United States Patent [19]

Williams, Jr. et al.

[11] **3,926,457**

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[54] **WELL COMPLETION APPARATUS**

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[73] Assignee: **Cameron Iron Works, Inc.,** Houston, Tex.

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[52] **U.S. Cl.** **285/39;** 166/125; 166/182; 285/93; 285/143; 285/307; 285/317; 285/321

[51] **Int. Cl.²** **F16L 35/00**

[58] **Field of Search** 285/18, 39, 140, 141, 142, 285/143, 307, 321, 340, 317, 93; 166/125, 123, 182

[56] **References Cited**

UNITED STATES PATENTS

3,268,241	8/1966	Castor et al.	285/139
3,404,736	10/1968	Nelson et al.	285/142 X
3,468,559	9/1969	Ahlstone	285/18
3,809,158	5/1974	Bonds et al.	285/18
3,827,488	8/1974	Piazza	285/18

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Attorney, Agent, or Firm—William H. Hyer; Marvin B. Eickenroht

[57] **ABSTRACT**

A seal assembly for closing off an annular space between the bore of a casing head and a casing hanger supported in the bore, and a tool for activating and preferably testing the seal assembly.

10 Claims, 9 Drawing Figures

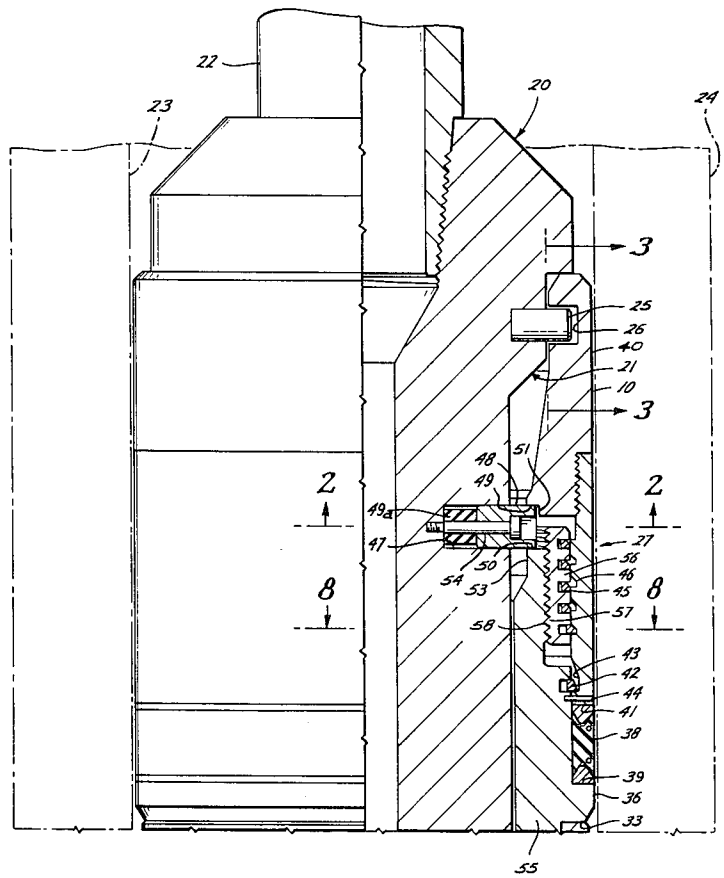


Fig. 1A

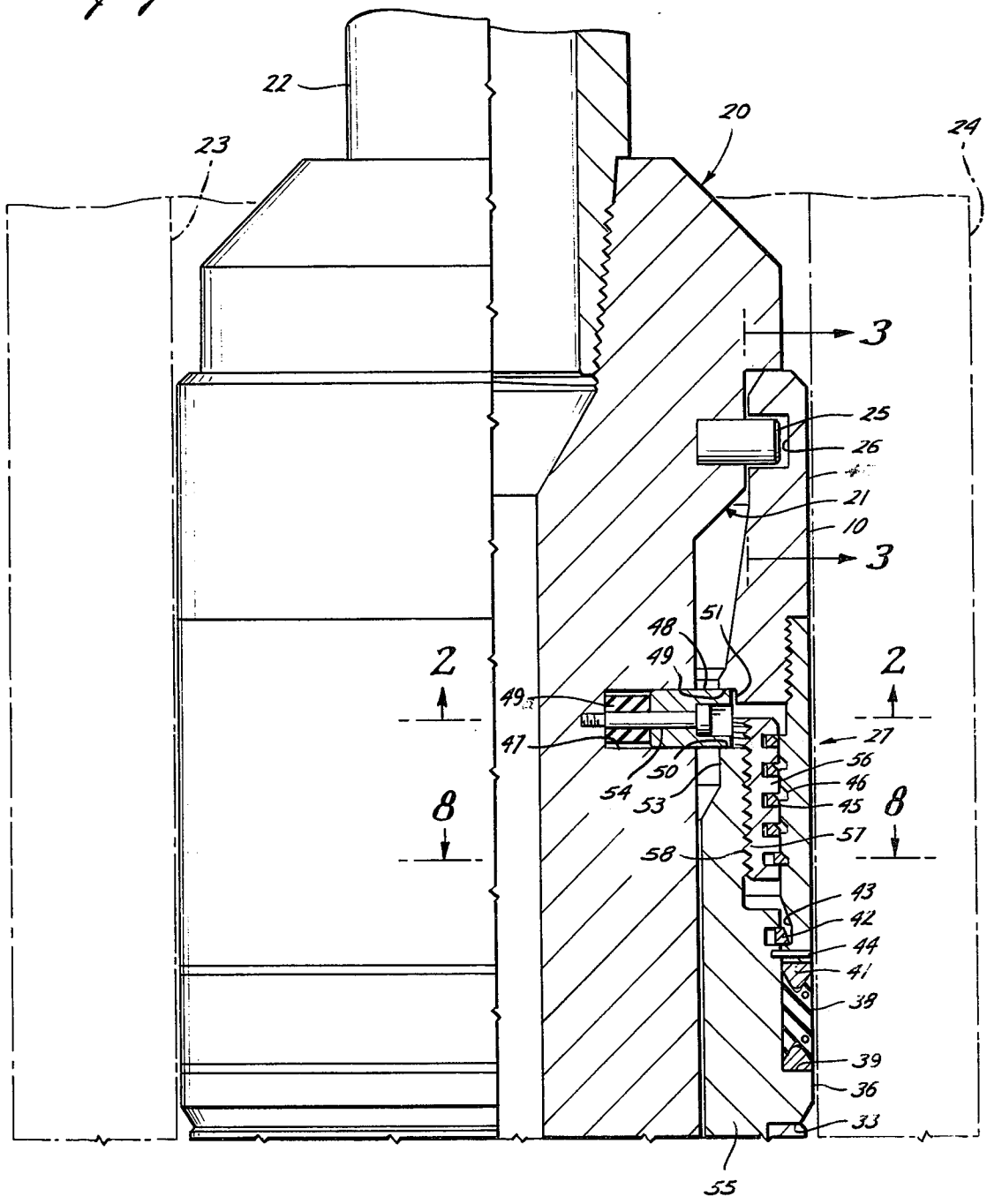

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Fig. 1B

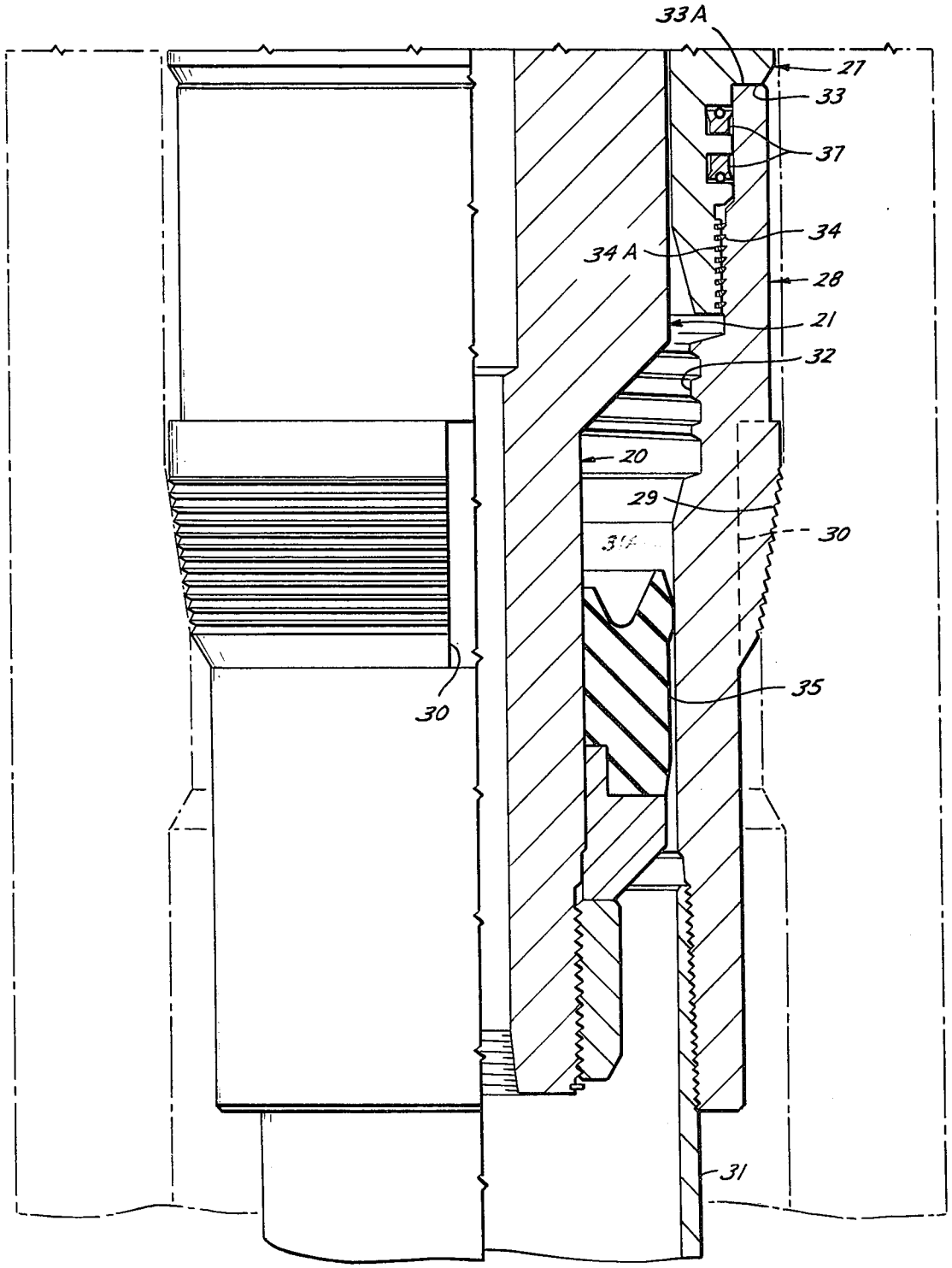


Fig. 3

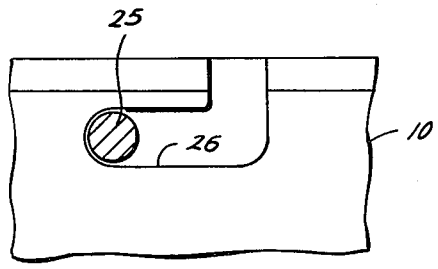


Fig. 2

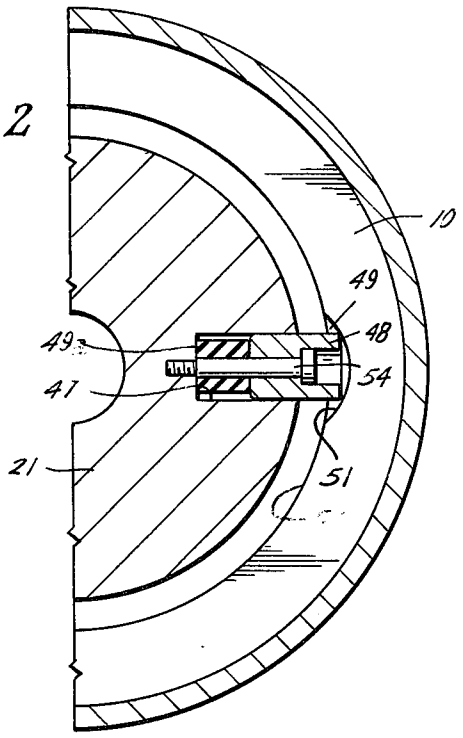


Fig. 5

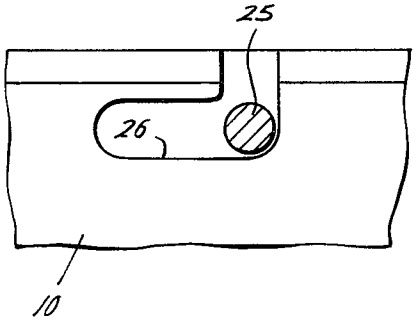


Fig. 4

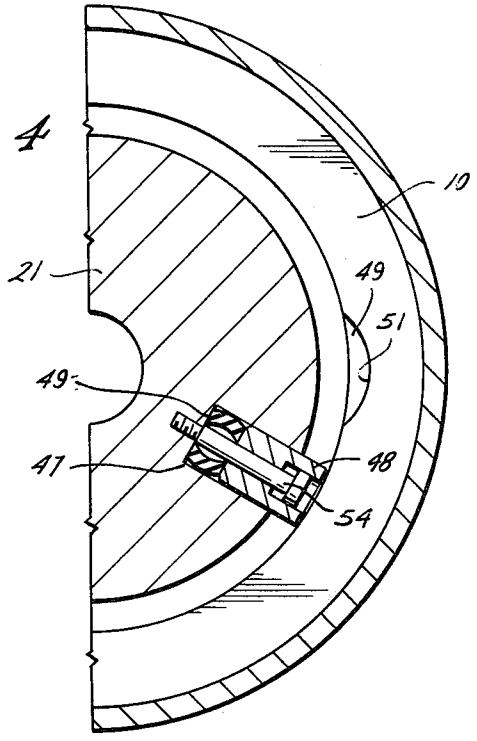


Fig. 6

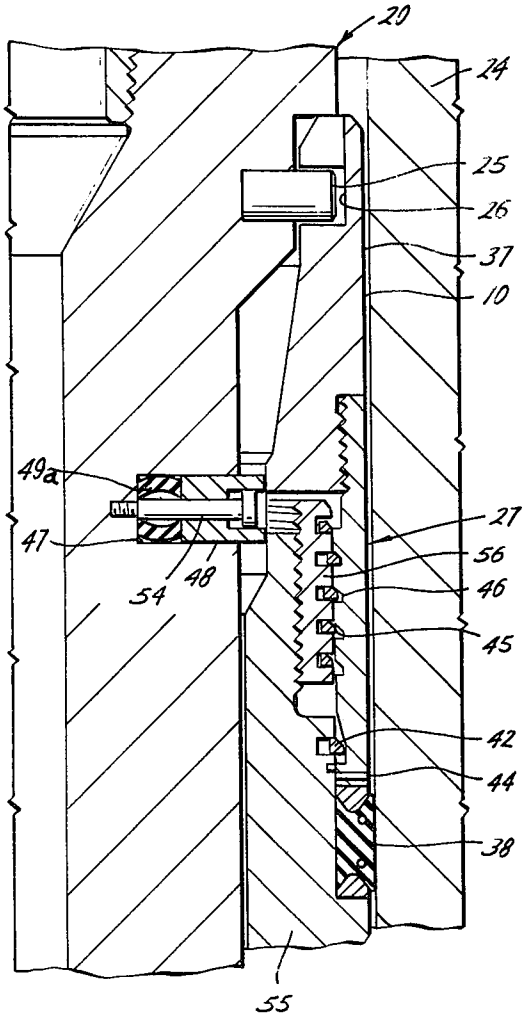


Fig. 7

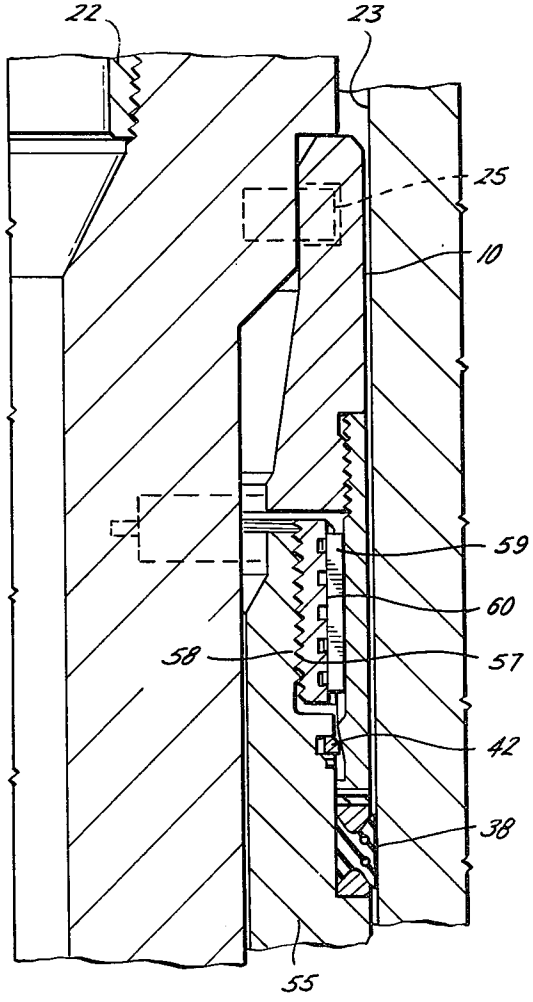
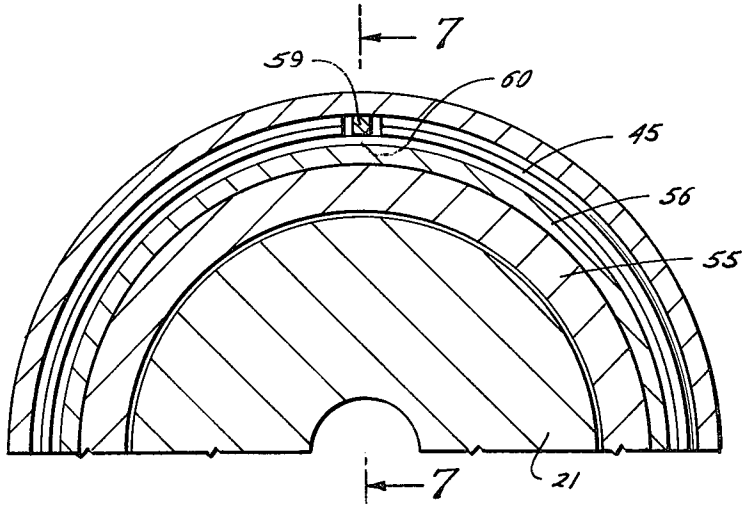


Fig. 8



WELL COMPLETION APPARATUS

This invention relates generally to apparatus for use in completing oil and gas wells, particularly at an underwater location, wherein casing strings are adapted to be suspended within a casing head by means of casing hangers landable on seats in the bore of the head, and the casing hangers are ported or slotted to provide flow passages through which returns may be taken as the casing strings are cemented within the well bore. In one of its aspects, this invention relates to improvements in seal assemblies for closing off the annular space between the hangers and bore of the casing head above such passages. In another of its aspects, it relates to improvements in tools for activating and preferably testing such seal assemblies.

As shown in U.S. Pat. No. 3,404,736, assigned to the assignee of the present application, in the completion of wells of this type, a casing head is connected to the upper end of an outer casing string, and one or more blowout preventers are connected to the upper end of the casing head. The casing hangers are connected to running tools

Although the above-described apparatus works quite well when the well is to be completed at a relatively shallow depth — e.g., less than 1,000 feet — difficulty may be encountered in applying the neccessary torque to the seal assembly at greater depths. Although other apparatus has been proposed for activating other seal assemblies by means of a downward force, which obviates the need for the application of torque, none have been found entirely satisfactory.

For example, Castor et al U.S. Pat. No. 3,268,241 shows a seal assembly including a seal ring which is activated by the weight of the running string, and then held in sealing position by means of a latch engageable with the bore of the casing head. One problem with such a seal assembly is that the seal ring will, after expansion by test pressure, spring back to the extent permitted by the position in which the seal assembly is latched. Consequently, the test is not a true indication of its pressure holding capabilities. Also, due to tolerances, the seal ring may not, in the latched position of the assembly, be expanded sufficiently to contain the well pressure for which it's designed. Furthermore, this prior apparatus requires that the bore of the casing head be provided with a groove for receiving the latch on the seal assembly. Still further, the seal assembly is of such construction that its seal ring may be prematurely activated if the seal assembly engages an obstruction within the bore of the casing head as it is lowered therein.

The seal assembly shown in Ahlstone U.S. Pat. No. 3,468,559 also permits a seal ring to be activated by means of a downward force, in this case by means of hydraulic pressure transmitted to the running tool through the running string. Further, the seal assembly is adapted to be connected to the casing hanger by a ratchet mechanism which permits it to be held in a number of different latched positions with respect to the hanger, and thus with the seal ring held in a plurality of expanded positions, depending on the downward force applied by the running tool. However, since the running tool of this prior apparatus is hydraulically operated, it is inoperable to activate the seal assembly in the event hydraulic pressure is lost. Furthermore, and as in the apparatus of U.S. Pat. No. 3,268,241, the seal ring of the seal assembly may be prematurely activated

by obstructions within the well bore. Still further, although the running tool of this apparatus is of such construction as to permit test pressure to be effective in urging the seal ring to a further expanded position, the force with which this is done is rather small, and, more particularly, limited to the effect of test pressure over the cross-sectional area of the seal ring.

An object of this invention is to provide a seal assembly of the type having a ratchet mechanism which permits the seal ring thereof to be held in different expanded positions, in response to force applied downwardly thereto, but so arranged that the seal ring will not be prematurely set by obstructions within the well bore.

Another object is to provide a seal assembly having such a ratchet mechanism which permits the seal ring to be held in a considerably greater number of expanded positions than is possible with the prior apparatus described above.

A further object is to provide such a seal assembly which may, in addition to being activated in response to downward force, be activated in response to torque applied to the running tool, as might be desirable in the event it is used at lesser depths, and as might be necessary if the ratchet mechanism should jam and/or the seal ring not hold test pressure when expanded by downward force transmitted thereto through the running string.

Still another object is to provide a seal assembly and a tool for activating it which are of such construction that the ratchet mechanism is selectively held against premature actuation due to downward force.

Yet another object is to provide such a seal assembly and tool in which the ratchet mechanism may be released for actuation merely in response to rotation of the running tool.

A still further object is to provide such a tool which is of simple and inexpensive construction.

Yet a further object is to provide a seal assembly and tool of such construction as to permit the seal ring of the seal assembly to be expanded by either the weight of the running string or the application of test pressure applied to the annulus thereabove, and more particularly, by a test pressure which is effective over a large area.

These and other objects are accomplished, in accordance with the illustrated embodiment of the invention, by a seal assembly with comprises, as in the seal assembly of U.S. Pat. No. 3,407,736, a first tubular member having means adapted to be supported on and connected to a casing hanger supported in the bore of the casing head, first seal means carried by the first member for sealing between it and the hanger, when so supported and connected, second seal means supported on an upwardly facing shoulder on the outer side of the first member, and a second tubular member having a downwardly facing shoulder above the second seal means and movable downwardly with respect to the first member, in response to manipulation of the tool on which it's run, so as to expand the second seal means into sealing engagement between the first member and the bore of the casing head. As in the seal assembly of the above-mentioned patent, the portion of the first member which is disposed beneath the upwardly facing shoulder on its outer side protects the second seal means supported on such shoulder from premature expansion, as might otherwise occur in the event the first member were to engage obstructions in the bore of the

casing head.

More particularly, the second tubular member is connected to the first tubular member by ratchet means which permits the second member to be moved into and held in vertically spaced, latched positions with respect to the first tubular member, in response to a downward force on the first member due to the weight of the running string. As previously described, this reduces the extent to which the second seal means may spring back, after testing, and also compensates for tolerances which might otherwise detract from the sealing capability of the assembly. Preferably, the ratchet means comprise grooves in one and expandible and contractible split rings on the other of the members normally urged toward positions for fitting within the grooves, with the grooves being equally vertically spaced apart distances slightly different than the equal vertical spacing between the rings. Thus, the differential in vertical spacing between successive latching positions of the second member will be determined by the differential spacing, rather than by the number of ratchet teeth and/or grooves, whereby spring back and tolerance problems are reduced to a minimum.

In the illustrated and preferred embodiment of the invention, the first tubular member includes a first portion on which are formed a downwardly facing shoulder for landing on the hanger, a means for connection to the casing hanger when so landed, and the upwardly facing shoulder to support the second seal means, and a second portion which is threadedly connected to the first portion. The ratchet means is formed on such second potion of the first member and on the second tubular member, and a means is provided for limiting rotation of the second member with respect to the second portion, as the second member moves downwardly with respect thereto. Thus, the threaded connection between the first and second portions is effective to lower the second member and the second portion of the first member relative to the first portion of the first member, and thereby permit the seal ring to be expanded, in response to rotation of the running tool connected to the second member.

The second tubular member is selectively held against downward movement with respect to the first tubular member, and thus prevented from moving downwardly to a lower latching position with respect thereto, by means on the running tool engageable between portions of the first and second members. In the illustrated embodiment of the invention, this means comprises a dog on the tool which is responsive to manipulation of the tool for selectively disengaging from between such portions so as to permit the second member to be moved downwardly to latching position. preferably, the dog is yieldably urged outwardly to engaging position, and is moved inwardly to disengaging position by cam surfaces on one of the tubular members, as the tool is rotated relatively to the second member.

When the second seal means has been expanded against the bore of the casing head and test pressure is supplied to an annular space above the seal assembly to test its effectiveness, the tool on which the seal assembly is run may be lowered further. Consequently, test pressure is effective across the sectional area between the outer diameter of the running string and the outer diameter of the second seal means to produce a large force further urging the second member of the seal assembly downwardly with respect to the first member, and thus into a still lower latched position. In the drawings:

FIGS. **1A** and **1B** are views, partly in elevation and partly in section, of the upper and lower ends, respectively, of a seal assembly and running tool constructed in accordance with this invention, with the seal assembly landed upon and connected to a casing hanger supported within a casing head (shown in broken lines), and with the running tool positioned to prevent premature expansion of a seal ring on the outer side of the assembly;

FIG. **2** is a partial cross-sectional view of the running tool and seal assembly, as seen along broken line **2--2** of FIG. **1A**;

FIG. **3** is a vertical sectional view of the tool and assembly, as seen along broken lines **3—3** of FIG. **1A**;

FIGS. **4** and **5** are views of the running tool and seal assembly, similar to FIGS. **2** and **3**, respectively, but upon rotation of the tool to a position releasing the second member of the seal assembly for movement downwardly to expand said second seal means;

FIG. **6** is a vertical sectional view of a portion of the upper end of the running tool and seal assembly, similar to the righthand side of FIG. **1A**, but upon lowering of the weight of the running string onto the seal assembly to expand the seal ring on its outer side against the bore of the casing head;

FIG. **7** is a view similar to FIG. **6**, but taken along broken lines **7—7** of FIG. **8**, and with the seal assembly further actuated to expand the seal ring; and

FIG. **8** is a partial cross-sectional view of the running tool and seal assembly, as seen along broken line **8—8** of FIG. **1A**.

With reference now to the details of the abovedescribed drawings, the running tool, which is indicated in its entirety by reference character **20**, comprises a hollow body **21** connected at its upper end to a running string **22** (FIG. **1A**), which may be a string of drill pipe, to permit it to be raised and lowered within the bore **23** of the casing head **24**, the blowout preventer (not shown) and the riser pipe (also not shown) thereabove. One or more pins **25** extend outwardly from body **21** of the running tool near its upper end for fitting within one or more slots **26** formed in the inner circumference of the upper end of the seal assembly, which is indicated in its entirety by reference character **27**. As will be decribed below, the running tool is manipulatable by means of the running string **22** to move the pin **25** between positions for raising or lowering, transmitting the weight of the string to, and rotating such upper end of the assembly, and then upon activation and testing of the seal assembly, to a position for removal upwardly therefrom.

As shown in FIGS. **1A** and **1B**, seal assembly **27** is adapted to be landed upon and releasably connected to a casing hanger, which is indicated in its entirety by reference character **28** and shown in FIG. **1B** landed upon and supported by a seat **29** in the bore **23** of the casing head. As well known in the art, the enlarged bore of the head above the seat **29** is continued upwardly through the blowout preventer and riser pipe so as to permit the seal assembly **27** to be raised and lowered therein.

As previously described, casing hangers of this type are of such construction as to permit cement to be circulated downwardly through a string of casing **31** suspended therefrom and upwardly in the annulus between the casing and an outer casing (not shown) to the upper end of which the casing head **24** is con-

nected. More particularly, the outer side of the portion of the casing hanger which is supported by the seat **29** is slotted at **30** to provide passages through which returns may pass upwardly into the annulus above the seat **29** between the bore of the wellhead and running string **22.** As also previously described, when the cementing operation has been completed, these flow passages are closed by means of the seal assembly **27** which is caused to seal with respect to both the casing hanger and the bore of the casing head above such passages.

As shown in FIG. **1B,** the casing hanger **28** has a reduced bore **31A** intermediate its upper and lower ends and relatively coarse threads **32** above the reduced bore to which a suitable running tool (not shown) may be connected for lowering the casing hanger into the position shown in FIG. **1B.** Then, of course, the running tool is released and raised from the casing hanger.

As shown in FIG. **1B,** the lower portion of the seal assembly has a downwardly facing shoulder **33** adapted to land on the upwardly facing shoulder **33A** on the upper end of the casing hanger **28,** and means for connecting it to the casing hanger when so landed. In the illustrated embodiment of this invention, the connecting means comprises a retractable coil spring **34** carried about and normally protruding from the lower end of the seal assembly for releasably latching within a matching spiral groove about the inner diameter of the upper end of the casing hanger intermediate its upper end and the the coarse threads **32.** More particularly, coils of the spring **34** are retractable to permit them to slide downwardly into latching position, as the seal assembly is lowered into landed position on the casing hanger. As known in the art, the seal assembly may be disconnected from the casing hanger merely by rotation of the seal assembly, through lefthand torque applied thereto by a running tool **20.**

As shown in FIG. **1B,** with the seal assembly lowered on the running tool **20** into landed and connected position with respect to the casing hanger **28,** a packer **35** carried about a lower portion of tool body **21** sealably engages the reduced diameter portion **31A** of the casing hanger. In this way, with the seal assembly sealably engaging the casing hanger and the bore of the casing head, and with the rams of the blowout preventer above the casing head sealed about the running string **22,** test pressure may be applied to the annulus between the running string and the bore of the casing head intermediate the blowout preventer rams and the packer **35** for testing the effectiveness of the sealing engagement of the seal assembly with both the casing hanger and the casing head.

As previously described, the seal assembly **27** includes a first tubular member **36** having the downwardly facing shoulder **33** formed thereon and the coil spring **34** carried thereon, whereby it may be landed upon and connected to the casing hanger, as well as seal rings **37** carried thereabout intermediate the shoulder **33** and spring **34** for sealably engaging the casing hanger when so landed and connected thereto. The seal assembly also includes a seal ring **38** which is carried on an upwardly facing shoulder **39** on the outer side of the first member **36** above the downwardly facing shoulder **33** thereon. The inner diameter of the seal ring fits closely about the member **36,** while the outer diameter thereof is spaced from the bore of the casing head when in its unexpanded position (FIG. **1A**).

The seal assembly also includes a second tubular member **40** having the slot **26** formed on its inner diameter for receiving the pin **25** of the running tool **20,** and a shoulder **41** on its outer side which faces downwardly above the seal ring **38.** More particularly, and as will be described in more detail below, the lower end of the second member **40** surrounds the upper end of the first member and is connected thereto in such a manner that it supports the first member for movement therewith, as the assembly is lowered onto the casing hanger, and then moves downwardly with respect thereto, in order to expand seal ring **38** radially outwardly into sealing engagement with the bore of the casing head, as shown in FIGS. **6** and **7,** when the weight of the running string is placed thereon.

As shown, this connection includes a split ring **42** which is carried within a groove about the first tubular member, and is normally urged outwardly therefrom to engage a groove **43** on the second tubular member when the second tubular member is in the position shown in FIG. **1A.** As can be seen from this Figure, the downwardly facing shoulder **41** is at this time adjacent the upper end of the unexpanded seal ring **38.** The ring **42** has a generally horizontally lower surface which engages a generally horizontal upwardly facing surface on the groove **43,** so that the first member is supported from the second member as the seal assembly is lowered into the position of FIG. **1A.** During storage and shipment, the first and second members are held in this position by a relatively weak shear pin **44** connecting them just above the seal ring **38.**

The first and second members are also connected by a ratchet means comprising a series of expandible and contractible split rings **45** carried within grooves in the first member and normally urged radially outwardly to positions for fitting within grooves **46** in the second member, when disposed opposite therto. As shown, each groove **46** has a profile corresponding to the outer end of each ring **45,** including upper bevels and lower horizontal surfaces, so that when the ring is engaged in the groove, it latches the second member against upward movement with respect to the first member. Thus, as the second member moves downwardly from the position of FIG. **1A,** the latch provided by the ratchet means will take the place of the latch provided by the split ring **42** in supporting the first tubular member from the second tubular member. In this respect, it will be noted from FIGS. **6** and **7,** that a cam surface above the groove **43** permits the second member to be moved downwardly over the latch ring **42.**

As also previously described, the ratchet means is of such construction that it provides a large number of latching positions for the second member with respect to the first member, and in particular a much larger number of latching positions than there are latching rings and grooves. For this purpose, the grooves **46** are spaced equal distances apart somewhat greater than the equal spacing between the latch rings **45.** Consequently, only one latch ring will latch within one latch groove in each latching position, and the vertical distance which the second member must be moved between successive latching positions is only the difference in spacing between successive grooves and successive latch rings.

As will be appreciated, the latch rings offer relatively small resistance to downward movement of the second member with respect to the first member. Consequently, as the seal assembly is being lowered on the

running string, a means is provided for holding the second member against downward movement with respect to the first member. For this purpose, body **21** of running tool **20** is provided with one or more sockets **47** each receiving a day **48** which is urged outwardly from the outer diameter of the tool body by means of a rubber sleeve **49a** disposed between the end of the socket and the inner end of dog **48.** As best shown in FIG. **1A,** the outer end of dog **48** fits between a downwardly facing surface **49** on the inner diameter of second tubular member and an upwardly facing surface **50** on the inner diameter of lower tubular member. Consequently, when the dog is disposed in the position shown in FIGS. **1A** and **2,** it holds the second member against downward movement with respect to the first member.

However, as shown in FIGS. **2** and **4,** a cam surface **51** is formed on the inner diameter of the second member adjacent the surface **49** in position to cause the dog to be moved inwardly to the innermost diameter **52** of the second tubular member, when the dog is rotated with the running tool **20** in a righthand direction (as viewed looking downwardly). Since the inner diameter **53** of the first tubular member is axially aligned with diameter **52** of the second tubular member, the dog is thus disengaged from between portions of the members, whereby the second member is free to be moved downwardly with respect to the first member.

As shown, the dog **48** has a hole therethrough to receive a pin **54** threadedly connected at its inner end to the running tool body, and the pin has an enlarged outer end for fitting against an annular shoulder about the hole through the dog. The rubber sleeve **49***a* is of such length as to normally urge the shoulder against the enlarged head of the pin, and is of an outer diameter which permits it to be bowed outwardly, as the day **48** is moved inwardly, as shown in FIG. **4.**

This manipulation of the running tool for selectively engaging and disengaging the dog with respect to the oppositely facing surfaces **49** and **50** of the second and first tubular members is made possible by the configuration of each slot **26** which receives a pin **25** on the running tool. Thus, as shown in FIGS. **3** and **5,** each such groove is "J" shaped, with the horizontal leg of the J extending in a lefthand or counterclockwise direction with respect to the vertical leg thereof. Consequently, when the dog is engaged between the first and second tubular members, as shown in FIGS. **1** and **2,** the pin **25** will occupy the position shown in FIG. **3.** Then, upon righthand rotation of the running tool to disengage the dog from between portions of the first and second tubular members, as shown in FIGS. **4** and **6,** the pin **25** will move into the position shown in FIG. **5.** In this latter position, the pin is still located for exerting downward force on the second tubular member, and thus setting the weight of the running string thereon, but at the same time beneath the vertical leg of the slot **26,** so that, upon completion of the testing of the seal assembly, the running tool may be raised from the seal assembly merely upon lifting of the running string **22.**

In the use of this apparatus, as thus far described, the first and second tubular members of the seal assembly would be connected in the vertical positions shown in FIG. **1A,** wherein the latch ring **42** engages in the groove **43** to support the first member from the second member. The seal assembly would then be connected to the running tool **20** by causing the pins **25** to be moved downwardly into the J-slots **26,** with the dogs **48** being urged inwardly so as to move downwardly over the tapering surface on the inner diameter of the second member. The running tool would then be rotated to the left to move the pins **25** into the position of FIG. **3,** which permits the dogs **48** to extend outwardly into the positions of FIG. **2** for engaging between the surfaces **49** and **50** of the first and second tubular members. The seal assembly would then be lowered on the running tool until it lands upon and connects with the casing hanger **28,** as shown in FIG. **1B.** With the seal assembly so landed, the packer **35** on the running tool is engaged within the reduced bore **31A** through the casing hanger.

At this time, the running tool would be rotated to the right a distance permitted by movement of pin **25** in slot **26** from the position shown in FIG. **3** to the position shown in FIG. **5.** As previously described, this causes the dog **48** to disengage from between portions of the first and second tubular members and to assume the position shown in FIG. **4.** The weight of the running string may then be set on the second tubular member to move it downwardly and thus expand the seal ring **38** outwardly into engagement with the bore of the casing head. This might move the second tubular member downwardly to a position shown in FIG. **6,** for example, in which the second from the uppermost latch ring is latched within the uppermost groove. At this time, the effectiveness of the seal may be tested in the manner previously described.

In addition to testing the sealing engagement of the seal assembly with both the casing hanger and the bore of the casing head, this test pressure is also effective over a cross-sectional area between the outer diameter of running string **22** and the outer diameter of seal ring **38** to exert a large force urging the second tubular member downwardly an additional distance to further expand the seal ring **38,** as indicated in FIG. **7.** As will be understood, substantially all of the further expansion of the seal ring will be retained due to the fact that if the ratchet mechanism is not engaged at the lower limit of downward movement of the second member, it will be in response to only a slight upward vertical movement of the second tubular member, Then, as previously described, and assuming that the seal assembly holds the desired pressure, the running tool may be removed therefrom merely by lifting it.

There are occasions in which it may be desirable to apply torque to the seal assembly for the purpose of tightening the seal of the seal ring **38,** when conditions permit. This may occur, for example, in the event the ratchet means is jammed, or in the event one or both of the seals between the seal assembly and casing hanger and casing head, or the seal of the packer **35,** does not hold test pressure. For this purpose, the first tubular member includes first and second tubular portions **55** and **56,** respectively, which are connected to one another by threads **57** and **58** therebetween. As shown, the first portion **55** comprises generally the lower part of the first tubular member on which the shoulders **33** and **39** and coil spring **34** are provided, and the second portion **56** comprises the upper part of the first tubular member on which the latch rings **45** are carried for fitting within the grooves **46** within the second tubular member. As shown in FIGS. **7** and **8,** the second tubular member is provided with a groove which extends downwardly across the ring grooves **46** to receive a spline **59** which fits within a vertical groove **60** (FIG. **7**) extending downwardly through the splits in latch rings

45. This spline and groove thus limit rotation of the second tubular member with respect to second portion 56 of the first tubular member, while permitting them to be moved vertically with respect to one another. As a result, rotation of the second tubular member will in turn rotate the second portion, and thus cause it to be threaded downwardly over the first portion 55 of the first tubular member. Consequently, as long as it is possible to transmit torque through the running string to the running tool, this apparatus permits the seal ring 38 to be further expanded by means of such torque, should this be desirable.

As will be appreciated from the drawings, this rotation of the running string is imparted to the seal assembly by means of the pins 25 within the slots 26. That is, rotation of the running string to the right will move the pins 25 to a position next to the vertical leg of the slot, as shown in FIG. 5, whereby further righthand rotation is effective to rotate the second member. Also, in this position, of course, the running tool is so located as to maintain the dogs 48 out of engaging position between portions of the first and second tubular members, so that as in the case of setting the seal ring by weight, the second tubular member is free to be moved downwardly with respect to the first member.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described what is claimed is:

1. A seal assembly for closing off an annular space between the bore of a casing head and a casing hanger supported in the bore, said seal assembly comprising a first tubular member having means adapted to be supported on and connected to the hanger, said first member having first seal means carried thereon for sealably engaging between the first member and the hanger, when said first member is so supported and connected, and an upwardly facing shoulder on its outer side, second seal means supported on the upwardly facing shoulder on the first member, a second tubular member having a downwardly facing shoulder above the second seal means and being movable downwardly with respect to said first member, whereby the shoulders on said members may be moved toward one another to expand said second seal means into engagement between the first member and the bore of the casing head, ratchet means on the first and second member for carrying said first member from said second member and latching said second member in a plurality of vertically spaced positions as it is moved downwardly with respect to said first member, said ratchet means comprising grooves in one and radially expandible and contractible rings on the other of said members, and said grooves being equally vertically spaced apart distance different than the equal vertical spacing between the rings, and means on the second member connectible to a tool for transmitting a downward force thereto for causing it to move downwardly with respect to the first member, when said first member is supported on the hanger.

2. A seal assembly for closing off an annular space between the bore of a casing head and a casing hanger supported in the bore, said seal assembly comprising a first tubular member including a first tubular portion having means adapted to be supported on and connected to the hanger, said first portion of the first member having first seal means carried theron for sealably engaging between said first portion and the hanger, when said first portion is so supported and connected, and an upwardly facing shoulder on its outer side, second seal means supported on the upwardly facing shoulder of said first portion, and a second tubular portion threadedly connected to the first portion, a second tubular member having a downwardly facing shoulder above the second seal means and being movable downwardly with respect to said first portion of the first member, whereby said second seal means may be expanded between said shoulders into sealing engagement between said first portion and the bore, means on the second member and the second portion of the first member for carrying said first member from said second member and latching said second member in at least one vertical position as it is moved downwardly with respect to said first portion of the first member, means for limiting rotation of the second member with respect to the second portion of the first member, as the second member moves downwardly with respect to said first portion, whereby the threaded connection therebetween is effective to lower said second member with the second portion of the first member relative to the first portion of the first member in response to rotation of said second member, and means on the second member connectible to a tool for transmitting a downward force to and rotating said second member.

3. A seal assembly of the character defined in claim 2, wherein the means preventing relative rotation between the second member and the second portion of the first member comprises a groove in one and a spline on the other slidable within the groove.

4. Apparatus for closing off an annular space between the bore of a casing head and a casing hanger supported in the bore, said apparatus comprising a seal assembly including a first tubular member having means adapted to be supported on and connected to the hanger, said first member having first seal means for sealably engaging between said first member and the hanger, when the first member is so supported, and an upwardly facing shoulder on its outer side, second seal means supported on the upwardly facing shoulder, a second tubular member having a downwardly facing shoulder above the second seal means and being movable downwardly with respect to said first member, whereby said second seal means may be expanded between said shoulders into sealing engagement between the first member and the bore, means on the first and second members for carrying said first member from said second member and latching said second member in at least one vertical position as it is moved downwardly with respect to said first member, a tool having a body adapted to be suspended on a running string, said body having means releasably connectible with the second member for transmitting a downward force thereto, and a dog responsive to manipulation of the

body for selectively engaging between portions of the first and second tubular members, so as to prevent the second member from moving downwardly to latching position with respect to the first member, and disengaging from between said portions, so as to permit the second tubular member to be moved downwardly to said latching position.

5. Apparatus of the character defined in claim **4,** wherein the portions of the first and second tubular members comprise oppositely facing surfaces on the inner sides thereon, the dog is normally urged outwardly from the tool body to engage between said surfaces, in one rotative position of the tool body, and there are means on the seal assembly for urging the dog inwardly to disengage between said surfaces, when said tool body is moved to another rotative position.

6. A running tool for activating an annular seal assembly disposed with a bore of a casing head for closing off an annular space between the bore and a casing hanger supported therein, said tool comprising a body having means for connection to the lower end of a running string to permit it to be moved vertically within the well bore for fitting within the seal assembly, said body having upper and lower concentric cylindrical portions of enlarged and reduced diameter, respectively, pins extending outwardly from the enlarged portion of the body, a recess in the reduced portion, a dog guidably slidable within the recess between a retracted position and an extended position in which its outer end is within the vertical projection of the upper portion of the body, means yieldably urging the dog to its extended position, and means for limiting outward movement of the dog to its extended position.

7. A running tool of the character defined in claim **6,** wherein the dog has a hole therethrough, the limiting means comprises a rod extending through the hole to connect at its inner end with said body within said recess and having an enlargement on its outer end, and the urging means comprises a rubber sleeve surrounding the rod on the inner side of the dog in position to be expanded against the recess as the dog is moved inwardly.

8. A seal assembly for closing off an annular space between the bore of a casing head and a casing hanger supported in the bore, said seal assembly comprising a first tubular member having means adapted to be supported on and connected to the hanger, said first member having first seal means carried thereon for sealably engaging between said first member and the hanger, when said first member is so supported and connected, and an upwardly facing shoulder on its outer side, second seal means supported on the upwardly facing shoulder of said first member, and a second tubular member having a downwardly facing shoulder above the second seal means and being movable downwardly with respect to said first member, whereby said second seal means may be expanded between said shoulders into sealing engagement between the first member and the bore, means on the first and second members for carrying said first member from said second member and latching said second member in at least one vertical position as it is moved downwardly with respect to said first member, means on the second member connectible to a tool for transmitting a downward force to the second member, said first and second tubular members having oppositely facing surfaces adapted to engage upper and lower surfaces on an outwardly urged dog on the tool, whereby said second member may be held by said dog from movement downwardly relative to the first member to said position for expanding said second seal means, and cam means on one of said members for forcing said dog inwardly and out of engagement from between said surfaces on the members as the tool is rotated relative thereto.

9. Well completion apparatus for use in closing off an annular space between the bore of a casing head and a casing hanger supported in the bore, said apparatus comprising a seal assembly, including a first tubular member having means adapted to be supported on and connected to the hanger, said first member having first seal means carried thereon for sealably engaging between the first member and the hanger, when said first member is so supported and connected, and an upwardly facing shoulder on its outer side, second seal means supported on the upwardly facing shoulder on the first member, a second tubular member having a downwardly facing shoulder above the second seal means and being movable downwardly with respect to said first member, whereby the shoulders on said members may be moved toward one another to expand said second seal means into engagement between the first member and the bore of the casing head, ratchet means on the first and second members for carrying said first member from said second member and latching said second member in a plurality of vertically spaced positions as it is moved downwardly with respect to said first member, and a tool including a body having means thereon releasably connectible to the second member for lowering the seal assembly within the well bore and transmitting a downward force to the second member to move it downwardly relative to said first member, and a packer for sealably engaging between the body and the hanger beneath the seal assembly so that test pressure may be supplied to the annular space above said seal assembly for testing the effectiveness of its seal, said body and packer also being movable downwardly relative to said hanger in response to said test pressure, whereby said second member may be moved downwardly to a still lower position.

10. Apparatus of the character defined in claim **9,** wherein the means of the tool releasably connectible to the second member includes means for rotating said second member, and said first and second members have means thereon responsive to rotation of said second member for lowering the second tubular member and thus the shoulder thereon with respect to the shoulder on said first member.

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