in packed-off condition in the well casing and with the surface connections intact. Otherwise, the valve is in its closed condition or, if the passage through the well packer 18 and valve 17 is open, as when the packer is in an unset condition, or the blanking plug 125 is to be run into the valve 17 of removed therefrom, the top of the well casing is closed through use of the lubricator in conjunction with a wire line employed for setting the packer, running the blanking plug in or out of its latched position within the actuating sleeve 101, or retrieving the well packer 18 and valve 17 from the well casing.

The above arrangement permits a well packer to be used that has a passage 76 of very large cross-sectional area. The advantage of such large cross-sectional area remains undiminished, since the ports 22, 21, when aligned, can be provided of a combined area at least as great as the packer passage area. Moreover, because of the tapered valve used, a large annular area 23 remains between the valve body 91 at the location of discharge of the gas, or other fluid, from the ports 22, 21 and the surrounding well casing. This annular area can be at least as great as the area through the packer passage, and, in fact, it can be substantially greater. This is to be distinguished from the use of a safety valve in which the ports are provided in a cylindrical body, as distinguished from a frustoconical body, the cylindrical body being disposed much closer to the wall of the well casing, as compared with the present frustoconical body construction. With a cylindrical body in the region of its port area, the annular area between such body and the well casing will be must less than the area of the packer body passage, severely limiting the flow of fluid from the packer passage and the open ports, regardless of their area.

With applicants' safety valve arrangement, gas can flow from the storage reservoir through the packer passage 76, open ports 22, 21 and upwardly through the annular space 23, 24 between the valve body 91 and casing 20, and between the

tubing string **16** and casing to the gas delivery line **10** at a very high rate, when required, the gas flow through the apparatus being unrestricted.

We claim:

1. In apparatus for controlling fluid flow in a well bore: a well packer set in the well bore and having a passage through which fluid from the well bore can flow; a control valve in the well bore connected to the packer and having port means through which fluid can flow from said passage into the well bore above said packer, said control valve comprising valve means rotatable between positions opening and closing said port means, and fluid operated means responsive to the pressure of the fluid in said passage for rotating said valve means from its position opening said port means to a position closing said port means.

2. In apparatus as defined in claim **1**; a tubular string operatively connected to said control valve and extending to the top of the well bore, said port means being communicable with the annular space between said control valve and well bore, said fluid operated means being responsive to the pressure of the fluid in said tubular string for rotating said valve means from its position closing said port means to a position opening said port means.

3. In apparatus as defined in claim **1**; said fluid operated means having a central passage therethrough communicable with said valve means, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore into a position closing said central passage.

4. In apparatus as defined in claim **1**; said fluid operated means having a central passage therethrough communicable with said valve means, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore into a position closing said central passage; a tubular string operatively connected to said control valve and extending to the top of the well bore, said port means being communicable with the annular space between said control valve and well bore, said fluid-operated means being responsive to the pressure of the fluid in said tubular string for rotating said valve means from its position closing said port means to a position opening said port means.

5. In apparatus as defined in claim **1**; running means for lowering said control valve and well packer connected thereto as a unit in the well bore, said running means including means for setting said well packer in the well bore.

6. In apparatus as defined in claim **1**; wire-line-operated running means for lowering said control valve and well packer connected thereto as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore.

7. In apparatus as defined in claim **1**; running means for lowering said control valve and well packer connected thereto as a unit in the well bore, said running means including means for setting said well packer in the well bore; and retrieving means for releasing said packer from the well bore and for withdrawing said packer and control valve as a unit to the top of the well bore.

8. In apparatus as defined in claim **1**; wire-line-operated running means for lowering said control valve and well packer connected thereto as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well bore to enable said running means to be withdrawn from the well bore; and wire-line-operated retrieving means for releasing said packer from the well bore and for withdrawing said packer and control valve as a unit to the top of the well bore.

9. In apparatus as defined in claim **1**; running means for lowering said control valve and well packer connected thereto as a unit in the well bore, said running means including means for setting said well packer in the well bore; said fluid-operated means having a central passage therethrough communicable with said valve means, said fluid operated means comprising plug means adapted to be lowered from the top of the well bore into a position closing said central passage.

10. In apparatus as defined in claim **1**; wire-line-operated running means for lowering said control valve and well packer connected thereto as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; said fluid-operated means having a central passage therethrough communicable with said valve means, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore on a wire line into a position closing said central passage.

11. In apparatus as defined in claim **1**; wire-line-operated running means for lowering said control valve and well packer connected thereto as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; said fluid-operated means having a central passage therethrough communicable with said valve means, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore on a wire line into a position closing said central passage; and wire line operated retrieving means for releasing said packer from the well bore and for withdrawing said packer and control valve as a unit to the top of the well bore.

12. In apparatus for controlling fluid flow in a well bore; a well packer set in the well bore and having a passage through which fluid from the well bore can flow; a valve body connected to the packer and having a frustoconical portion tapering in an upward direction, said frustoconical portion having side ports therethrough; a valve member rotatably mounted in said body and having a frustoconical portion conforming to said body frustoconical portion, said valve member frustoconical portion having side ports therethrough; fluid-operated means shiftable longitudinally in said valve body and having a cam connection with said valve member, whereby longitudinal movement of said fluid-operated means in one direction in said body rotates said valve member in said body to a position aligning said valve member ports and body ports and permitting fluid flow from said passage into the well bore above said packer and longitudinal movement of said fluid-operated means in the opposite direction rotates said valve member in said body to a position disaligning said valve member ports and body ports to close said body ports and prevent such fluid flow from said passage, said fluid operated means being responsive to the pressure of fluid in said passage.

13. In apparatus as defined in claim **12**; a tubular string operatively connected to said valve body and extending to the top of the well bore, said body side ports being communicable with the annular space between said body and well bore, said fluid-operated means being responsive to the pressure of the fluid in said tubular string for rotating said valve member to its position opening said body ports.

14. In apparatus as defined in claim **12**; said fluid-operated means having a central passage therethrough communicable with said valve member, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore into a position closing said central passage.

15. In apparatus as defined in claim **12**; a tubular string operatively connected to said valve body and extending to the top of the well bore, said body side ports being communicable with the annular space between said body and well bore, said fluid-operated means being responsive to the pressure of the fluid in said tubular string for rotating said valve member to its position opening said body ports; said fluid-operated means having a central passage therethrough communicable with said valve member, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore into a position closing said central passage.

16. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore.

17. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; and wire-line-operated retrieving means for releasing said packer from the well bore and for withdrawing said packer, valve body and valve member as a unit to the top of the well bore.

18. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; said fluid-operated means having a central passage therethrough communicable with said valve body, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore on a wire line into a position closing said central passage.

19. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; said fluid-operated means having a central passage therethrough communicable with said valve body, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore on a wire line into a position closing said central passage; and wire-line-operated retrieving means for releasing said packer from the well bore and for withdrawing said packer, valve member and valve body as a unit to the top of the well bore.

20. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; a tubular string releasably connected to said valve body and extending to the top of the well bore, said body side ports being communicable with the annular space between said body and well bore, said fluid-operated means being responsive to the pressure of the fluid in said tubular string to be shifted thereby downwardly in said valve body and rotate said valve member to its position opening said body ports.

21. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; a tubular string releasably connected to said valve body and extending to the top of the well bore, said body side ports being communicable with the annular space between said body and well bore, said fluid-operated means being responsive to the pressure of the fluid in said tubular string to be shifted thereby downwardly in said valve body and rotate said valve member to its position opening said body ports; and wire-line-operated retrieving means for releasing said packer from the well bore and for withdrawing said packer, valve body and valve member as a unit to the top of the well bore.

22. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; a tubular string releasably connected to said valve body and extending to the top of the well bore, said body side ports being communicable with the annular space between said body and well bore, said fluid-operated means being responsive to the pressure of the fluid in said tubular string to be shifted thereby downwardly in said valve body and rotate said valve member to its position opening said body ports; said fluid-operated means having a central passage therethrough communicating with said valve member, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore on a wire line into a position closing said central passage.

23. In apparatus as defined in claim 12; wire-line-operated running means for lowering said valve member, valve body and well packer as a unit in the well bore, said running means including means for setting said well packer in the well bore; said running means being releasable following setting of said well packer to enable said running means to be withdrawn from the well bore; a tubular string releasably connected to said valve body and extending to the top of the well bore, said body side ports being communicable with the annular space between said body and well bore, said fluid-operated means being responsive to the pressure of the fluid in said tubular string to be shifted thereby downwardly in said valve body and rotate said valve member to its position opening said body ports; said fluid-operated means having a central passage therethrough communicating with said valve member, said fluid-operated means comprising plug means adapted to be lowered from the top of the well bore on a wire line into a position closing said central passage; and wire-line-operated retrieving means for releasing said packer from the well bore and for withdrawing said packer, valve body and valve member as a unit to the top of the well bore.