United States Patent [19]

Crowe

[11] **3,871,447**

[45] **Mar. 18, 1975**

[54] **TUBING HANGER SETTING TOOL**

[75] Inventor: **Talmadge L. Crowe**, Houston, Tex.

[73] Assignee: **Baker Oil Tools, Inc.**, Los Angeles, Calif.

[22] Filed: **June 8, 1974**

[21] Appl. No.: **475,384**

Related U.S. Application Data

[62] Division of Ser. No. 275,911, July 28, 1972, Pat. No. 3,830,295, which is a division of Ser. No. 243,806, April 13, 1972, Pat. No. 3,771,603.

[52] **U.S. Cl.** **166/120**, 166/124

[51] **Int. Cl.** **E21b 23/00**

[58] **Field of Search** 166/237, 120, 212, 123, 166/125, 124, 181, 182, 189

[56] **References Cited**

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3,265,132	8/1966	Edwards, Jr.	166/120

Primary Examiner—James A. Leppink

Attorney, Agent, or Firm—Bernard Kriegel

[57] **ABSTRACT**

A setting tool releasably attachable to a tubing hanger and lowered into a well casing on a running string, the hanger being set in the casing by fluid pressure imposed on the setting tool to effect expansion of tubing hanger slips into anchoring engagement with the well casing. When the fluid pressure reaches a predetermined value, it conditions the setting tool with respect to the tubing hanger to enable the setting tool to be released from the tubing hanger, as by rotating the running string and the setting tool attached thereto.

12 Claims, 37 Drawing Figures

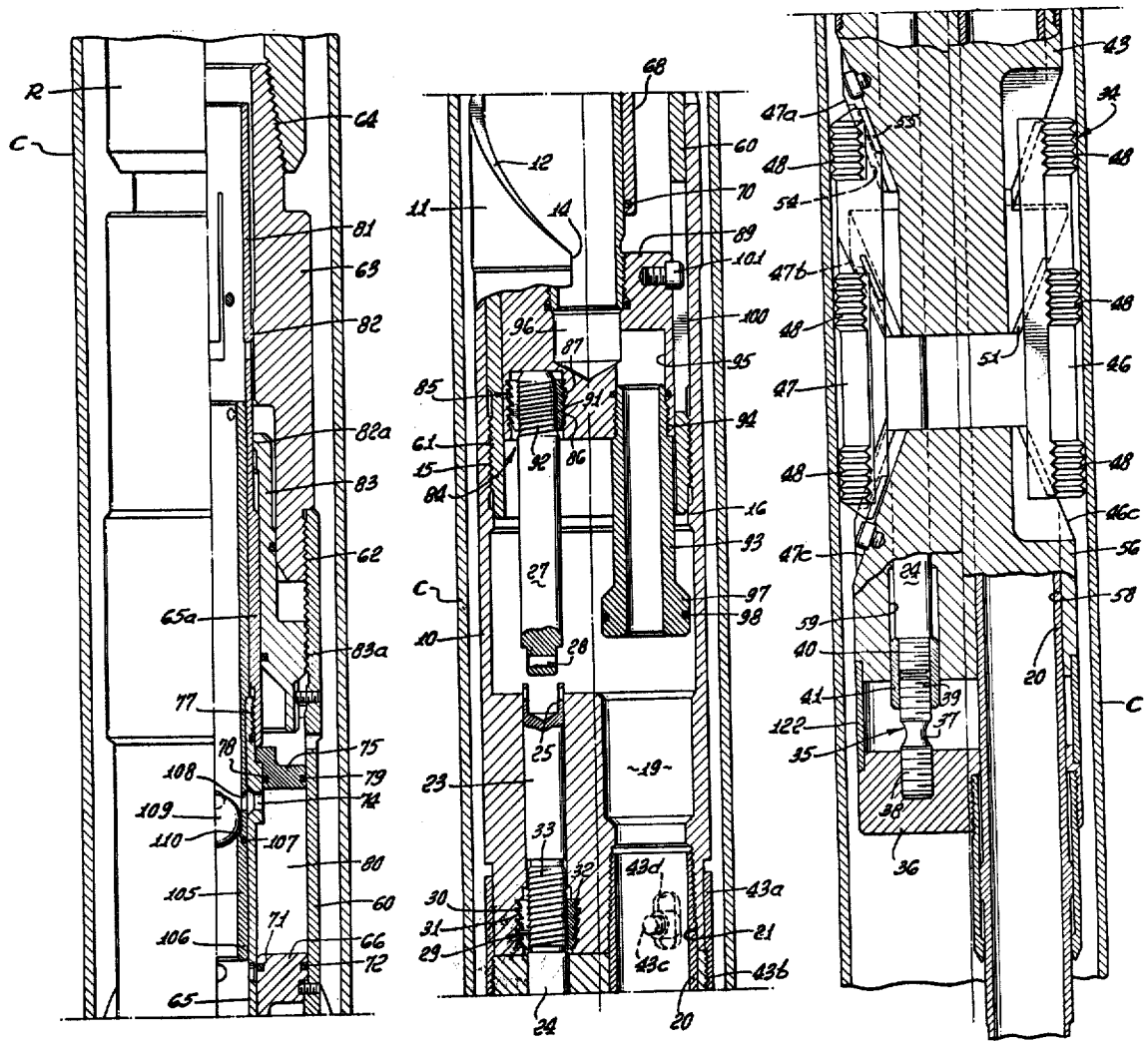


FIG. 1.

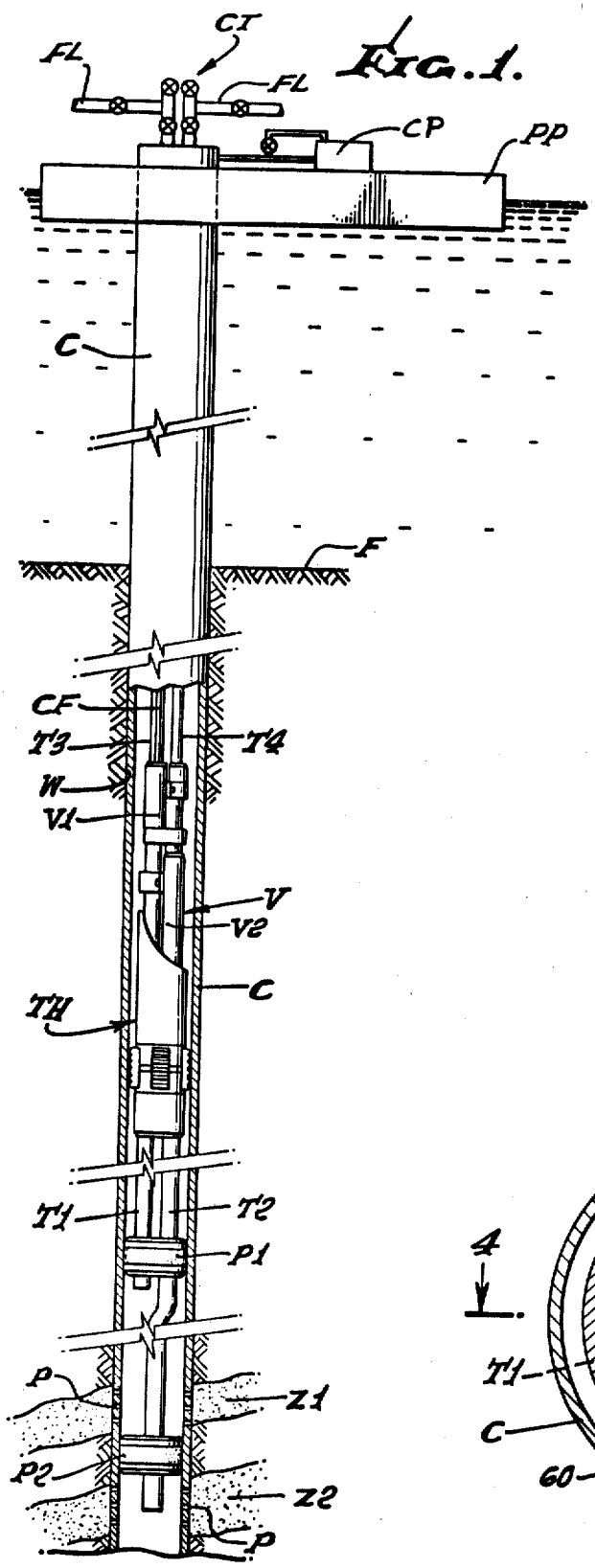


FIG. 2.

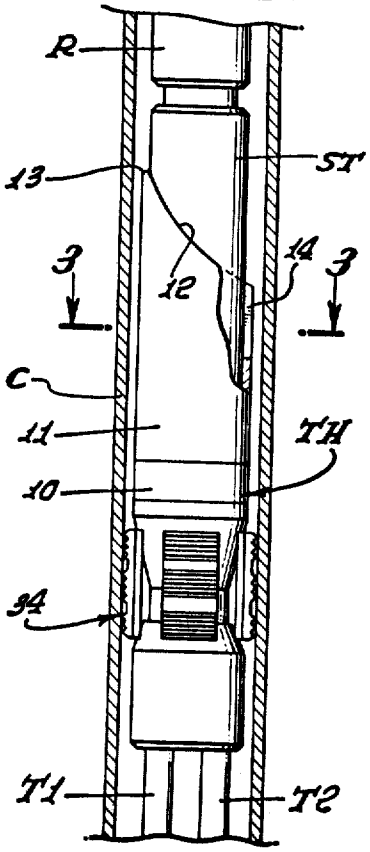


FIG. 3.

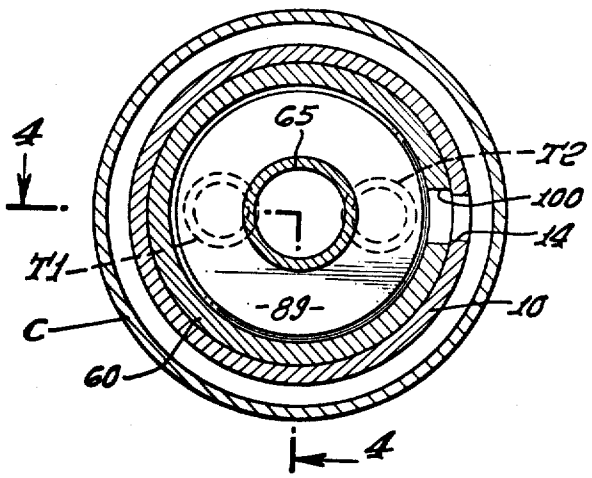


FIG. 4a.

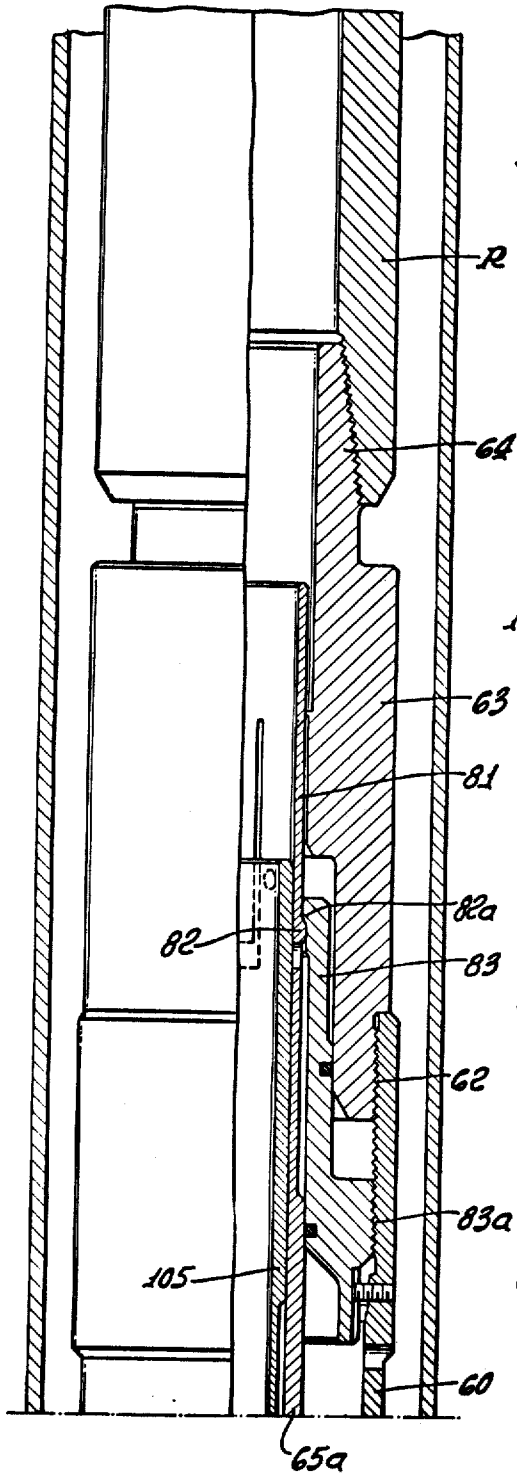

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FIG. 4b.

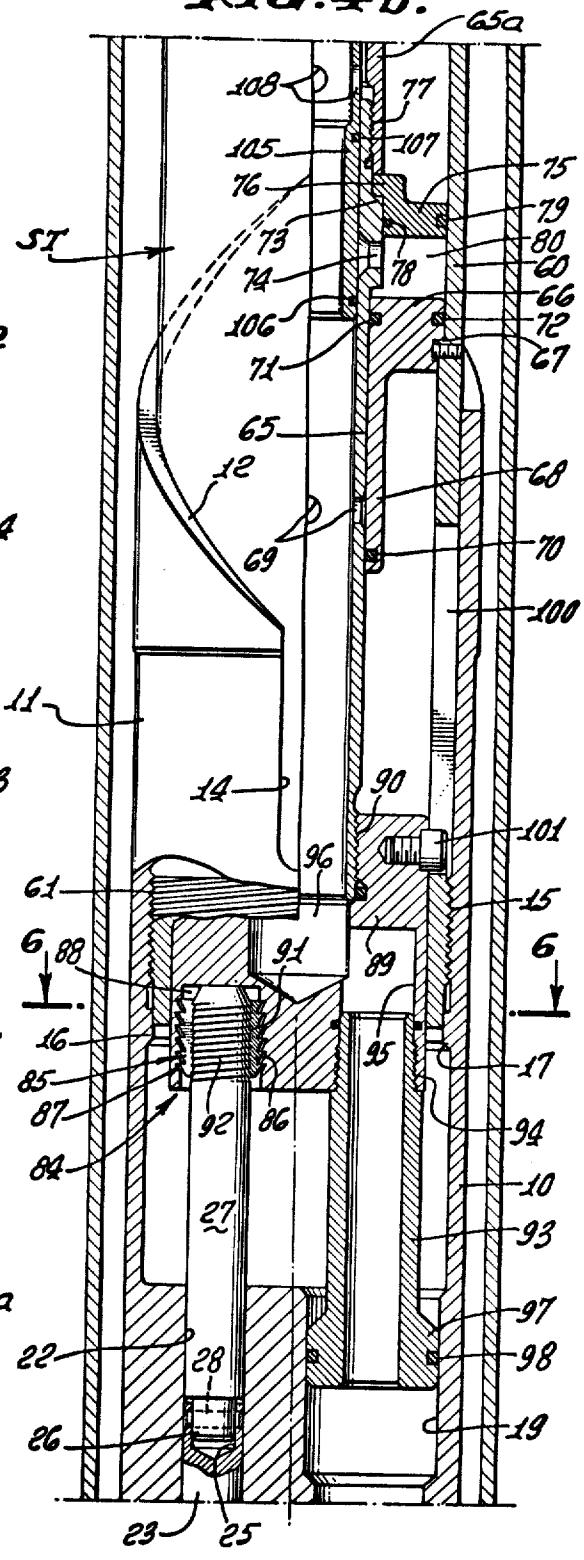

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FIG. 4c.

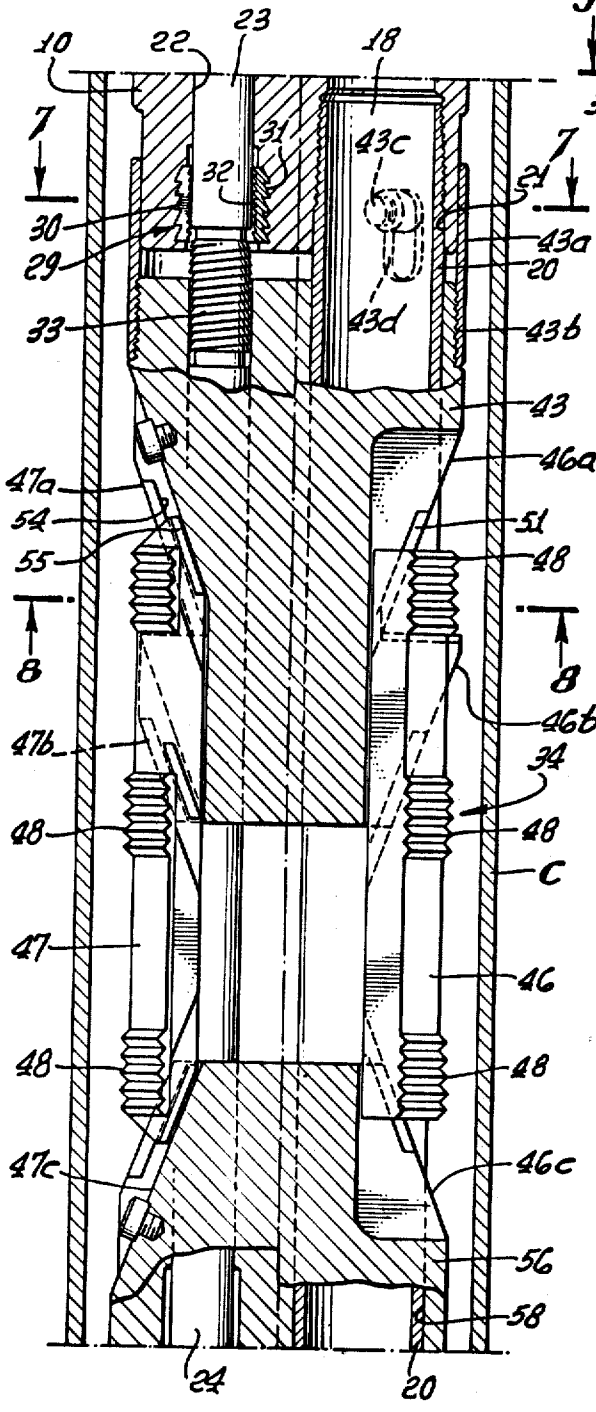

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FIG. 4d.

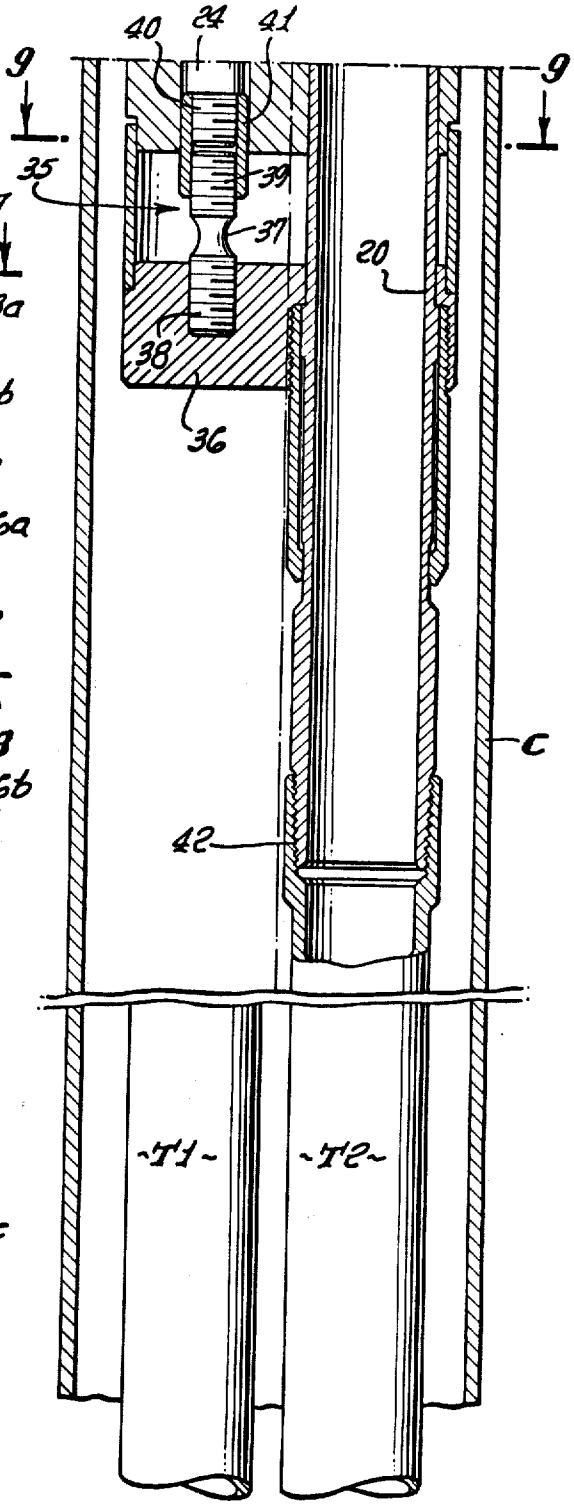

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FIG. 9.

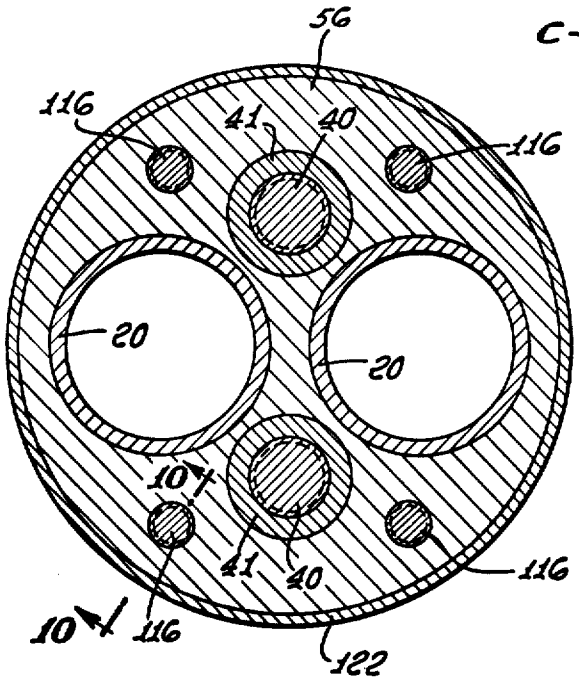


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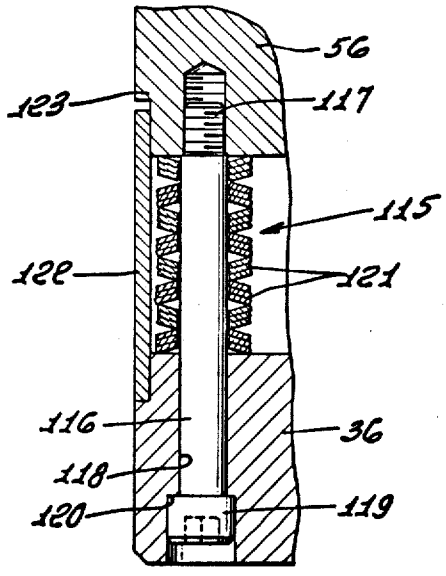


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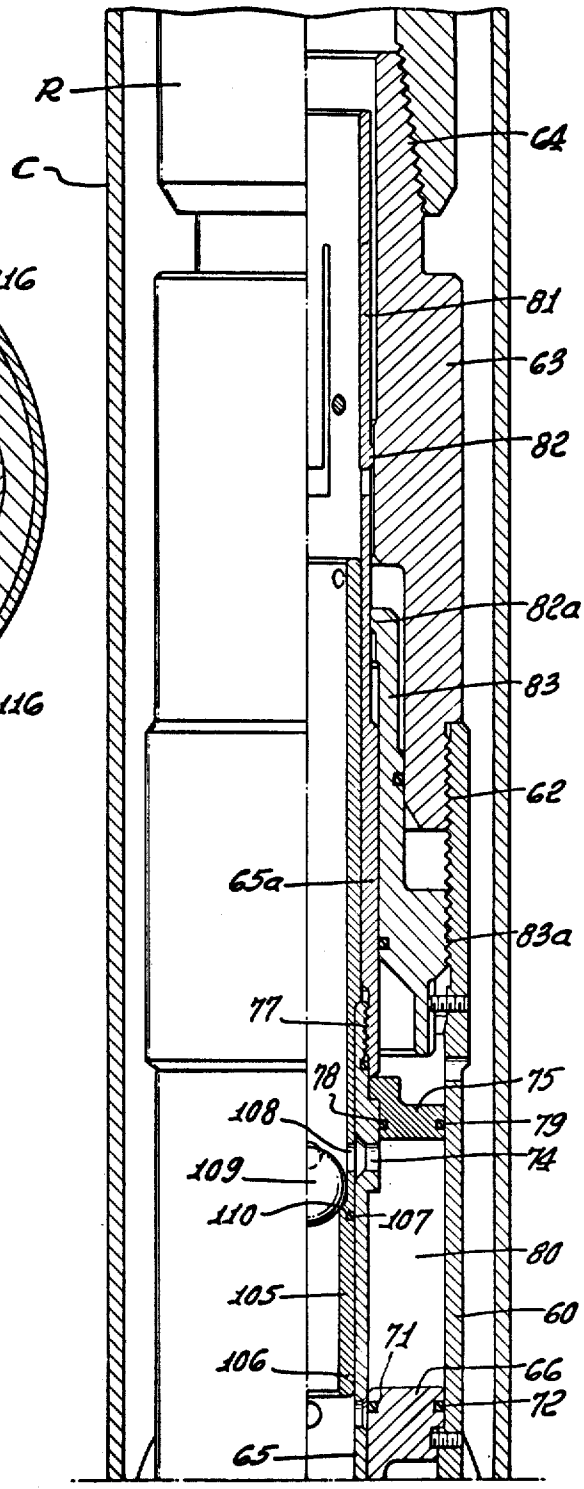


FIG. 5b.

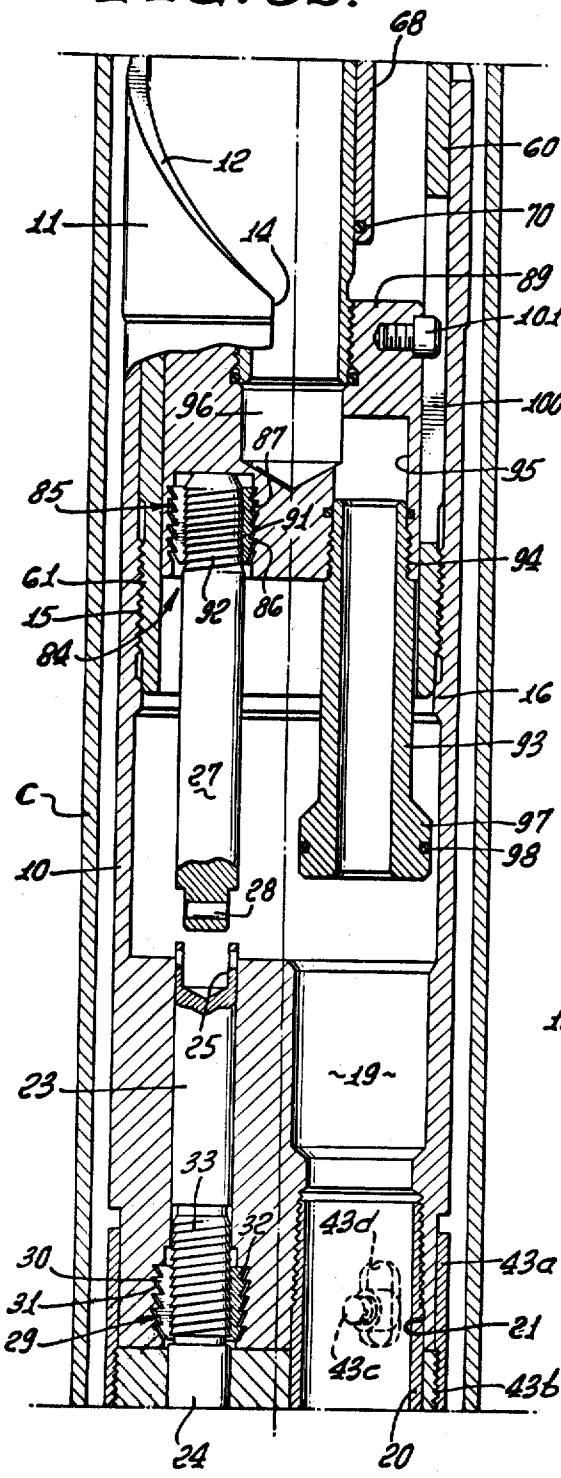

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FIG. 5c.

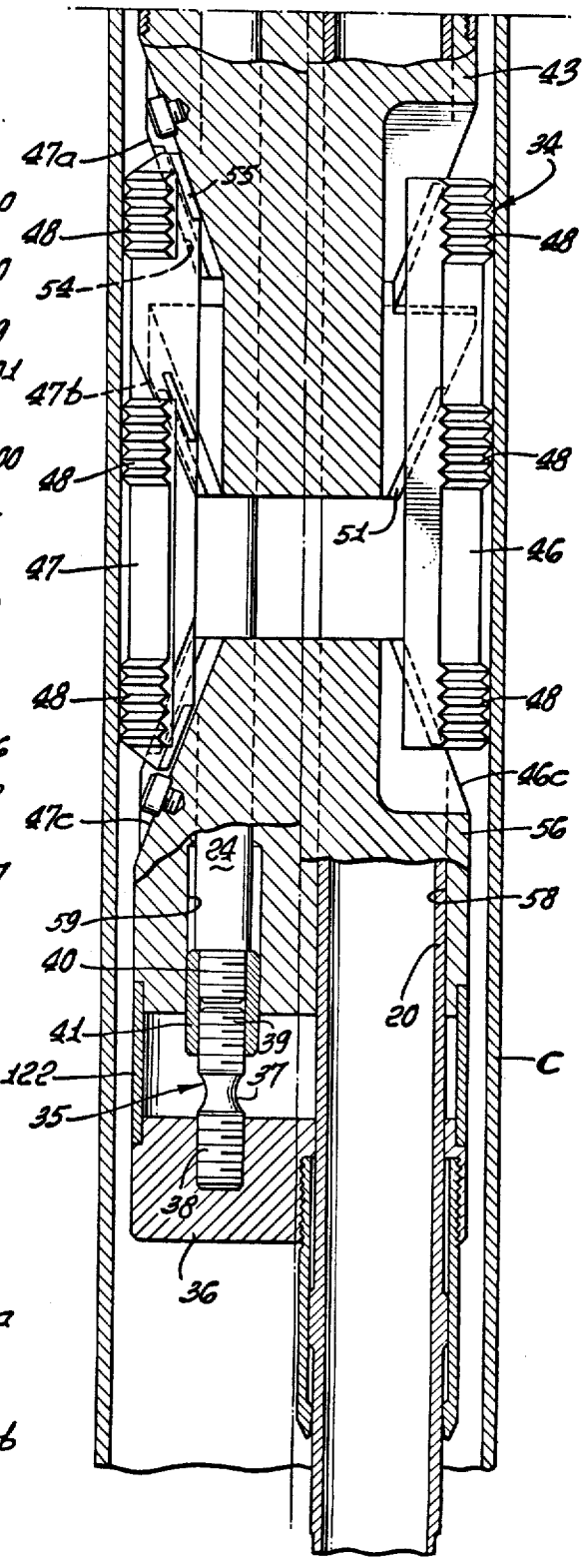

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FIG. 6.

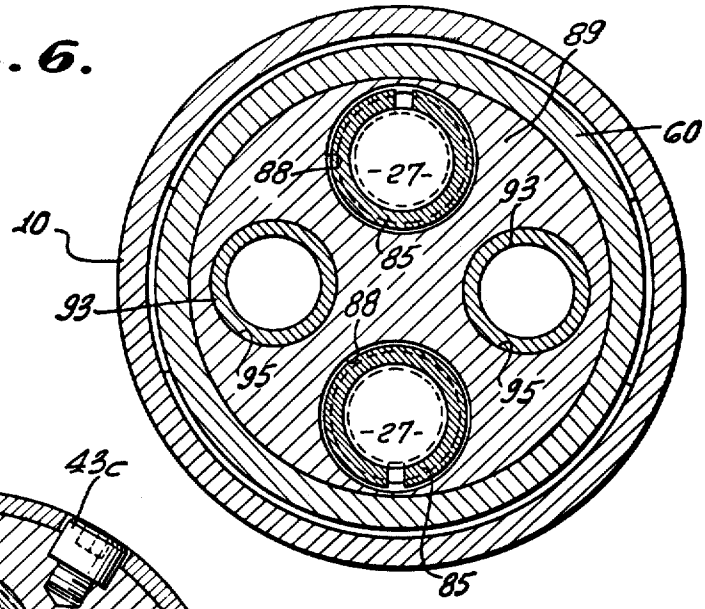


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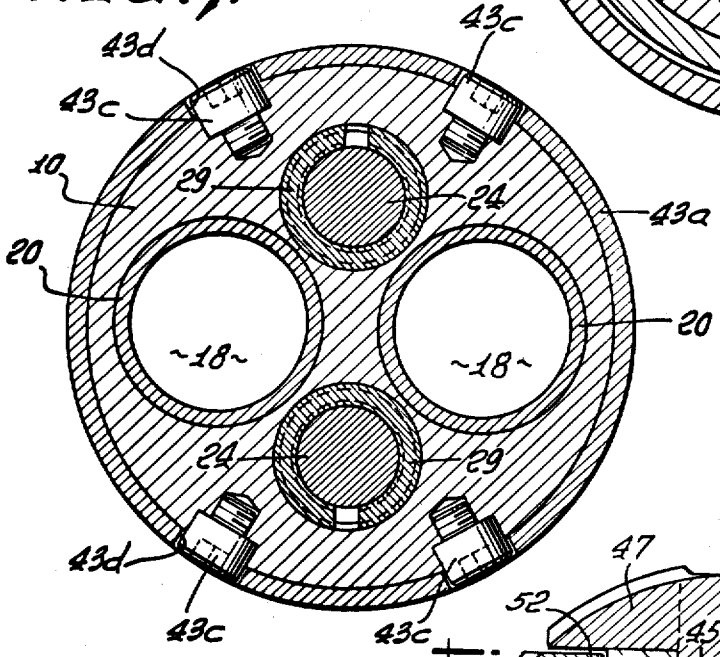


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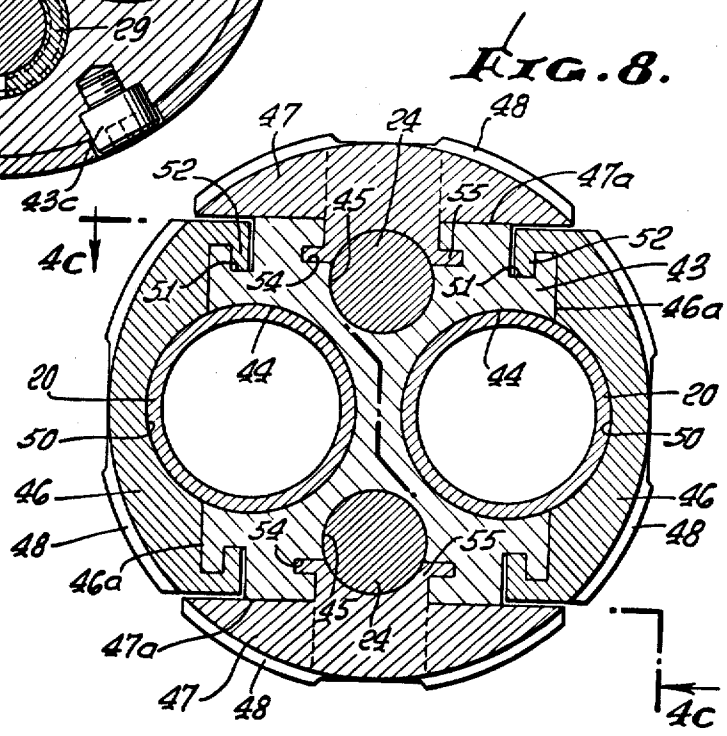


FIG. 11a.

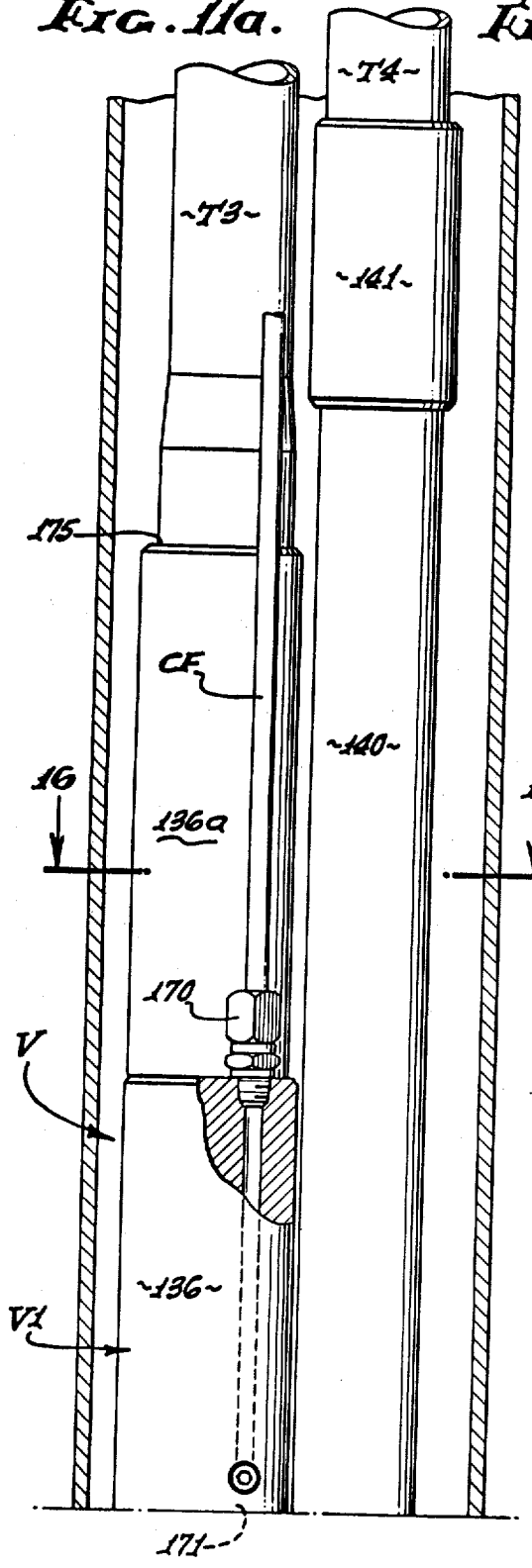


FIG. 11b.

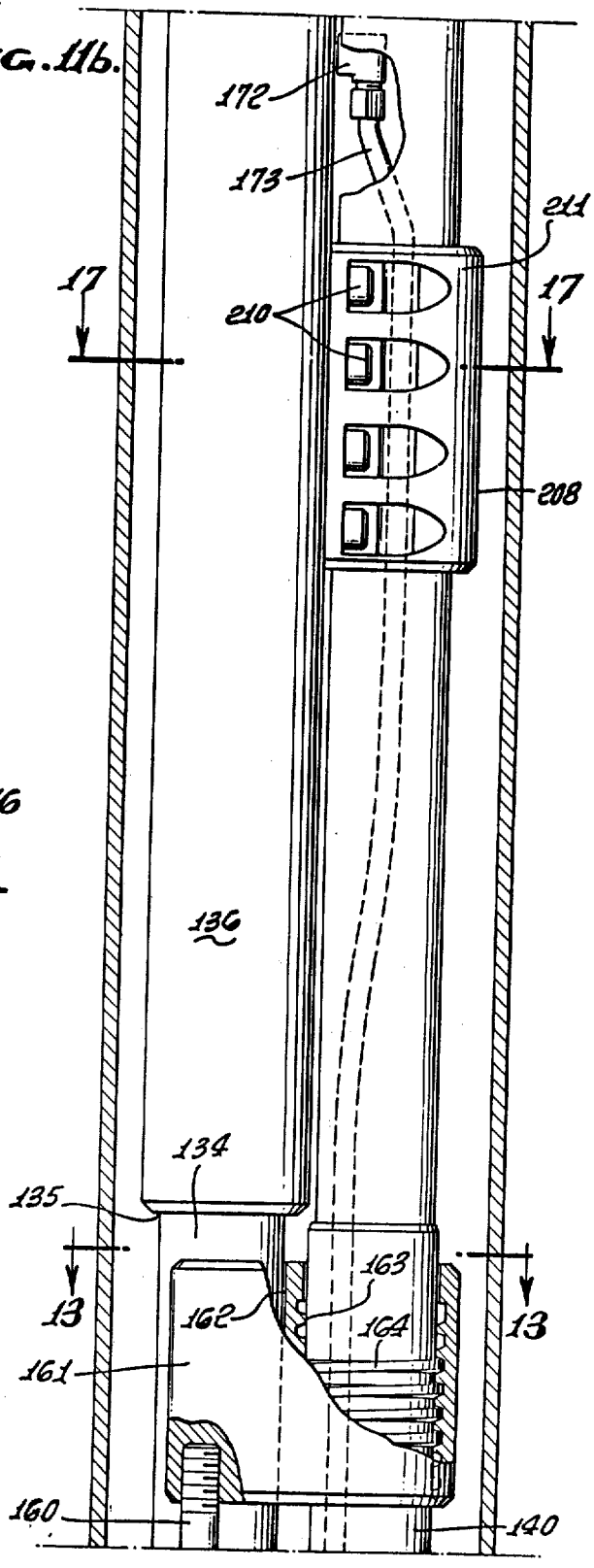


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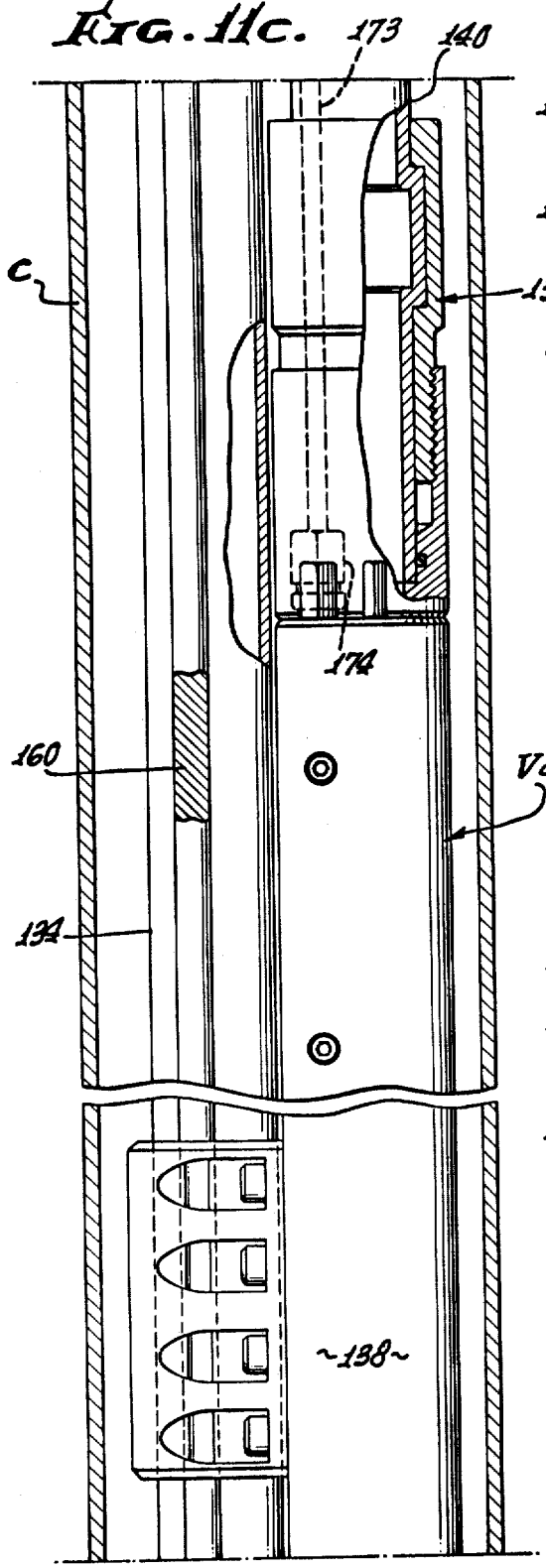


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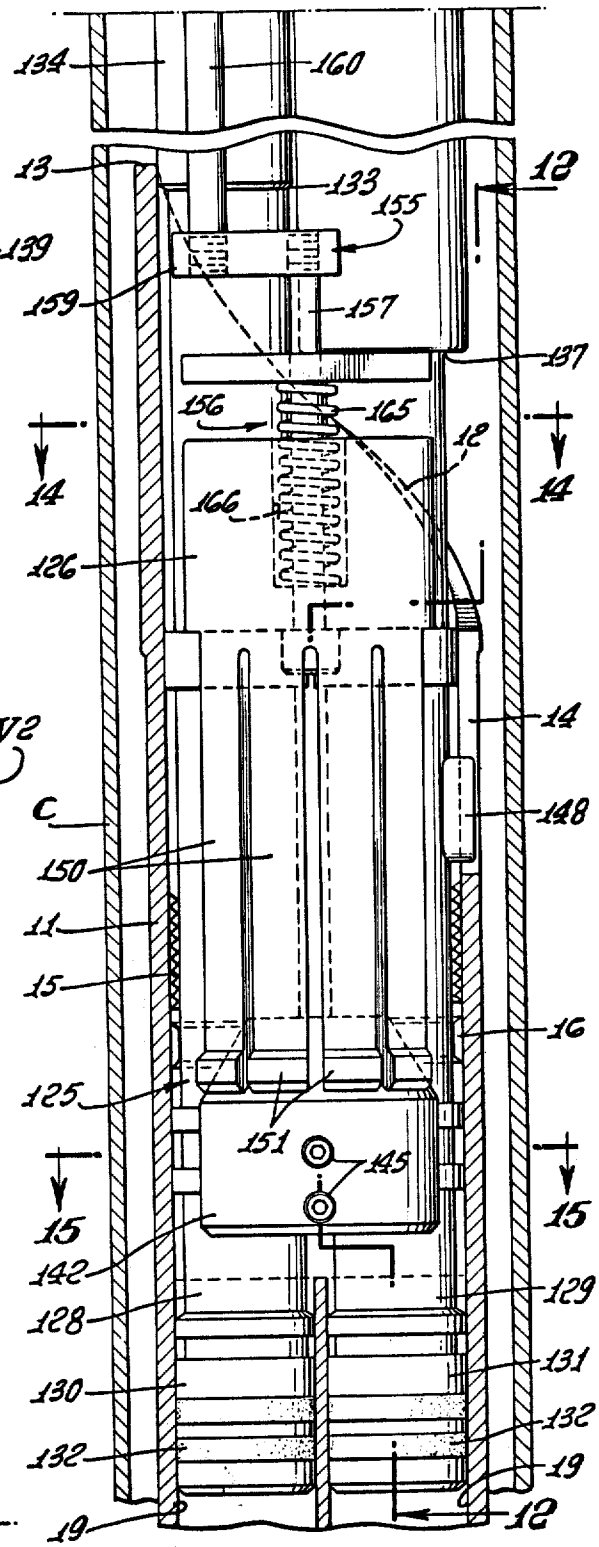


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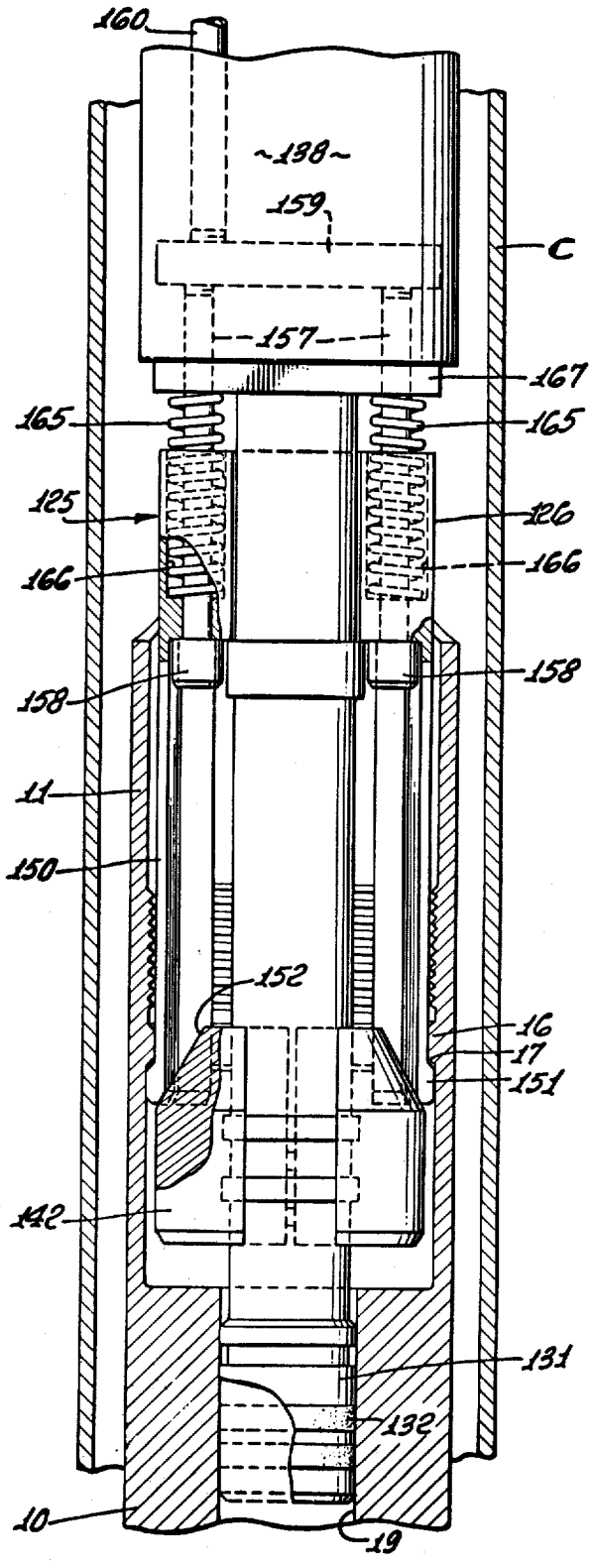


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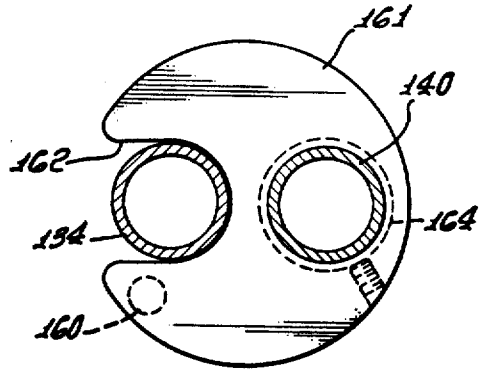


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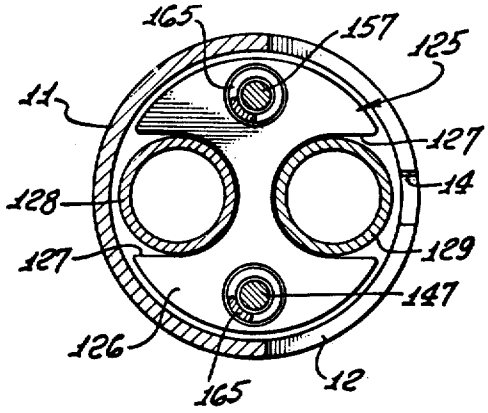


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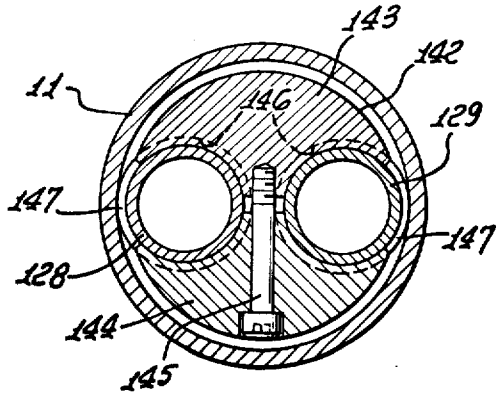


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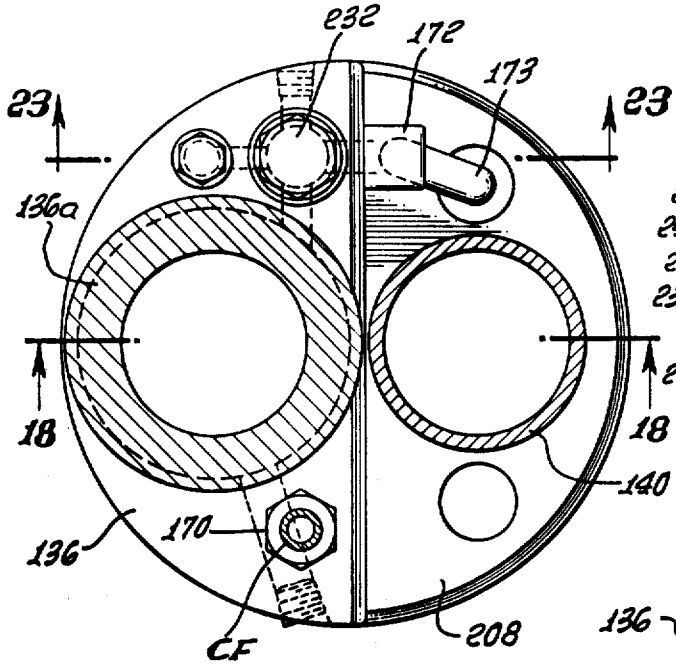


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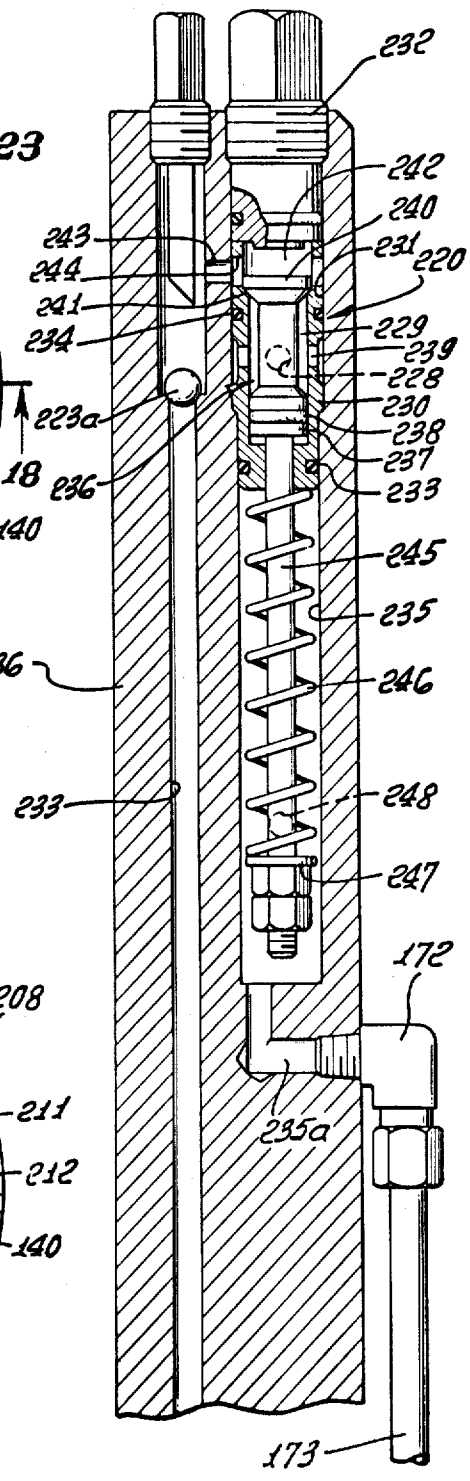


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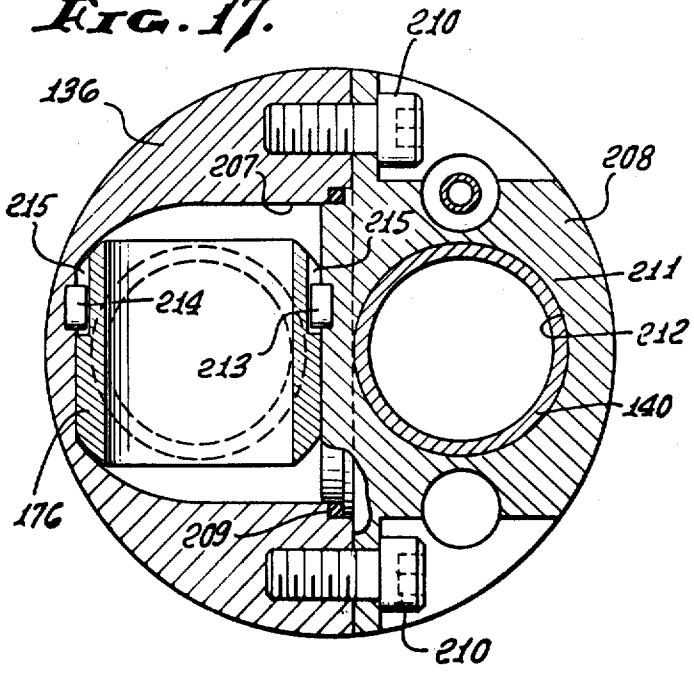


FIG. 18a.

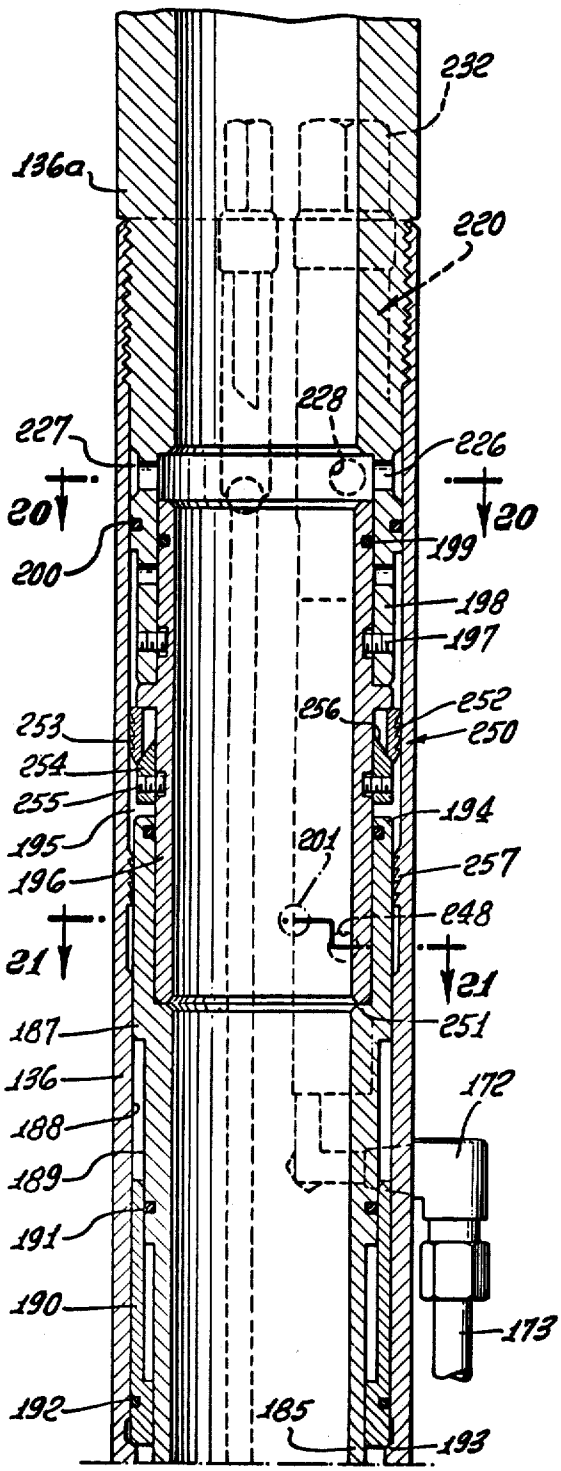


FIG. 18b.

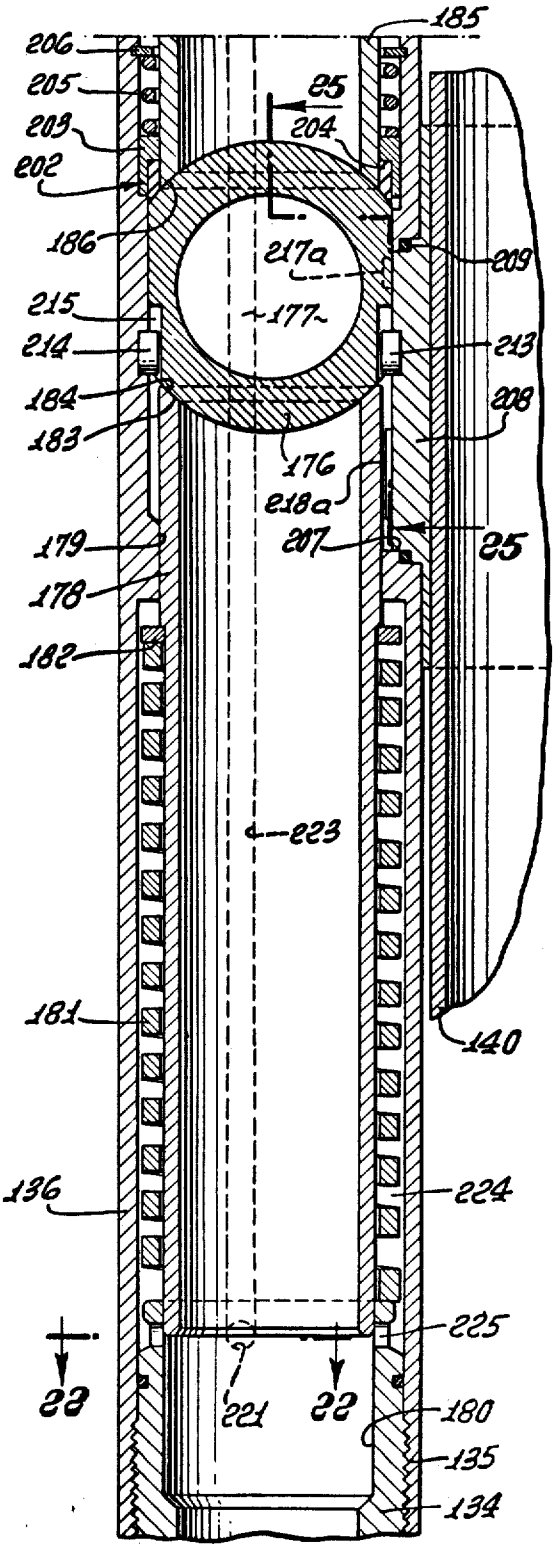


Fig. 19a.

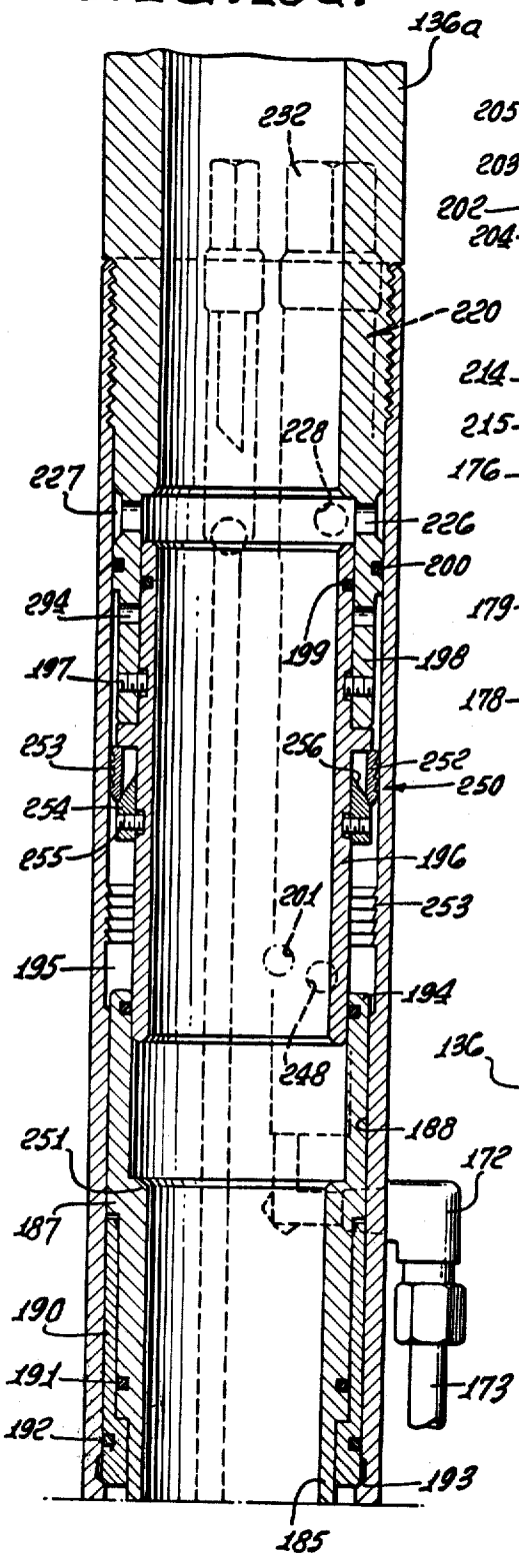


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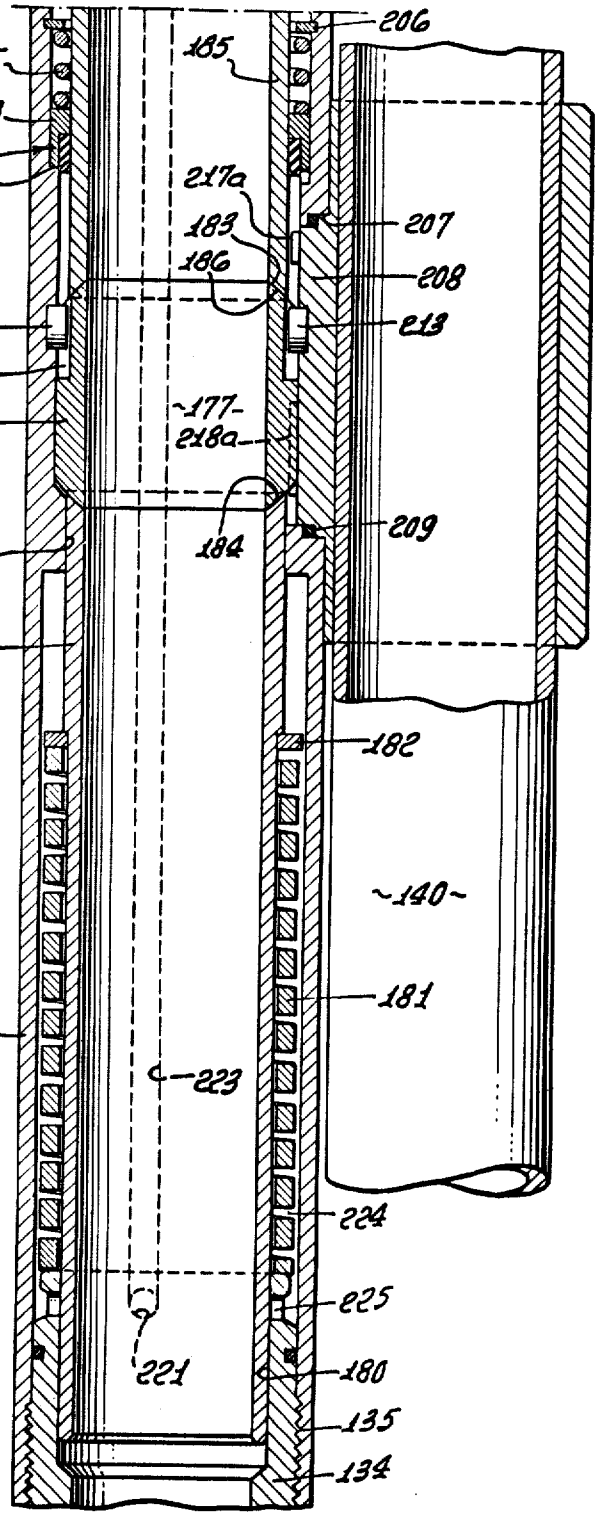


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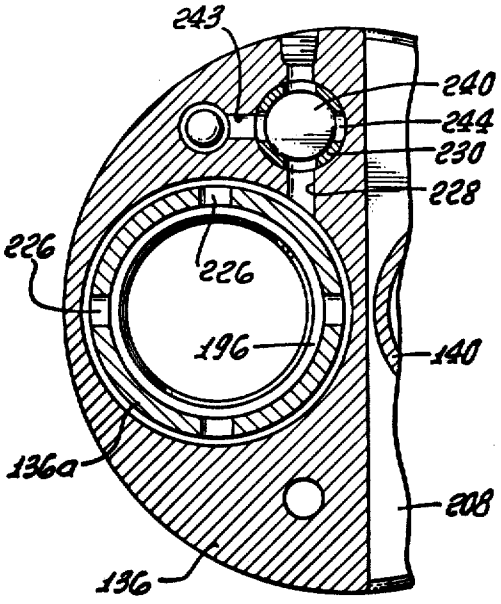


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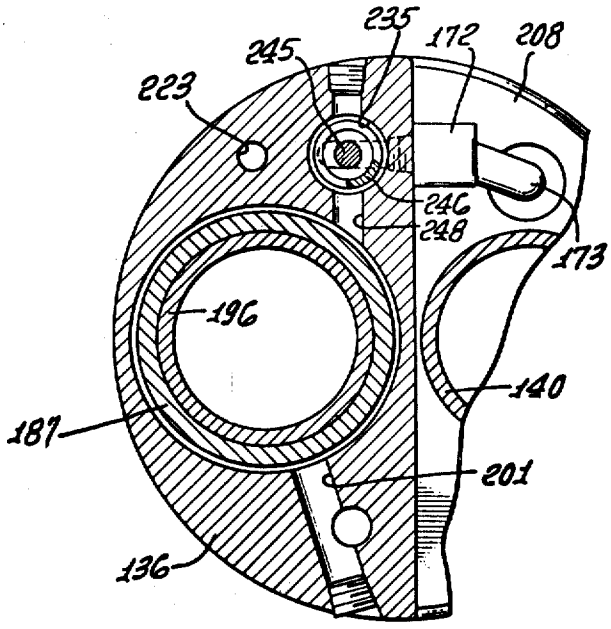


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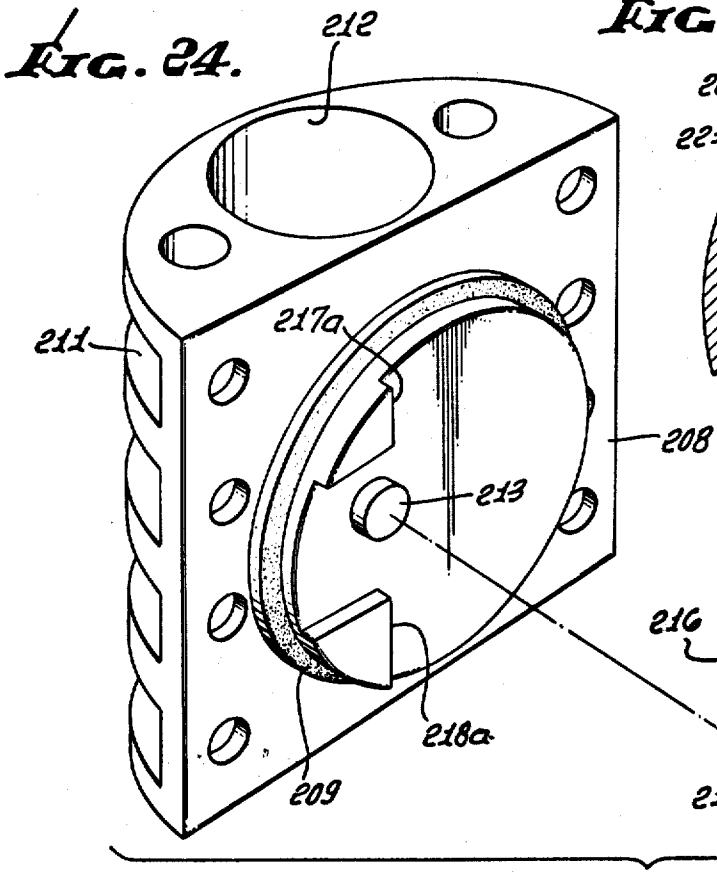
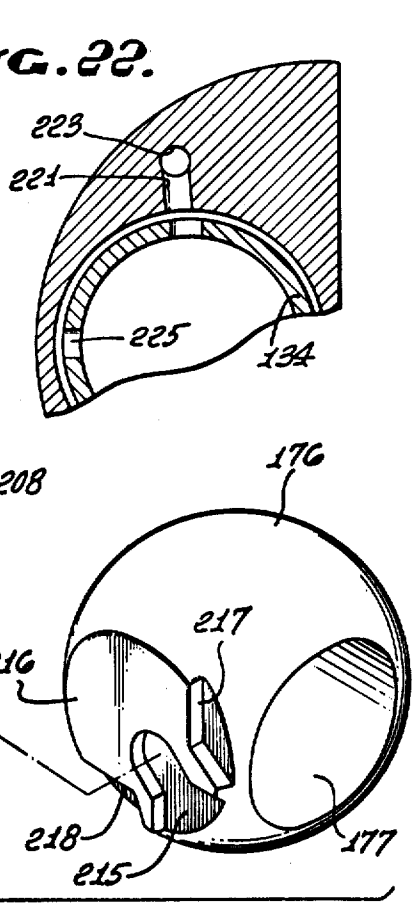


FIG. 22.



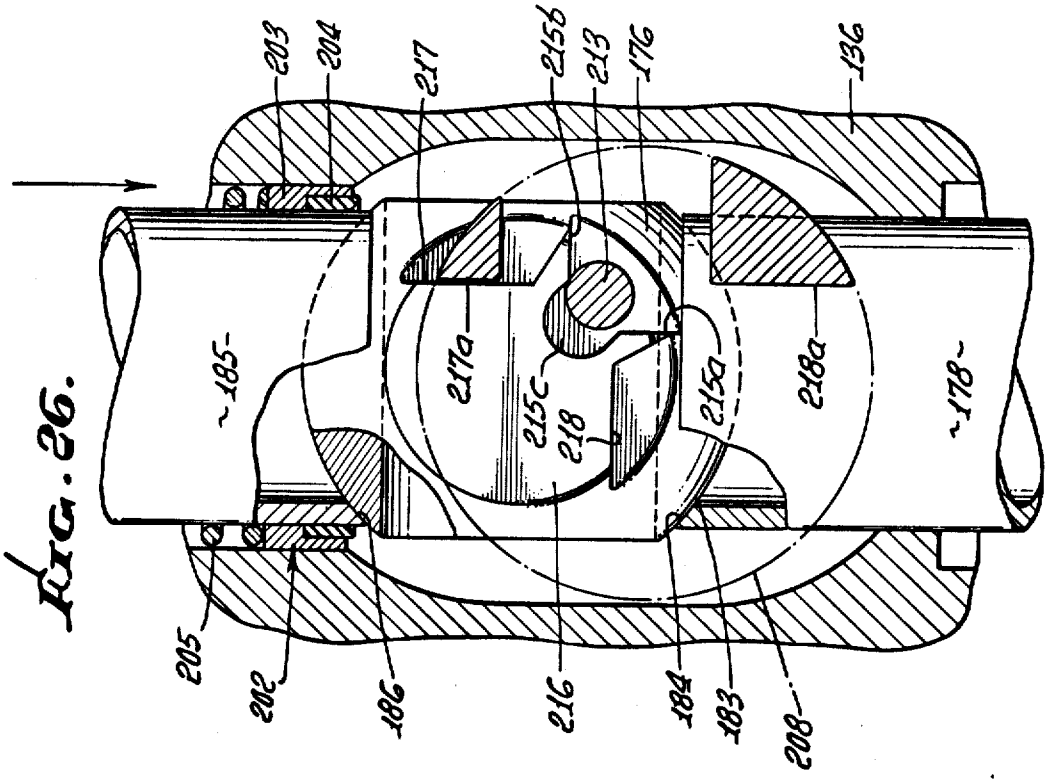

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Fig. 26.

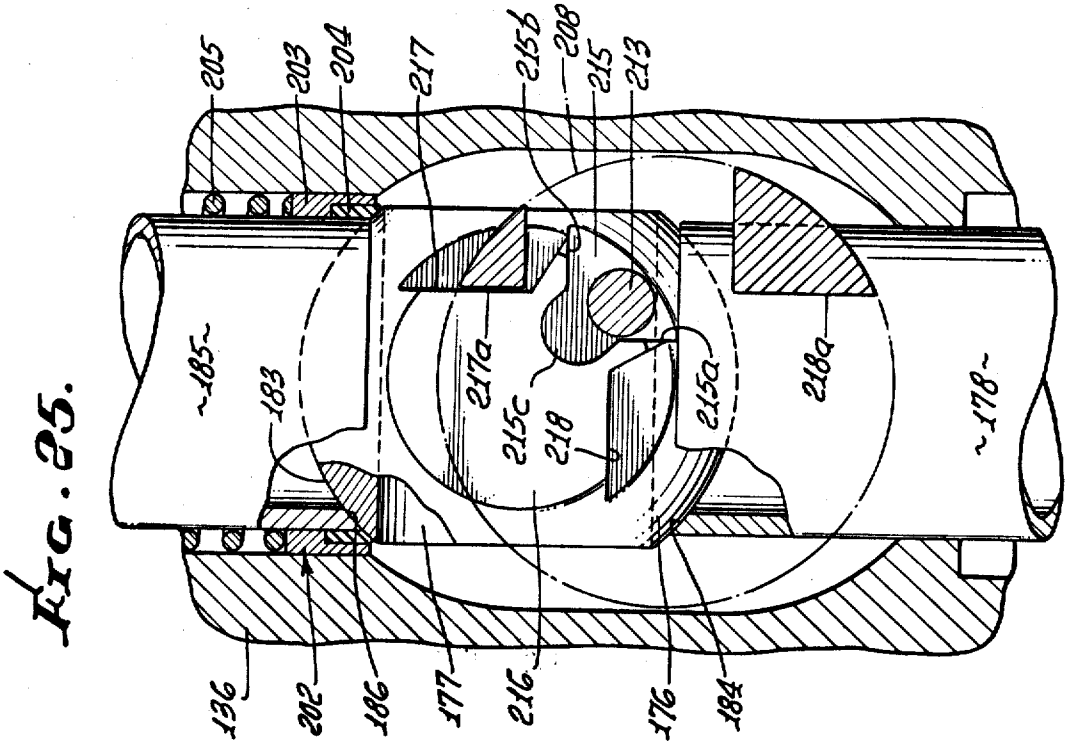

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Fig. 25.

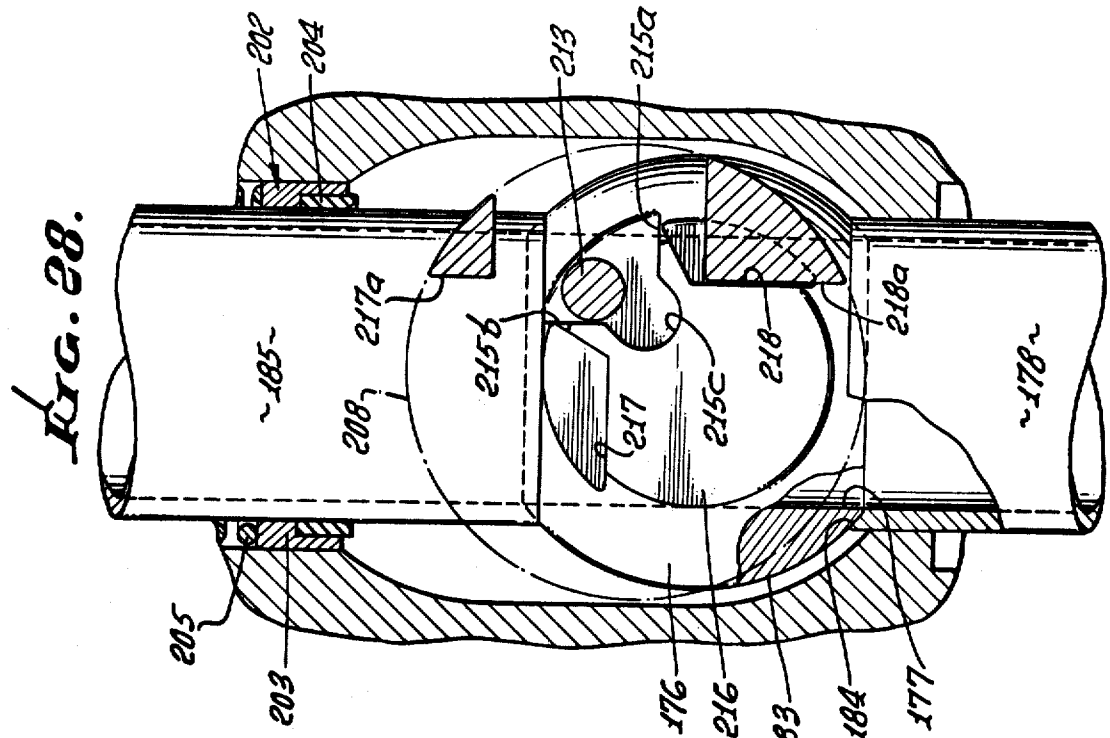

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Fig. 28.

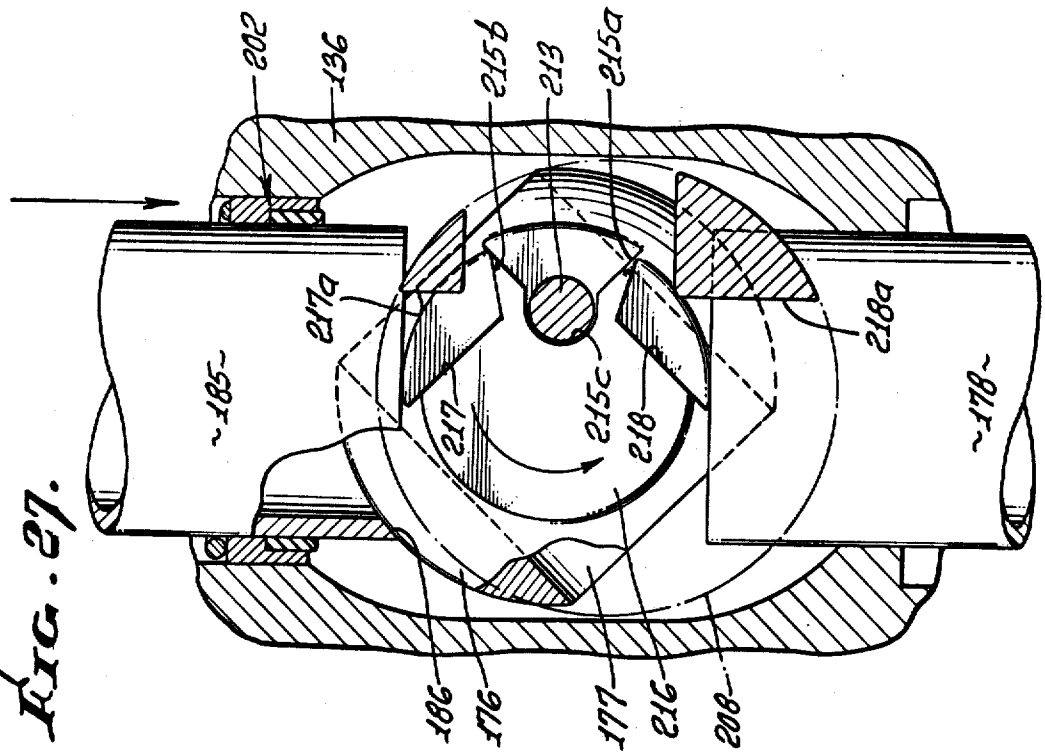

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Fig. 27.

Fig. 29a.

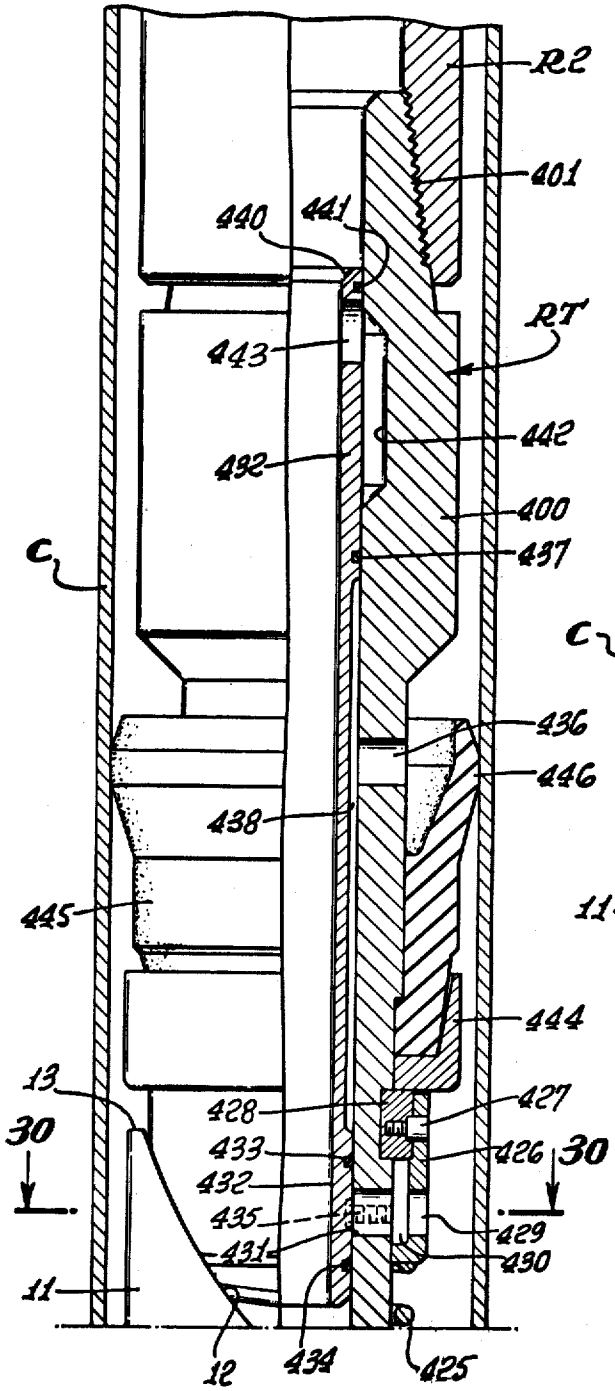


Fig. 29b.

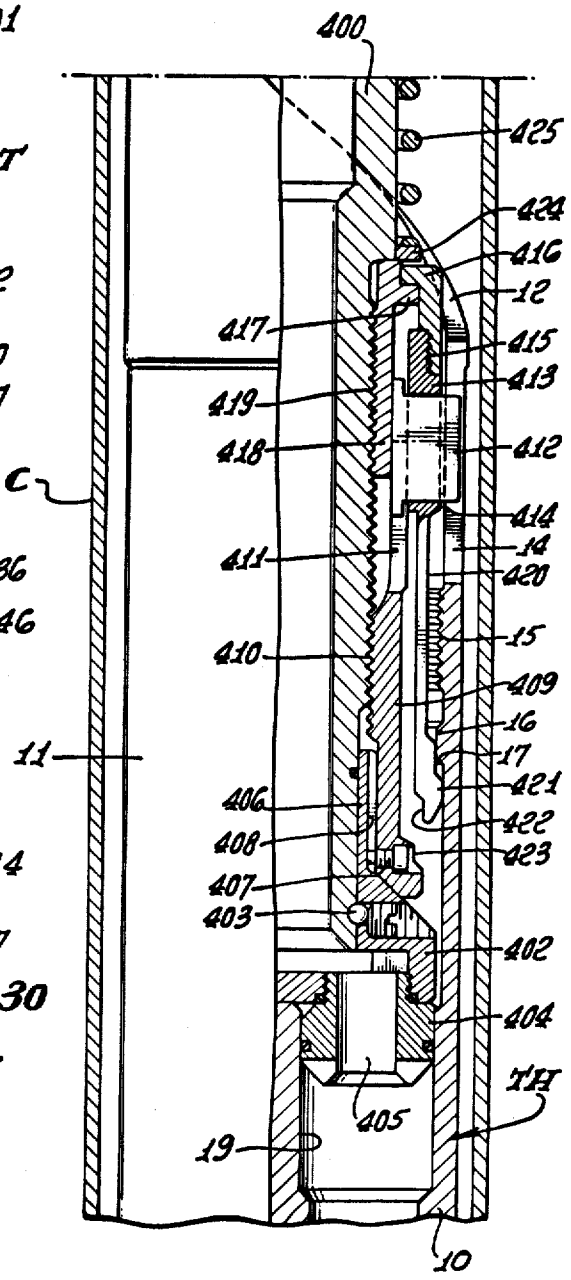


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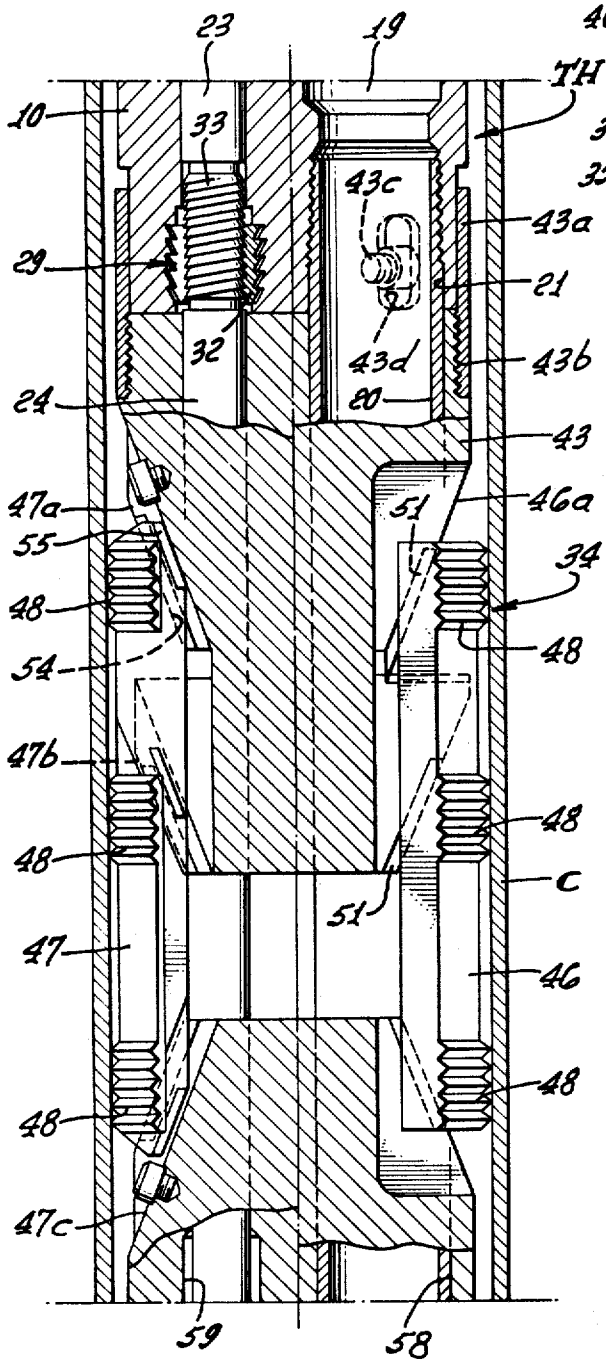


FIG. 29d.

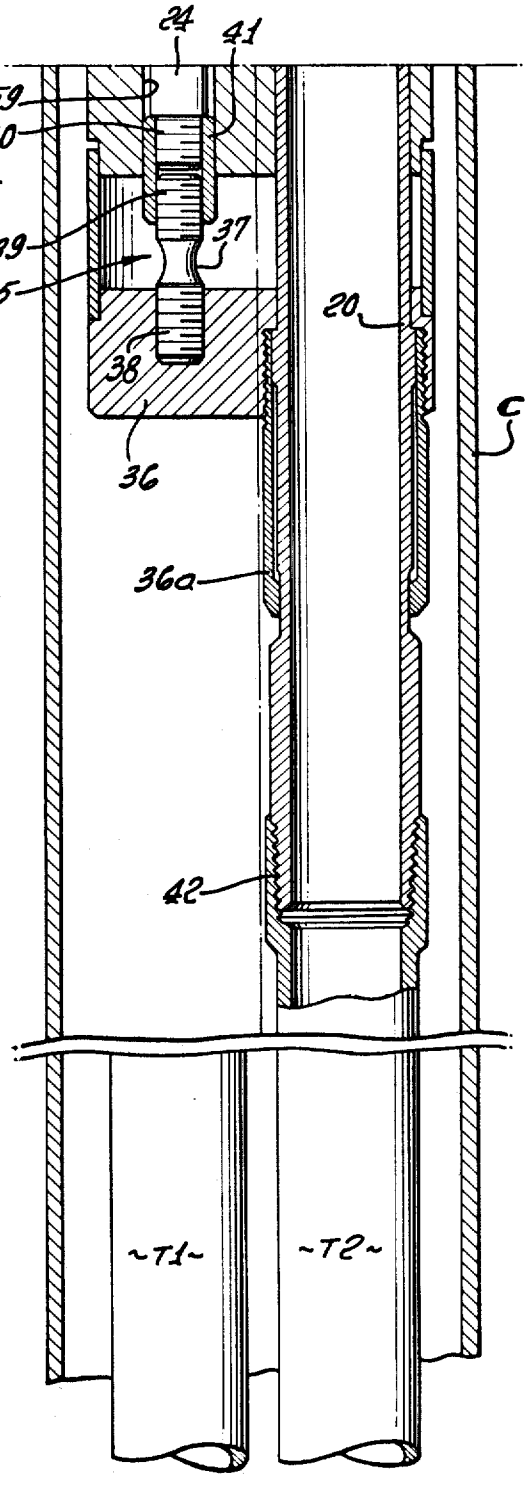


FIG. 31a.

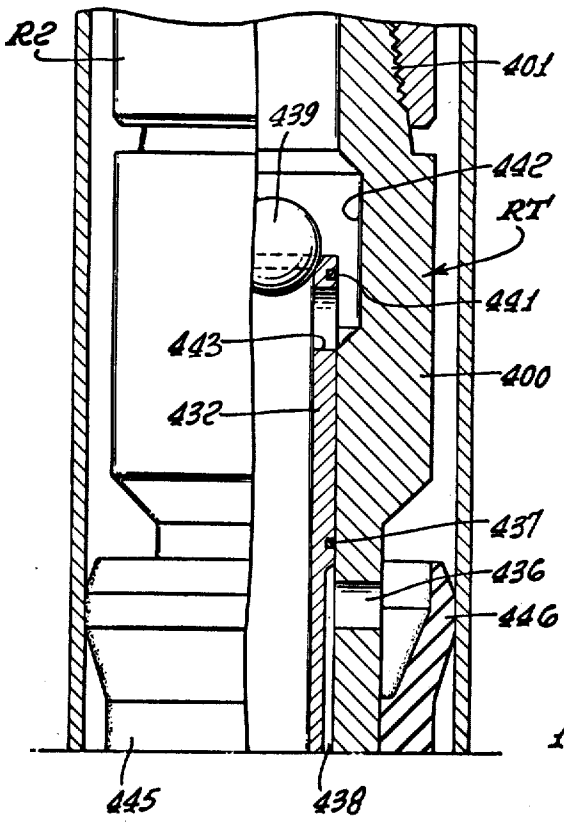


FIG. 30.

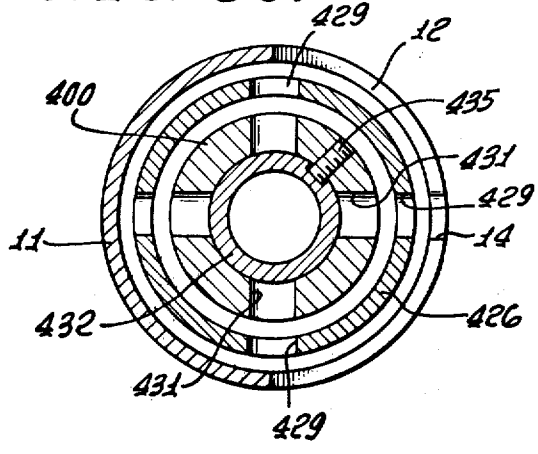


FIG. 31b.

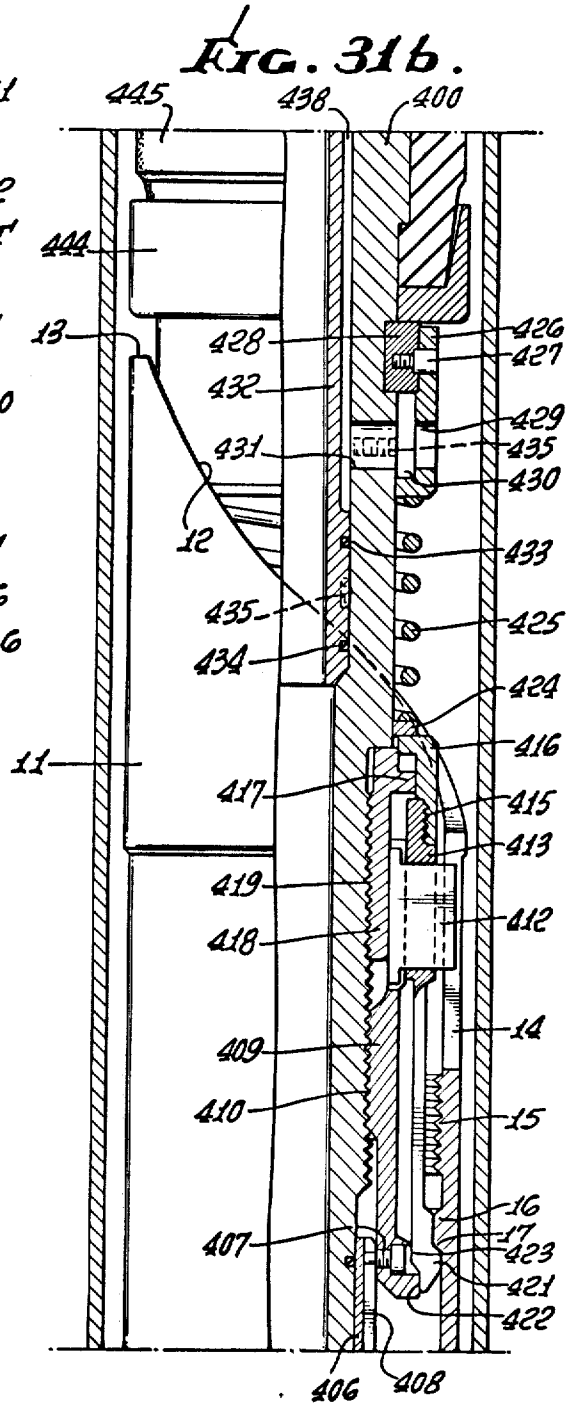


FIG. 31c.

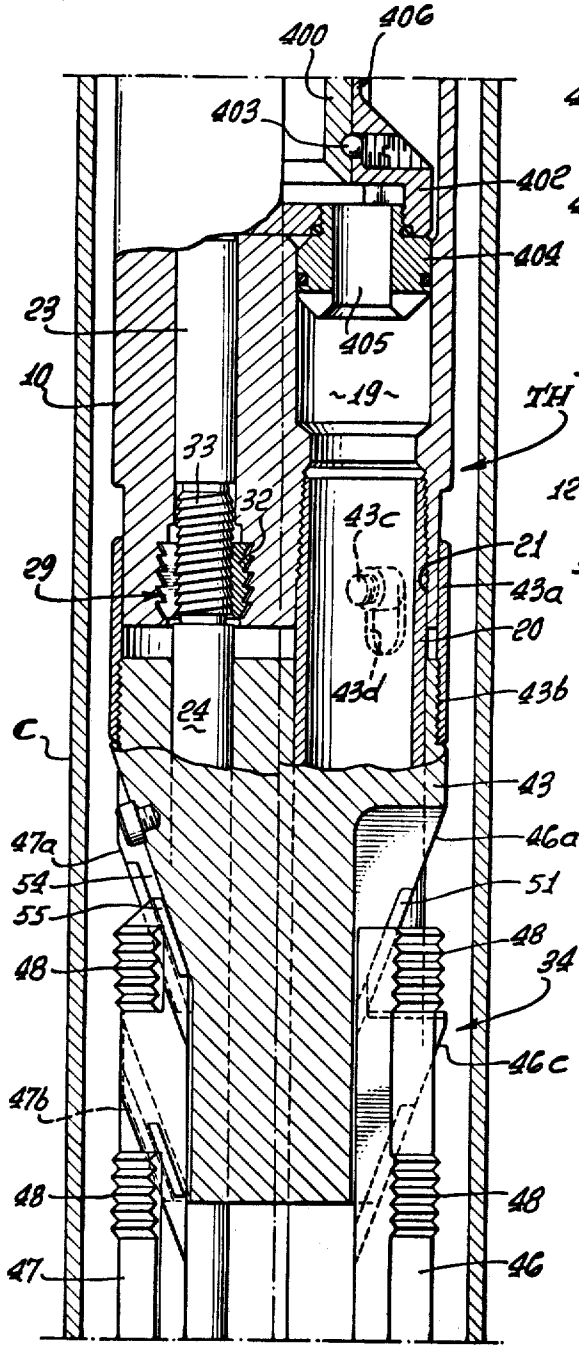
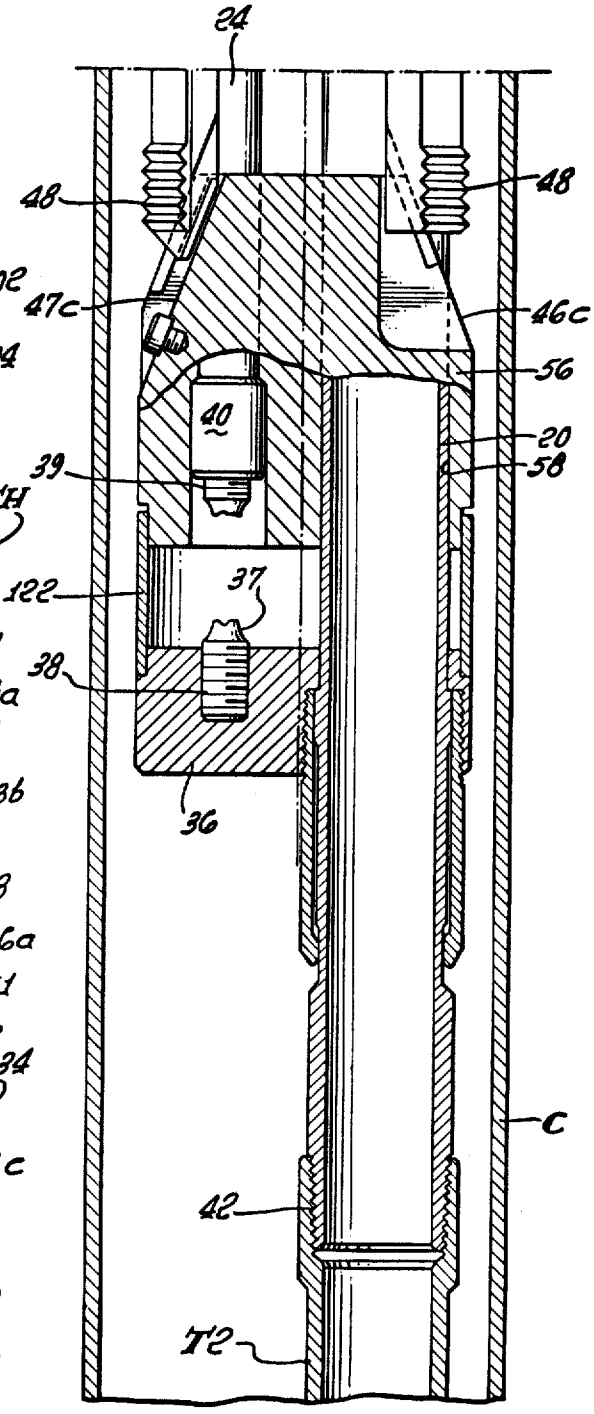


FIG. 31d.



TUBING HANGER SETTING TOOL

This application is a division of application Ser. No. 275,911, filed July 28, 1972, now U.S. Pat. No. 3,830,295 which is a division of application Ser. No. 243,806, now U.S. Pat. No. 3,771,603 filed Apr. 13, 1972.

The present invention relates to setting tools for lowering tubing hangers, and the like, into well casings disposed in a well bore and for setting such hangers in the well casings, and more particularly to setting tools used in conjunction with tubing hangers having a plurality of longitudinal passages through which well production from a plurality of formation zones may be conducted to the top of the well bore, or to a location above the well bore.

As set forth in applicant's copending United States application, Ser. No. 275,911, filed July 28, 1972, a tubing hanger is provided which supports a plurality of production tubing strings depending therefrom, such strings appropriately communicating with a plurality of production zones in the well bore. The tubing hanger has seats for removable safety valves that control fluid flow through the production tubing strings.

The present invention involves an improved setting tool attachable to a running string, and releasably securable to a tubing hanger for lowering the tubing hanger, with production tubing depending therefrom, into a desired setting location in well casing located in the well bore, the setting tool being appropriately operated to effect anchoring of the tubing hanger to the well casing, and then being releasable from the tubing hanger, permitting withdrawal of the running string and setting tool from the well bore.

More specifically, the setting tool can be operatively associated with a tubing hanger having a plurality of longitudinal fluid passages, the setting tool being actuated by fluid pressure to effect anchoring of the tubing hanger against the surrounding well casing, and also to condition the setting tool for subsequent release from the tubing hanger, as by rotating the running string to which the setting tool is attached. The setting tool is threadedly attached to the tubing hanger, rotation of the setting tool by the running string effecting unthreading and release of the setting tool from the tubing hanger.

A further objective of the invention is to provide a setting tool threadedly attachable to a tubing hanger, and in which the setting tool is hydraulically actuated to shift portions of the tubing hanger in opposite longitudinal directions, to produce anchoring of the tubing hanger in the well casing and to condition the setting tool to permit its rotation with respect to the tubing hanger and its release there from.

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:

FIG. 1 is a diagrammatic illustration showing dual safety valve apparatus installed in a tubing hanger anchored in a well casing extending through vertically spaced productive well zones which are isolated from one another by packers, and from which well fluids are produced through a pair of production tubing strings;

FIG. 2 is a fragmentary detailed view illustrating the tubing hanger set in the well casing by a setting tool;

FIG. 3 is an enlarged horizontal section as taken on the line 3—3 of FIG. 2;

FIGS. 4*a*, 4*b*, 4*c* and 4*d* together constitute a longitudinal section through the tubing hanger and setting tool, as taken on the line 4—4 of FIG. 3, with certain of the parts shown in elevation, FIGS. 4*b* through 4*d*, respectively, constituting successive downward continuations of FIGS. 4*a*, and shown prior to setting of the tubing hanger in the well casing;

FIGS. 5*a*, 5*b* and 5*c* together constitute a longitudinal section generally corresponding to FIGS. 4*a* through 4*d*, FIGS. 5*b* and 5*c*, respectively, constituting successive downward continuations of FIG. 5*a*, and showing the tubing hanger set in the well casing and also showing the setting tool released from the tubing hanger;

FIG. 6 is a horizontal section as taken on the line 6—6 of FIG. 4*b*;

FIG. 7 is a horizontal section as taken on the line 7—7 of FIG. 4*c*;

FIG. 8 is a horizontal section as taken on the line 8—8 of FIG. 4*c*;

FIG. 9 is a horizontal section as taken on the line 9—9 of FIG. 4*d*;

FIG. 10 is a fragmentary vertical section as taken on the line 10—10 of FIG. 9;

FIGS. 11*a*, 11*b*, 11*c* and 11*d* together constitute a view generally in elevation, but with certain parts broken away, showing the subsurface valve assembly landed in the tubing hanger, FIGS. 11*b* through 11*d*, respectively, constituting successive downward continuations of FIG. 11*a*;

FIG. 12 is a view partly in elevation and partly in section as taken on the line 12—12 of FIG. 11*d*;

FIG. 13 is a horizontal section as taken on the line 13—13 of FIG. 11*b*;

FIG. 14 is a horizontal section as taken on the line 14—14 of FIG. 11*d*;

FIG. 15 is a horizontal section as taken on the line 15—15 of FIG. 11*d*;

FIG. 16 is a horizontal section as taken on the line 16—16 of FIG. 11*a*;

FIG. 17 is a horizontal section as taken on the line 17—17 of FIG. 11*b*;

FIGS. 18*a* and 18*b* together constitute a vertical section through one of the subsurface valve assemblies, as taken on the line 18—18 of FIG. 16, FIG. 18*b* constituting a downward continuation of FIG. 18*a*, and the valve being shown in the normally closed condition;

FIGS. 19*a* and 19*b* together constitute a view generally corresponding to FIGS. 18*a* and 18*b*, showing the valve assembly in the open condition;

FIG. 20 is a vertical section as taken on the line 20—20 of FIG. 18*a*;

FIG. 21 is a horizontal section as taken on the line 21—21 of FIG. 18*a*;

FIG. 22 is a fragmentary horizontal section as taken on the line 22—22 of FIG. 18*b*;

FIG. 23 is a fragmentary vertical section as taken on the line 23—23 of FIG. 16;

FIG. 24 is an exploded detail view in perspective, showing a typical ball valve and a removable side closure and valve supporting member;

FIG. **25** is a fragmentary detailed view partly in elevation and partly in section showing the ball valve in a closed position;

FIG. **26** is a view generally corresponding to FIG. **25**, but showing the ball valve shifted longitudinally downwardly from engagement with the resilient seal but prior to rotation towards the open position;

FIG. **27** is a view corresponding to FIGS. **25** and **26**, showing the ball valve rotated towards an open position;

FIG. **28** is a view corresponding to FIGS. **25** through **27**, but showing the ball valve in the full open position;

FIGS. **29***a*, **29***b*, **29***c* and **29***d* together constitute a view, partly in vertical section and partly in elevation, showing a tubing hanger retrieving tool landed in the set tubing hanger, FIGS. **29***b* through **29***d*, respectively, constituting downward continuations of FIG. **29***a*;

FIG. **30** is a horizontal section as taken on the line **30—30** of FIG. **29***a*; and

FIGS. **31***a*, **31***b*, **31***c* and **31***d* together constitute a view, partly in vertical section and partly in elevation, showing the retrieving tool locked in engagement with the tubing hanger and showing the tubing hanger released from the well casing, FIGS. **31***b* through **31***d*, respectively, constituting successive downward continuations of FIG. **31***a*.

As seen in the drawings, referring first to FIG. **1**, a well bore W extends downwardly into the earth below the ocean floor F through vertically spaced well fluid producing zones Z1 and Z2. A casing C is set in the well bore and perforations P in the casing establish communication between the productive zones Z1 and Z2 and the casing C. Set in the casing C is an upper packer P1 located above the productive zone Z1 and a lower packer P2 located in the casing between the productive zones Z1 and Z2. A first production tubing string T1 extends through the packer P1 and opens into the casing therebelow to communicate with the productive zone Z1, and a second production tubing string T2 extends downwardly through the upper packer P1 and downwardly through the lower packer P2 into the casing therebelow for communication with the productive zone Z2. The tubing strings T1 and T2 may extend a number of thousands of feet downwardly in the casing to the packers P1 and P2 and the tubing strings T1 and T2 are supported by tubing hanger means TH which is set or anchored in the well casing and forms a seat for a shutoff valve assembly V which comprises dual shutoff valves V1 and V2 for the respective tubing strings T1 and T2. The tubing hanger TH and the valve assembly V are located below the ocean floor or the mud line of a body of water, at a desired or required depth of say 500 to 1,000 feet, more or less. The casing C extends upwardly through the water to a production platform or barge PP, as shown in the diagrammatic illustration. However, as is well known, the well may be completed at the ocean floor and one or a number of additional casings (not shown) may be set in larger diameter well bores, and the casing C may be suspended or hung from a casing hanger located at the ocean floor, in which case, a conductor pipe or other casing (not shown) may extend to the production platform PP. In any event, upper production fluid tubings T3 and T4 extend upwardly from the respective valves V1 and V2 of the valve assembly V and are connected with the usual Christmas Trees CT on the platform PP whereby the flow of well fluids from the well zones Z1 and Z2 may be controlled or manually shut off. Flow lines FL are provided to conduct well fluids from the Christmas Trees to suitable reservoirs or tanks (not shown).

The respective subsurface valves V1 and V2, which are normally closed, are adapted to be held open, to enable the flow of production fluids therethrough, by means of control fluid pressure supplied through a control fluid conduit CF, or through a pair of such conduits, from a source of control fluid pressure CP. So long as the control fluid pressure is adequate to maintain the subsurface valves V1 and V2 open, well fluids may flow from the zones Z1 and Z2 to the respective flow lines FL, but, if it is desired for any reason to close either of the shutoff valves V1 or V2, or in the event of damage of the control fluid tubing, the control fluid pressure may be reduced so that the subsurface valves V1 and V2 are automatically closed, thereby shutting the well in at a location below the ocean floor, to prevent continued production fluid flow.

As will be later described, the tubing hanger assembly TH and the tubing strings T1 and T2 are adapted to be lowered from the platform PP downwardly through the casing C on a setting tool ST, as seen in FIG. **2**, and the valve assembly V is thereafter adapted to be lowered through the casing C into the tubing hanger TH on the upper tubing strings T3 and T4. Likewise, the valve assembly V can be retrieved from the tubing hanger TH, so that under normal circumstances requiring repair or service of the subsurface valve assembly V, it is not necessary to pull the entire dual tubing strings T1 and T2, as has heretofore been the practice. Since only the comparatively short upper tubing strings T3 and T4 need be pulled from the well to remove the valve assembly V, and the substantially longer tubing strings T1 and T2 remain in the well, the platform PP need not be equipped with or supplied with high-powered hoisting apparatus. Instead, the platform PP may simply be provided with a small low-powered hoist mechanism or a gin pole hoist. In addition, the tubing strings T1 and T2 can be plugged off at or below the tubing hanger TH to enable the service or repair of the valves V1 and V2 without requiring that the well be killed.

As seen in FIGS. **2** through **5***c*, the tubing hanger TH comprises a body section **10** having an upwardly extended tubular guide section **11**, the upper end edge **12** of which is arched downwardly from a peak **13**, in opposite directions, to a vertically extended slot **14** at the side of the guide section **11** diametrically opposite the peak **13**. Internally of the guide section **11**, between the lower end of the slot **14** and the body section **10**, is a thread **15** to which the setting tool ST is connected, as will be later described. Below the internal thread **15**, is an internal flange **16** which provides a downwardly facing shoulder **17**, for purposes also to be later described.

Extending downwardly into the body section **10** from the guide section **11**, are a pair of diametrically spaced fluid passages **18, 18** at the upper end of each of which is a cylindrical receptacle or socket **19**. At the lower end of the body section **10**, a pair of tubular members **20** are threadedly engaged in a bore **21** in communication with the respective body passages **18, 18**. Also, at diametrically spaced locations, the body section **10** has a pair of bores **22** in which the upper ends **23** of tie rods **24** are disposed. Each of these tie rods **24** has a socket **25** in its upper end **23** adapted to receive the reduced lower end **26** of a setting tool connector rod **27**, the re-

duced end **26** being connected to the tie rods **24** by shear pins **28.** At the lower end of each bore **22** is a resilient split lock ring **29** having external, upwardly facing buttress threads **30** loosely fitting within complemental buttress threads **31** in an enlarged bore in the body section **10.** The lock ring **29** has internal upwardly facing smaller threads **32** engageable by external threads **33** on the tie rods **24,** as seen in FIG. **5***b*, when, as will later be described, the tie rods **24** are pulled upwardly. The tie rods **24** extend downwardly through normally retracted but outwardly expansible anchor means **34,** and, at their lower ends, the rods **24** are releasably connected by a frangible connector screw **35** to a lower end or body member **36** of the tubing hanger assembly. The frangible connector screw **35** has a reduced frangible section **37** and a threaded end **38** engageable in the lower end member **36,** as well as an upper threaded end **39** connected to the threaded lower end **40** of the rod **24** by an internally threaded connector sleeve **41.** The pair of tubular members **20,** previously referred to, also extend slidably downwardly through a split collar **36***a* (FIG. **29***d*)carried by the lower body **36** and have threaded lower ends **42** adapted for connection with the respective tubing strings T1 and T2.

The anchor means **34,** as seen in FIGS. **4***c*, **5***c* and **8,** comprises an upper expander member **43** having longitudinally extended openings **44** at opposite sides thereof to accommodate the tubular conduit members **20,** as well as elongated openings **45** to accommodate the tie rods **24.** The expander member **43** is connected to the tubing hanger body **10** for limited relative axial movement by a sleeve **43***a* which is threaded on the expander member **43,** at **43***b*, and slidably extends onto the lower end of the tubing hanger body **10.** Screws **43***c* at circumferentially spaced locations, as seen in FIG. **7,** extend through elongated slots **43***d* in the sleeve **43***a* and are threaded into the body **10.** Connected to the upper expander member **43** are opposed pairs of expansible, casing engaging slip elements **46, 46** and **47,** 47, respectively, disposed at opposite sides of the expander member **43.** The slip elements **46** and **47** are so constructed as to engage the casing over a substantial portion of the surrounding casing and have vertically spaced sets of teeth or wickers **48** adapted to anchor in the casing responsive to outward expansion of the slip elements **46** and **47.**

As best seen in FIGS. **4***c* and **8,** the upper expander member **43,** at opposite sides thereof, has upwardly and outwardly inclined wedge surfaces **46***a* and **46***b*, in vertically spaced relation thereon, and at opposite sides of the expander surfaces are suitable elongated slots **51** adapted to receive marginal inturned flanges **52** on the slip elements **46,** as best seen in FIG. **8,** whereby the slip elements **46** are retained in assembly with the expander member **43.** The bores **44** for the tubular members **20** interrupt the expander surfaces **46***a*, **46***b* and the inner face of the slip elements **46** are recessed at **50** to accommodate peripheral portions of the tubular members **20,** so that the latter may be of a larger diameter. The expander member **43** also has opposed upwardly and outwardly inclined expander surfaces **47***a* and **47***b*, and opposed T-slots **54** which receive correspondingly T-shaped portions **55** of the slip elements **47** whereby these slip elements are also connected to the upper expander member **43.** The expander surfaces **47***a*, **47***b* are interrupted by the bores **45** which accommodate the connector rods **34,** and the T-shaped portions **55** of the slip elements **47** are longitudinally recessed to receive peripheral portions of the connector rods **24.**

At their lower ends, the slip elements **46** and **47** are connected to a lower expander member **56** having upwardly and inwardly inclined expander surfaces, such as the expander surfaces designated **46***c* and **47***c* in FIGS. **4***c* and **5***c*, for forcing the lower portions of the slips **46** and **47** toward the casing. The lower expander member **56** also has openings **58** for the tubular conduits **20** and openings **59** for the rods **24.** It will be apparent without need of further illustration or description that when the expander members **43** and **56** are moved axially toward one another, the expander surfaces described above will effect outward expansion of the slip elements **46** and **47** from their normally retracted positions into anchoring engagement with the casing, i.e., from the position of FIG. **4***c* to the position of FIG. **5***c*, in which, for clarity, one of the respective slip elements **46** and **47** is illustrated in elevation. Casing engaging anchor means of this general type are well known.

However, in the present case, the slip elements **46** and **47** are units having the teeth or wickers formed in axially spaced locations which are directly engaged by the respective wedge surfaces **46***a*, **46***b* and **46***c* and by the respective wedge surfaces **47***a*, **47***b* and **47***c*. The wedge surfaces **46***a* and **46***b* and the wedge surfaces **47***a* and **47***b* are forced downwardly by the weight of the tubing strings T1 and T2 to force the upper two sets of wickers or teeth **48** on the slip elements or units **46** and **47** into gripping engagement with the casing to support the tubing strings T1 and T2. In the event that well pressure should tend to force the tubing hanger upwardly in the well casing, say when the valves V1 and V2 are closed, the lower set of teeth or wickers **48** on the slips **46** and **47** will be forced outwardly by wedge or expander surfaces **46***c* and **47***c* to hold the hanger down.

As best seen in FIG. **8,** moreover, the slip elements **46** and **47** are essentially chordal in section and the expander body **43** is essentially square in section. The slip elements **47,** at their vertical side portions, overlap the vertical side edges of the slip elements **46,** so that, in combination, the slip elements define a substantially circumferentially continuous anchor means, which when set in engagement with the casing will be interrupted at the overlapping slip portions to an extent determined by the relative longitudinal movement between the expander body **43** and the slip elements **46** and **47,** and the angle of the wedge surfaces, to effect anchoring engagement of the slip elements with the casing.

The setting tool means for setting the tubing hanger TH in the casing, with the tubing strings T1 and T2 suspended thereby, is illustrated in FIGS. **4***a* and **4***b* in the running in condition and in FIGS. **5***a* and **5***b* in a condition for setting the tubing hanger. The setting tool ST is adapted to be made up in an assembly with the tubing hanger TH, before the tubing hanger is run into the well casing, and includes an elongated tubular outer body **60** having an external thread **61** engageable in the internal thread **15** of the upper section **11** of the tubing hanger TH. At its upper end, the setting tool body **60** is threadedly connected at **62** to a connector sub **63** which in turn is threadedly connected at **64** to the

lower end of a running-in string of pipe R, whereby the setting tool ST with the tubing hanger TH connected thereto may be lowered into the well casing. Reciprocably disposed within the setting tool body **60** is an inner tubular body **65**. Connected to the outer body **60** is an annular piston **66** which seats on an upwardly facing shoulder **67** and has an inner skirt **68** extending downwardly about the inner body **65** to a position below a suitable number of radial ports **69** in the body **65**. Seal ring means **70** are disposed between the skirt **68** and the body **65**, and the annular piston **66** has inner sealing ring means **71** and outer sealing ring means **72**, respectively, engaged with the inner body **65** and with the outer body **60**. Above the annular piston **66**, the inner body **65** has a collar **73** provided with a suitable number of radial ports **74**, and an upper annular piston **75** has an internal flange **76** which seats on the collar **73** and is retained in place by an upper, inner body section **65***a* which is threadedly connected at **77** to the inner body **65**, and which extends upwardly through the outer body **60** and into the connector sub **63**. The upper piston **75** has inner sealing ring means **78** and outer sealing ring means **79** sealingly engaged with the collar **73** and with the outer body **60**. Accordingly, there is defined between the inner and outer bodies **65** and **60** and the lower and upper pistons **66** and **75**, an annular pressure chamber **80** with which the ports **74** communicate.

The upper inner body section **65***a* is provided with resilient collett fingers **81** spaced circumferentially therein and having lower latch lugs **82** initially held in latching engagement beneath an inner shoulder **82***a* on an outer body member **83** which is threadedly connected at **83***a* within the outer body **60**. The collett fingers **81** cooperate with body locking means **84** at the lower end of the inner setting tool body **65** to hold the setting tool bodies **60** and **65** in an initial telescopically contracted condition. The body lock means **84**, as seen in FIG. **4***b*, comprises a resilient lock ring **85** having external buttress teeth **86** engageable with complemental teeth **87** within a bore **88** in a lower body member **89** which is threaded at **90** to the lower end of the inner body **65**. The lock ring **85** has inner and smaller buttress teeth **91** adapted to engage complemental teeth **92** on the upper end of the connector rod **27** when the latter is forced axially into the lock ring **85** upon assembly of the setting tool with the tubing hanger. The inner body member **89** also has a pair of slow tubes **93** threadedly engaged, as at **94**, in diametrically spaced bores **95** in the body member **89** and communicating with a central bore **96**, which in turn communicates with the tubular body **65**. The flow tubes **93** have lower end sealing portions **97** having sealing rings **98** engageable in the diametrically opposed receptacles or bores **19** in the tubing hanger body **10**, previously described, whereby fluid may be circulated downwardly through the running-in string of pipe R. The outer setting tool body **60** has an elongated vertical slot **100** which receives the head of a key in the form of a screw **101** which is threaded into the inner body member **89**, whereby rotation of the running-in string R is transmitted to the body **60**.

The ports **74** leading to the pressure chamber **80** are initially closed by an inner sleeve **105** which has vertically spaced seals **106** and **107** straddling the ports **74** to initially close the same. Above the seal **107**, the sleeve **105** has a number of radial ports **108** adapted to communicate with the pressure chamber ports **74**, upon downward movement of the sleeve **105**, to the position shown in FIG. **5***a*, when a ball **109** is introduced into the fluid stream and engages the seat **110** in the sleeve **105** so that fluid pressure shifts the sleeve **105** downwardly. The sleeve **105** extends upwardly, initially, past the lower ends of the collett fingers **81** and normally holds the latter in latching engagement with the flange **83**, as shown in FIG. **4***a*, until the sleeve **105** is shifted downwardly to release the collett latch fingers **81**.

From the foregoing, it will be understood that the tubing hanger assembly TH is run into the well casing on the setting tool ST. When it is desired to set the tubing hanger in the casing, the ball **109** is dropped onto the sleeve seat **110**, and the application of fluid pressure will force the sleeve **105** downwardly to the position of FIG. **5***a*, at which the sleeve ports **108** and the pressure chamber ports **74** are in registry. Fluid pressure is then applied in the pressure chamber **80** between the annular pistons **66** and **75** to telescopically extend the setting tool bodies **60** and **65**, which have been released for extension when the upper end of the sleeve **105** clears the collett fingers **81** so that they may flex inwardly.

flow a downward force is applied through the piston **66** to the outer setting tool body **60** which is transmitted to the tubing hanger body section **11**. An upward force is applied to the inner setting tool body **65** by the piston **75** and this upward force is transmitted through the connecting rods **27** to the tie rods **24**. Since the tie rods **24**, as previously described, are connected to the lower end member **36** of the tubing hanger assembly, the latter is pulled upwardly while the tubing hanger body **10** is pushed downwardly, and the expander members **43** and **56** of the tubing hanger are correspondingly moved towards one another to force the slip elements **46** and **47** outwardly into anchoring engagement with the casing. When the slip elements are fully set and anchored so that no further telescopic contraction of the setting tool is permitted, the shear pins **28**, which connect the connector rods **27** to the tie rods **24**, will be broken, as seen in FIG. **5***b*, and the inner setting tool body **65** and its connected member **89** are then free to move upwardly, clearing the flow tubes **93** from the tubing hanger, so that the setting tool assembly is then free for rotation. The running-in string R is then rotated to release the thread **61** on the outer setting tool body **60** from the inner tubing hanger thread **15**, as will be apparent.

Means are incorporated in the tubing hanger assembly to maintain a force which tends to urge the expanders **43** and **56** towards one another, such a means is best seen in FIGS. **9** and **10**, as comprising a suitable number of angularly spaced spring means **115**. More particularly, at each location a bolt **116** is threaded at **117** into the lower end of the lower expander member **56** and extends downwardly, slidably, through holes **118** in the lower end member **36**, the bolt heads **119** shouldering at **120** to retain the member **36** in assembly. Interposed between the lower end member **36** and the expander **56** is a stack of Belville washers **121** adapted to exert substantial force tending to spread the members **36** and **56** apart. As previously indicated and as seen in FIG. **4***d*, for example, the tie rods **24** are also connected to the lower member **36**, and when the tie rods **24** move upwardly, the teeth **33** thereon (FIG. **4***c*)

will move into engagement with the lock ring **29** (FIG. 5*b*) so that the force of the Belville washers **121** is applied downwardly to the upper expander **43** and upwardly to the lower expander **56.** The Belville washers **121** are compressed during setting of the tubing hanger to the extent determined by the movement of an outer sleeve **122** carried on the lower body member **36** and movable upwardly relative to the expander member **56** into engagement with a downward facing shoulder **123,** as the anchor means **34** are being set.

When the setting tool has been removed from the well casing, the tubing hanger assembly is then in condition to receive the dual valve assembly V, as seen in FIGS. **11***a* through **11***d*.

The dual valve assembly V, as previously indicated, comprises, in the illustrated embodiment, a pair of valves V1 and V2, since the apparatus is shown as applied to producing from a pair of well zones Z1 and Z2, but it will be understood that the invention is applicable, also, to the production from more than two well zones.

At its lower end, as seen in FIGS. **11***d* and **12,** the valve assembly V is adapted to be received in the upper tubing hanger body section **11** and to be latched in place by releasable latch means **125** beneath the internal flange **16** in the hanger body section **10.** At diametrically spaced locations in a cross-head **126** of the latch means **125,** the latch means **125** has elongated laterally opening spaces **127, 127** accommodating flow tubes **128** and **129** which are respectively adapted to establish communication between the tubing strings T1 and T2 and the valve assemblies V1 and V2, respectively.

At their lower ends, the flow tubes **128** and **129** have sealing end portions **130** and **131,** respectively, each having sealing ring means **132** engageable within the bores or receptacles **19** in the tubing hanger body **10.** The flow tube **128** extends upwardly from the cross-head **126** and is connected at **133** to a length of tubing **134** which extends further upwardly a suitable distance, and is connected at **135** to the housing **136** of the upper valve assembly V1, which will be hereinafter described. The flow tube **129** also extends upwardly from the cross-head **126** and is connected at **137** to the valve assembly V2, which is spaced vertically downwardly from the valve assembly V1 to enable utilization of valve assemblies V1 and V2 having full bore flow passages, as will also be later described. Extending upwardly from the valve housing **138** through swivel means **139** is a rotatable tubular member **140** which is connected at its upper end by a coupling **141** to the tubing string T4 above the connection of the tubing string T3 to the valve assembly V1, as seen in FIG. **11***a*. Rotation of the tubing string T4 and, thus, the tubular member **140** is utilized to engage and release the latch means **125** when the valve assembly V is run into the tubing hanger TH.

The flow tubes are retained in parallel, assembled relation by a vertically split body **142** comprising opposed half sections **143** and **144,** as seen in FIG. **15,** clamped together by fasteners **145.** The body sections **143, 144** have internal grooves **146** which receive annular ribs **147** on the flow tubes **128, 129** to hold the latter against relative axial movement.

When the valve assembly V is being lowered into the tubing hanger TH, a key **148** on one side of the assembly, shown on the flow tube **129,** and engageable with the peak **13** of the hanger body section **11** will cause rotation of the valve assembly V, as the key **148** rides downwardly on the inclined surface **12** and is guided into the vertical slot **14,** whereby the lower ends **130,** 131 of the flow tubes **128, 129** will be properly positioned or oriented so as to be stabbed into the bores or receptacles **19** in the hanger body **11.**

The latch means **125** referred to above, comprises a plurality of resilient, normally retracted collett fingers **150** depending from the cross-head **126** and having outwardly projecting latch lugs **151** at their lower ends. The lower ends of the latch fingers **150** are expansible outwardly by a wedge surface **152** on the split body **142** when the cross-head **126** is moved downwardly relative to the body **142,** from the position of FIG. **11***d* to the position of FIG. **12.** Means **155** are provided for normally holding the latch fingers **150** in the retracted positions, and spring means **156** are provided for actuating the cross-head **126** downwardly to cam the fingers **150** outwardly.

More particularly, a pair of bolts **157** extend through the cross-head **126** and have their heads **158** engageable beneath the cross-head **126** to hold the latter in an upper position, as seen in FIG. **11***d*. These bolts **157** are threaded into a plate **159** which is connected to a pull rod **160,** the pull rod extending upwardly alongside the length of tubing **134** and being connected, as seen in FIG. **11***b*, to a non-rotatable nut **161,** having a notch **162** for straddling the tubing **134** to prevent rotation of the nut. The nut **161** has a threaded bore **163,** in which a complemental thread **164** on the rotatable tubing section **140** is engaged. Accordingly, when the tubing string T4, which, as previously indicated, is connected to the tubing section **140,** is rotated, the nut **161** is moved axially on the tubing section **140,** downwardly, from the position of FIG. **11***b*, to allow downward movement of the plate **159** and the bolts **157.**

The spring means **156** are operable to force the cross-head **126** downwardly and comprises a pair of coiled compression springs **165** disposed about the bolts **157** and seating at their lower ends in bores **166** in the cross-head **126** and at their upper ends against a spring seating plate **167** which abuts beneath the lower valve housing **138.** When the cross-head **126** is moved downwardly by the springs **166,** the lugs **151** on the latch fingers **150** are cammed by the cam surface **152,** outwardly for engagement beneath the latch shoulder **17** of the tubing hanger body section **11.**

As seen in FIGS. **11***a* through **11***d*, the control fluid conduit CF is connected by a fitting **170** to the upper valve housing **136** of the valve V1 and passage means **171** in the housing **136** conduct control fluid to an outlet fitting **172** which is connected to a conduit **173** leading to an inlet fitting **174** for the lower valve V2. However, if preferred, plural control fluid tubings CF may be employed to supply control fluid pressure to the valves V1 and V2.

The fluid pressure responsive shutoff valve V1 is representative of the two valves V1 and V2 and will now be described. The valve structure is the subject matter of the companion application for patent, Ser. No. 275,910, filed July 28, 1972.

In this form, as seen in FIGS. **11***a*, **11***b*, **18***a*, **18***b* and **19***a*, **19***b*, the valve assembly comprises the outer body **136** and an upper tubular sub **136***a* which is connected with the lower end of the tubing string T3. The upper body **136***a* is threadedly connected at **175** at its lower end to the body **136,** which, in turn, as previously de-

scribed, is threadedly connected at 135 to the flow tube 134 which seats in one of the bores or receptacles 19 in the tubing hanger body 10.

A ball valve 176 is disposed within the body 136 and has a passage 177 for the flow of well fluid when the ball valve is in the open position, with the passage 177 aligned with the body 136, the ball valve being rotatable 90°, as will be later described, to a closed position, in which flow of well fluid through the body 136 is prevented.

Normally, the ball valve 176 is biased to a closed position by a lower sealing and actuating sleeve 178 which is reciprocable in the valve body 136 between an upper position, as seen in FIG. 18*a*, and a lower position, as seen in FIG. 19*a*. The sleeve 178 is piloted in a reduced bore 179 in the body 136, and the lower end of the sleeve extends into a bore 180 in the upper end of the tube 134. A coiled compression spring 181 is disposed between the upper end of the tube 134 and a seating shoulder or ring 182 on the sleeve 178, and biases the sleeve 178 and the ball valve 176 upwardly. Externally, the ball valve 176 has a spherical sealing surface 183 sealingly engageable by a companion sealing end surface 184 at the upper end of the sleeve 178.

Above the ball valve 176 is an upper valve actuating and sealing sleeve 185 having a lower end sealing surface 186 which is complemental to the spherical valve surface 183 of the ball valve 176. At its upper end, the sleeve 185 has an enlarged piston section 187 which is slidably disposed within a cylinder portion 188 of the valve body 136. Below the piston section 187 is a cylindrical section 189 smaller than the outside diameter of the piston section 187. Between the cylindrical section 189 and the cylindrical wall 188 is a sleeve 190 engaged by an external seal ring 191 on the cylindrical section 189 and having an external seal 192 engaging with the cylinder wall 188. At its lower end, the sleeve 190 abuts with an upwardly facing shoulder 193. The difference between the annular cross-sectional area of the sleeve 190 and the annular cross-sectional end area of the upper end 194 of the piston section 187 constitutes the net piston area of the piston section 187 exposed, as will be later described, to control fluid pressure to hold the ball valve 176 open. The piston section 187 extends into an annular space 195 defined between the cylindrical wall 188 and a sleeve 196 which is connected by suitable shear screws 197 to a skirt 198 on the lower end of the upper body section 136*a*, the sleeve 196 carrying a seal ring 199 engageable within the skirt 198, and the skirt 198 having a seal ring 200 engageable in the cylindrical wall 188. The control fluid passage 171, previously referred to, communicates through a port 201 with the annular space 195 which constitutes a control fluid pressure chamber in which control fluid pressure is operable on the net piston area of the piston section 187 of the sleeve 185 to provide a downward force adapted to overcome the upward force applied to the ball valve 176 by the lower valve actuating sleeve 178, when the ball valve 176 is to be opened by moving the ball valve from the position of FIG. 18*b* to the position of FIG. 19*b*, as the upper sleeve 185 is forced downwardly.

Preferably, the valve assembly includes resilient sealing means 202 engageable with the ball valve 176 when it is in the closed position. In the embodiment now being described, the resilient sealing means 202 comprises a seal carrier ring 203 having an annular elastomeric seal ring 204 engageable with the ball valve 176 externally of the seating surface 186 at the lower end of the sleeve 185. The seal carrier ring 203 is normally biased downwardly by a coiled compression spring 205 which seats against a seating ring 206 carried within the valve body 136.

The respective valve assemblies V1 and V2 are full opening valve assemblies through which remedial operations can be performed when the ball valve is opened. In order to provide a ball valve 176 of maximum diameter, the ball valve 176 is installed in the body 136 through a side opening 207 which is closed by a valve supporting closure member 208 which fits within the opening 207, and is sealed therein by a suitable seal ring 209. Referring again to FIG. 11*b*, it will be noted that the closure and valve support member 208 is adapted to be secured to the valve body 136 by a suitable number of fasteners 210, and as best seen in FIG. 17, the closure member 208 includes a guide section 211 having a bore 212 through which the tubular member 140 rotatably extends.

In order to support the ball valve 176 and cause rotation thereof in response to movement of the ball longitudinally between the sleeves 185 and 178, the valve supporting member 208 has a pin or lug 213 projecting therefrom in aligned opposition to a corresponding pin or lug 214 carried within the valve body 136, and the ball valve 176 has at its opposite sides corresponding slots 215 in which the respective pins or lugs 213 and 214 are engageable for rotating the ball valve 176 between the opened and closed positions, as best illustrated in FIGS. 25 through 28. In these views, the side of the ball valve 176 supported by the closure 208 is illustrated, but similar structure will be understood to be located at the other side of the ball valve also. In FIG. 25, the valve is shown fully closed and sealed by the sleeves 178 and 185 as well as by the resilient sealing means 202. In FIG. 26, the valve 176 has been shifted downwardly away from the resilient seal means 202 through an initial increment of non-rotatable longitudinal movement. In FIG. 27, the ball valve 176 is in the partially opened position. In FIG. 28, the ball valve 176 is in the fully opened position.

More particularly, the ball valve member 176 on each of its opposite sides has a chordal flat surface 216 adjacent to the diametrically opposite portions of the body 136 and the support 208. The slot 215 extends radially with respect to the axis of rotation to the ball valve member 176, and at right-angularly spaced locations, the ball face 216 is recessed to form a stop surface 217 and a stop surface 218 cooperable with fixed stop lug surfaces 217*a* and 218*a* on the closure 208 to limit rotation of the ball 176 between the extremes of FIG. 25 and FIG. 28. When the ball valve member 176 is in the position of FIG. 25, the stop surface 217 engages the vertical stop surface 217*a*, thereby limiting rotation of the valve member 176 to the position at which the valve is open. The stop surface 218 engages the stop surface 218*a*, as shown in FIG. 28 to limit rotation of the valve member 176 to the position at which the valve is closed. Such rotation between the open and closed positions is caused by longitudinal or vertical movement of the valve member 176 relative to the body 136. As previously indicated, the ball member 176 is actuated or shifted longitudinally by longitudinal movement of the upper actuator sleeve 185 and the lower actuator sleeve 178, as indicated by the arrows

in FIGS. 26 and 27. The slot 215 is formed in such a manner as to cause such rotation of the valve member 176 as the latter moves vertically or longitudinally within the body 136. Thus, as seen in FIG. 25, the slot 215 is formed in the valve member 176 by opposed walls which are disposed at a right angle to one another and designated 215*a* and 215*b* and which respectively are parallel to the stop surfaces 217*a* and 217*b*. At the apex of the angle defined between the walls 215*a* and 215*b*, the slot opens radially inwardly at 215*c*. Thus, the relationship between the pin 213 and the wall 215*b* is such that the ball valve 176 will be rotated from the position of FIG. 25 to the position of FIG. 28 when the valve member 176 moves downwardly relative to the pin 213, and, conversely, the flat wall 215*a* will engage the pin 213 and rotate the ball valve member from the position of FIG. 28 to the position of FIG. 25 upon upward movement of the valve member 176. However, it will be noted that when the valve member 176 is in the position of FIG. 28, the pin 213 clears the flat wall 215*a* so as to allow freedom of longitudinal movement of the ball valve 176 after the stop surface 218 engages the stop 218*a*, and correspondingly limited free downward movement of the ball valve 176 is permitted when the ball valve is open, as seen in FIG. 25, where the pin 213 clears the slot wall 215*a*, and the stop surface 217 engages the stop 217*a*. Such free or lost motion connection of the ball valve 176 and the rotating pin 213 relieves the connection of damaging forces when the ball valve is in either of its closed or opened positions, and in addition saves the resilient seal 202 from relative rotative movement of the ball valve 176.

When the ball valve 176 is closed and is to be opened by applying control fluid pressure to the piston chamber 195, there may be substantial differential pressure across the valve tending to hold it closed, and in order to equalize the pressure across the valve, equalizing valve means 220 are provided, as seen in FIG. 23, for establishing communication between a port 221 below the ball valve 176 (FIG. 18*b*) and a port 228 above the valve 176 (FIG. 18*a*), via the elongated passage 223 in the valve body 136. The port 221 communicates with the annular space 224 between the body 136 and the lower valve actuating sleeve 178 which communicates with the passage through the tubular member 134 through radial ports 225 in the upper end of the member 134, when the valve 176 is closed, as seen in FIG. 18*b*. Above the ball valve 176, the skirt 198 of the upper valve body section 136*a* has a number of radial ports 226 communicating between the flow passage through the valve assembly and an annulus 227 which in turn communicates through a port 228 with a chamber 229 of the equalizing valve means 220. The equalizing valve chamber 229 is provided by a tubular insert 230 retained in a bore 231 in the body 136 by a sealing plug 232. Seals 233 and 234 on the insert 230 engage in the bore 231 and a reduced bore 235. A valve member 236 is reciprocable in the insert 230 and has its lower end 237 provided with a seal 238 slidably engaging within the insert 230 below inlet ports 239 in the insert which establish communication between the port 228 and the valve chamber 229, so that above the seal 238, the chamber 229 is exposed to the flow passage through the upper valve body 136*a*. At the upper end of the equalizing valve member 236 is a head 240 engageable with a seat 241 under the influence of pressure below the ball valve 176 supplied to an inlet chamber 242, above the head 240, via the passage 223 and via a radial port 243 in the body 136 and ports 244 in the insert 230. A rod 245 slidably extends downwardly through the lower end of the insert 230 and into the bore 235, and a coiled spring 246 engages the insert 230 and an adjustable spring seat 247 on the rod to provide a downward bias closing the head 240 against the seat 241. Leading into the bore 235 of the equalizing valve 220 is a port 248 which communicates with the control fluid chamber 195 of the shutoff valve means.

It will now be apparent that so long as the pressure differential across the closed ball valve 176 is such that well pressure in the equalizing valve chamber 242 and the force of spring 246 cause a downward force holding the valve head 240 seated, in excess of the force upwardly caused by control fluid pressure in the bore 235, there will be no communication between the ports 221 and 228, respectively, below and above the ball valve 176. However, as control fluid pressure is increased to open the shutoff valve 176, the increased pressure acts upwardly on the effective piston area at the lower end of the equalizing valve member 236 and will open the equalizing valve head 240, whereby pressure will equalize between the lower ports 221, through passage 223, ports 243 and 244, valve chambers 242 and 229, ports 239, and the upper equalizing port 228.

The effective areas in the equalizing valve means 220 and the force of the spring 246 are selected, as compared with the effective area of the shutoff valve actuating piston section 187 of the sleeve 185, so that the equalizing valve means 220 will open first, and thereby relieve the main shutoff valve 176 from the effect of differential pressure thereacross.

In order to assure that no back flow can occur when the shutoff valve 176 is open and the well is flowing therethrough, a back flow preventing valve 223*a* is provided between the equalizing valve chamber 242 and the passage 223.

In order to enable control fluid pressure to be supplied to both of the valve assemblies V1 and V2 in the valve means V, as previously indicated, the control fluid pressure chamber or bore 235 of the equalizing valve means 220 of the upper valve V1 has a passage 235*a* leading to the fitting 172, which in turn communicates with the lower valve assembly V2.

In the use of shutoff valves, such as the valve assembly V1 or V2, to control flow from a plurality of well zones, it may occur, under various circumstances, such as seal failure, that one or more of the shutoff valves will not open under applied control fluid pressure. In such event, it may be necessary to pull the shutoff valve means from the well in order to repair and replace the shutoff valve means. In the present apparatus, however, means are provided whereby the valve V1 or the valve V2 may be opened mechanically and locked open to allow continued production from one or both of the well zones Z1 and Z2. In addition, the present apparatus enables the use of an auxiliary or secondary shutoff valve, adapted to be run into and anchored in the locked open valve assembly V1 and V2.

As seen in FIGS. 18*a* and 18*b*, the sleeve 196 is held by the shear screws 197 in an initial upper position, and the sleeve 196 cooperates with the body 136 to form the control fluid pressure chamber or annular space 195. Initially released lock means 250 are provided, whereby, when the sleeve 196 is shifted downwardly, it will be locked in the lower position. When the sleeve

196 is shifted downwardly, it engages a shoulder 251 on the sleeve 185 and shifts the latter downwardly to open the ball valve 176. More particularly, the lock means 250 includes a resiliently contractable, split lock ring 252 having external upwardly facing buttress teeth 253. Beneath the lock ring 252 is an expander 254 which is secured to the sleeve 196 by fasteners 255 and has an expander surface 256 engageable within the lock ring 250 to expand the latter when it is lockingly engaged with internal teeth 257 within the body 136. A sleeve shifting tool is disclosed and claimed in the companion application for patent, Ser. No. 275,910, filed July 28, 1972.

As previously described, the valve assembly V may be removed from the tubing hanger assembly TH and thereafter, the tubing hanger and the tubing strings T1 and T2 may be removed from the well by the use of the retrieving tool RT, shown in FIGS. 29*a* to 29*d*, as being landed and latched into the upper end section 11 of the tubing hanger assembly TH, the retrieving tool RT being operable, as shown in FIGS. 31*a* through 31*d*, to release the tubing hanger TH so that it may be removed from the well.

More particularly, the retrieving tool RT comprises an elongated body 400 threadedly connected at 401, at its upper end, to a running-in string of pipe R2. At its lower end, the body 400 has an annular carrier 402 rotatably mounted thereon by ball bearing means 403, the carrier supporting a pair of inserts 404 providing flow passages 405 and adapted to be sealingly engaged within the respective receptacles or bores 19 in the tubing hanger body 10, whereby fluid may be circulated downwardly through the running-in string R2 and the retrieving tool body 400, into the tubing strings T1 and T2. The carrier 402 has an upwardly extending neck 406 rotatably receiving the lower end of the body 400. Suitably keyed to the neck 406, as by a screw 407 extending into a longitudinal slot 408 in the neck 406, is a retainer sleeve 409 which is threaded at 410 onto the body 400. The retainer sleeve 409, above the threaded connection 410, is provided with a vertically extended slot 411 into which projects a key 412 which is carried by the solid ring portion 413 of a latch sleeve 414 connected at 415 to a support ring 416 suspended from a flange 417 of a ring supporting member 418 threaded onto the body 400 at 419. The latch sleeve 414 comprises a plurality of downwardly extended and circumferentially spaced resilient latch fingers 420 having outstanding lugs 421 at their lower ends adapted to be engaged beneath the flange 16 within the body section 11 of the tubing hanger TH. The inner side of each lug 421 has a vertically extended face 422 engageable, upon actuation of the retrieving tool RT, by a companion vertical face 423 on the latch retainer 409. Above the carrier ring 416 is a spring seating ring 424 engaged by a coiled compression spring 425 which at its upper end engages a collar 426 secured by fasteners 427 to a support ring 428. The collar 426 has a plurality of radial ports 429 communicating with an annulus 430 between the collar 426 and the body 400, the annulus 430 communicating with ports 431 in the body 400. The ports 431 lead into the body 400, but are normally closed by a sealing sleeve 432 having an upper seal 433 and a lower seal 434 engaged within the body 400 and straddling the ports 431. This sealing sleeve 432 is initially held in the position shown in FIG. 29*a* by one or more shear screws 435, and the sleeve 432 extends upwardly within the body 400 to a location above an upper set of radial ports 436 located below a seal ring 437 carried by the sealing sleeve 432 and engaged within the body 400. Between the seals 433 and 437 on the sealing sleeve 432, the extension of the sealing sleeve is longitudinally grooved, as at 438, so that when the sleeve is shifted downwardly to the position of FIGS. 31*a* through 31*d* communication is established between the lower ports 431 and the upper ports 436.

The sleeve 432 is shifted downwardly, as mentioned above, by means of fluid pressure, when a ball 439 introduced into the running string R2 engages an upper seat 440 on the sleeve 432 to close the central passage through the sleeve. When the sleeve 432 is shifted downwardly, the upper end thereof which carries an outer ring seal 441 is disposed within an enlarged bore portion 442, which establishes communication between the running pipe string R2 and the interior of the sealing sleeve 432 via ports 443 adjacent the upper end of the sleeve 432.

Seating on the support ring 428 is a packer cup supporting ring 444 which supports an upwardly facing packing cup 445 having a sealing lip 446 engageable with the well casing C. When the retrieving tool RT is in the condition shown in FIGS. 29*a* and 29*b*, the annular space between the running string R2 and the tool body 400, above the packing cup 445, may be filled with fluid to apply a downward force opposing the release of the tubing hanger, but after the tubing hanger has been released, the ball 439 may be inserted into the running string R2 to shift the sealing sleeve 432 downwardly to the position shown in FIGS. 31*a* through 31*d* to equalize the fluid across the packing cup 445.

To release the tubing hanger assembly TH, the retrieving tool RT is run into the well casing, and the key 412 will engage the downwardly inclined upper face 12 of the tubing hanger body section 11 and be cammed into the vertical slot 14, thereby orienting the sealing inserts 404 with the receptacles or sockets 19 in the tubing body 10. Thereafter, rotation of the running string R2 will effect corresponding rotation of the retrieving tool body 400 relative to the carrier ring 402 which is held stationary by the sealing inserts engaged in the receptacles 19. The body 400 also rotates relative to the key 412 which is held non-rotatable in the tubing hanger slot 14 and thus holds the retainer sleeve 409 against rotation with the body 400, so that the retainer sleeve 409 will be threaded upwardly along the threaded connection 410 until the retaining surface 423 thereon engages within the vertical surface 422 on the latch lugs 421, as shown in FIG. 31*b*, thereby retaining the resilient latch fingers 420 against inward deflection, so that the latch lugs 421 are positively held outwardly for engagement beneath the tubing hanger body flange 16.

Thereupon, the running string R2 is pulled upwardly to apply an upward pull to the tubing hanger body 10 tending to pull the upper expander member 43 upwardly to release the slip elements 46 and 47, but release of the slip elements is initially precluded, inasmuch as the tie rods 24 engaged in the lock ring 29, as shown in FIG. 31*c*, are positively interconnected with the lower tubing hanger member 36, so that, as previously described, the anchor means 34 are retained in anchoring engagement with the casing C. However, sufficient upward strain on the running string R2 will cause the reduced section 37 of the frangible screw 35

to be broken, as shown in FIG. 31*d*, allowing the upper expander member **43** to move upwardly with respect to the lower expander **56**, and the slip elements **46** and **47** will be retracted. Since fracturing of the screw **35** results in the instantaneous release of the anchor means while the running string **R2** is under substantial tension, the fluid column supported in the annulus above the packing cup **445** constitutes a cushion which will absorb the energy stored in the running string **R2**. When the ball **439** is dropped through the running string **R2** and the sealing sleeve **430** is shifted downwardly, as described above, to equalize the fluid across the packing cup **435**, the tubing hanger assembly can then be elevated through the well casing by the retrieving tool RT, and the tubing strings T1 and T2 pulled from the well.

I claim:

1. In a setting tool for a tubing hanger anchorable in a well casing and having a receptacle for the setting tool, said setting tool comprising: an elongated outer tubular body having means at its upper end for connection with a running pipe string, an elongated inner body longitudinally shiftably disposed in said outer body, piston means carried by said bodies and forming a pressure chamber therebetween, said inner body having a fluid passage extending longitudinally therein and a port leading between said passage and said pressure chamber, valve means normally closing said port to admit pressure fluid to said pressure chamber from said passage, connector means on said outer body for connection with one part of the tubing hanger, connector means on said inner body for connection with another relatively movable part of the tubing hanger, whereby pressure fluid applied to said pressure chamber to effect relative longitudinal shifting of said bodies will effect corresponding shifting of the tubing hanger parts, and a plurality of flow tubes carried by said inner body and projecting downwardly therefrom, said flow tubes having passages communicating with said passage in said inner body.

2. In a setting tool as defined in claim **1**, said outer and inner bodies having longitudinally extended key and slot means for maintaining said bodies in a fixed relative orientation while said inner body is shifted longitudinally relative to said outer body.

3. In a setting tool as defined in claim **1**, said inner and outer bodies having cooperative releasable latch means releasably securing said bodies against relative longitudinal movement when said valve means closes said port.

4. In a setting tool as defined in claim **1**, said inner and outer bodies having cooperative releasable latch means releasably securing said bodies against relative longitudinal movement, said valve means having means cooperative with said latch means to prevent release thereof when said valve closes said port.

5. In a setting tool as defined in claim **1**, said connector means on said outer body comprising a thread engageable in the receptacle of the tubing hanger, and said connector means on said inner body comprising connector rod locking means engageable with a connector rod of the tubing hanger.

6. In a setting tool as defined in claim **1**, said valve means comprising a valve sleeve longitudinally shiftable in said passage in said inner body, said valve sleeve having seat means for a seating element travelling in fluid flowing through said passage to close said seat means to shift said valve sleeve responsive to fluid pressure.

7. In a setting tool as defined in claim **1**, said inner and outer bodies having cooperative releasable latch means initially securing said bodies against relative longitudinal movement, said latch means comprising a shoulder on one of said bodies and resilient latch fingers on the other of said bodies, and means releasably holding said latch fingers in engagement with said shoulder.

8. In a setting tool as defined in claim **1**, said inner and outer bodies having cooperative releasable latch means initially securing said bodies against relative longitudinal movement, said latch means comprising a shoulder on one of said bodies and resilient latch fingers on the other of said bodies, said valve means having means engageable with said latch fingers when said valve means closes said port to hold said latch fingers in engagement with said shoulder and releasable from engagement with said latch fingers when said valve means opens said port.

9. In a setting tool as defined in claim **1**, said inner and outer bodies having cooperative releasable latch means initially securing said bodies against relative longitudinal movement, said latch means comprising a shoulder on one of said bodies and resilient latch fingers on the other of said bodies, said valve means comprising a sleeve longitudinally shiftable in said passage in said inner body, said sleeve having a portion engaged with said latch fingers when said port is closed to hold said latch fingers in engagement with said latch fingers.

10. In a setting tool as defined in claim **1**, said inner and outer bodies having cooperative releasable latch means initially securing said bodies against relative longitudinal movement, said latch means comprising a shoulder on one of said bodies and resilient latch fingers on the other of said bodies, said valve means comprising a sleeve longitudinally shiftable in said passage in said inner body, said sleeve having a portion engaged with said latch fingers when said port is closed to hold said latch fingers in engagement with said latch fingers, said valve sleeve having seat means for a seating element travelling in fluid flowing through said passage to close said seat means and shift said sleeve responsive to fluid pressure to a position at which said port is open and said latch fingers are released from said shoulder.

11. In a setting tool as defined in claim **1**, said connector means on said outer body comprising a thread, and said connector means on said inner body comprising locking means engageable with a connector rod carried by the tubing hanger upon longitudinal movement of said inner body in said outer body.

12. In a setting tool as defined in claim **1**, said connector means on said outer body comprising a thread, and said connector means on said inner body comprising locking means engageable with a connector rod carried by the tubing hanger upon longitudinal movement of said inner body in said outer body, said inner and outer bodies having cooperative longitudinally extended key and slot means for maintaining said bodies in a fixed relative orientation, whereby said outer body is rotatable by said inner body to release said thread from said tubing hanger.

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