WELLHEAD CONSTRUCTIONS

Filed March 11, 1963 4 Sheets-Sheet 1

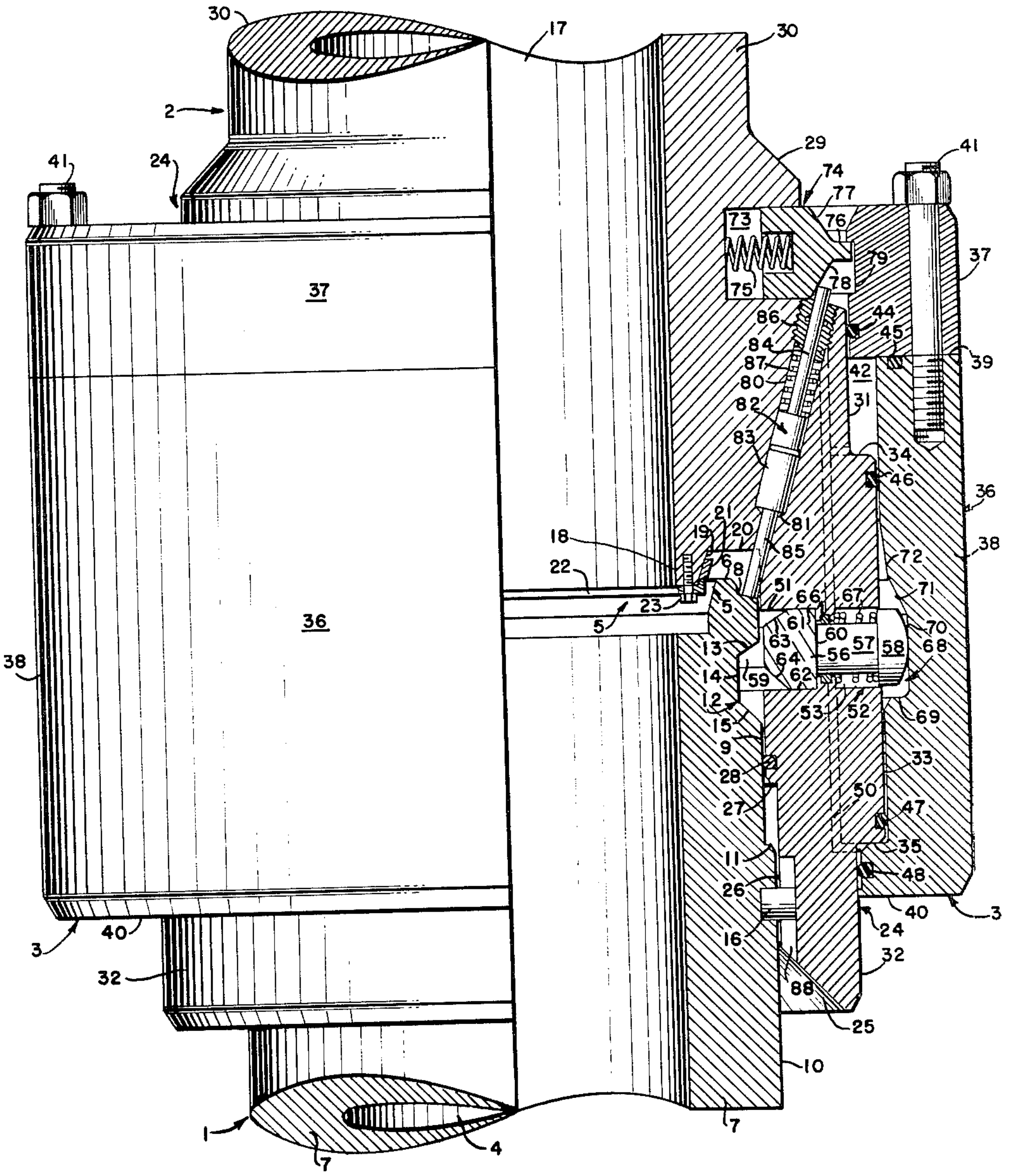

FIG. 1.

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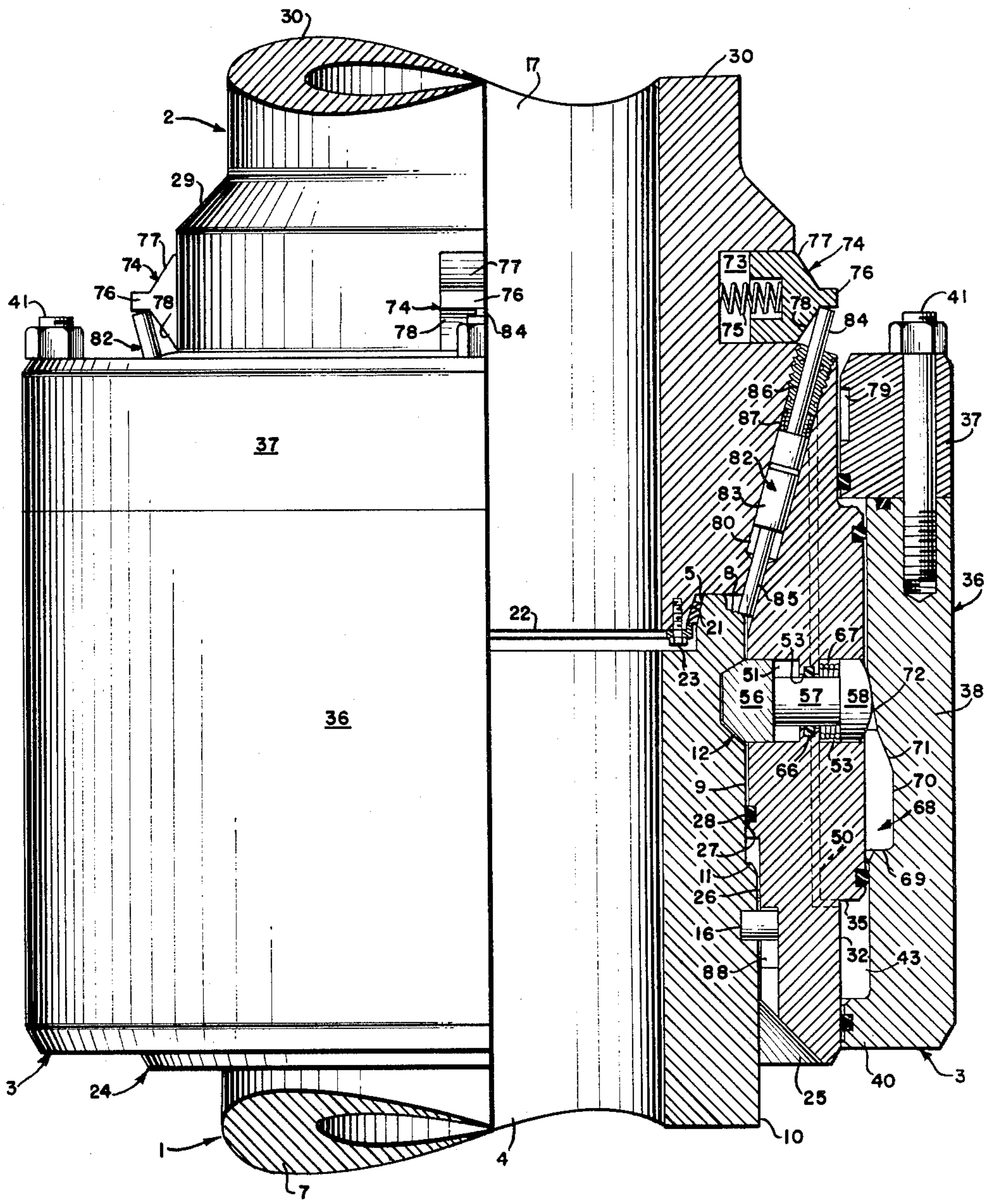

FIG. 2.

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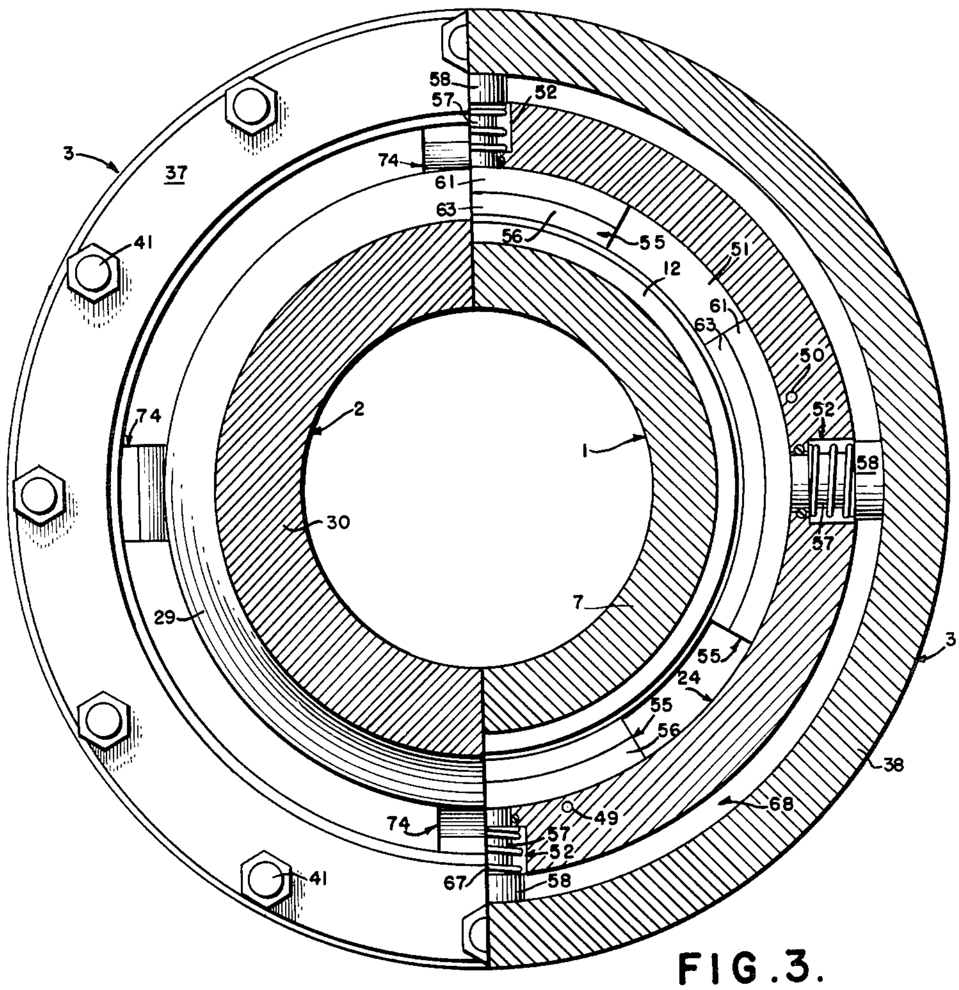

FIG. 3.

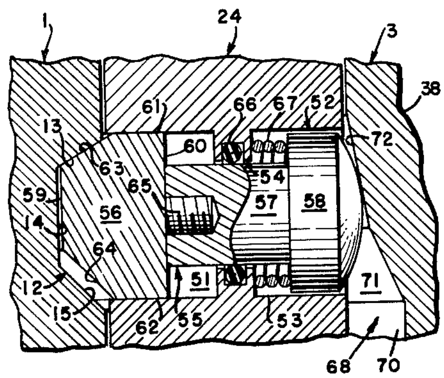

FIG. 4.

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Jan. 11, 1966 C. R. NEILON ETAL 3,228,715

WELLHEAD CONSTRUCTIONS

Filed March 11, 1963 4 Sheets-Sheet 4

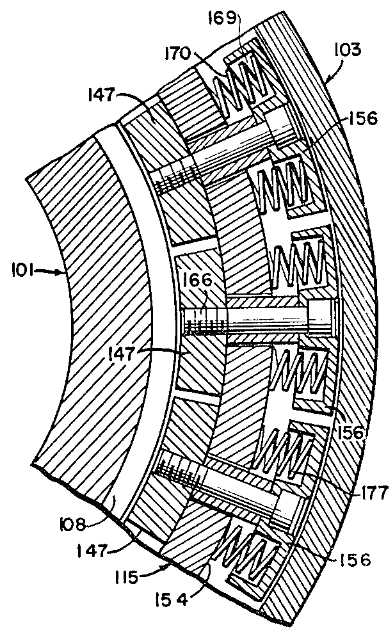

FIG.6.

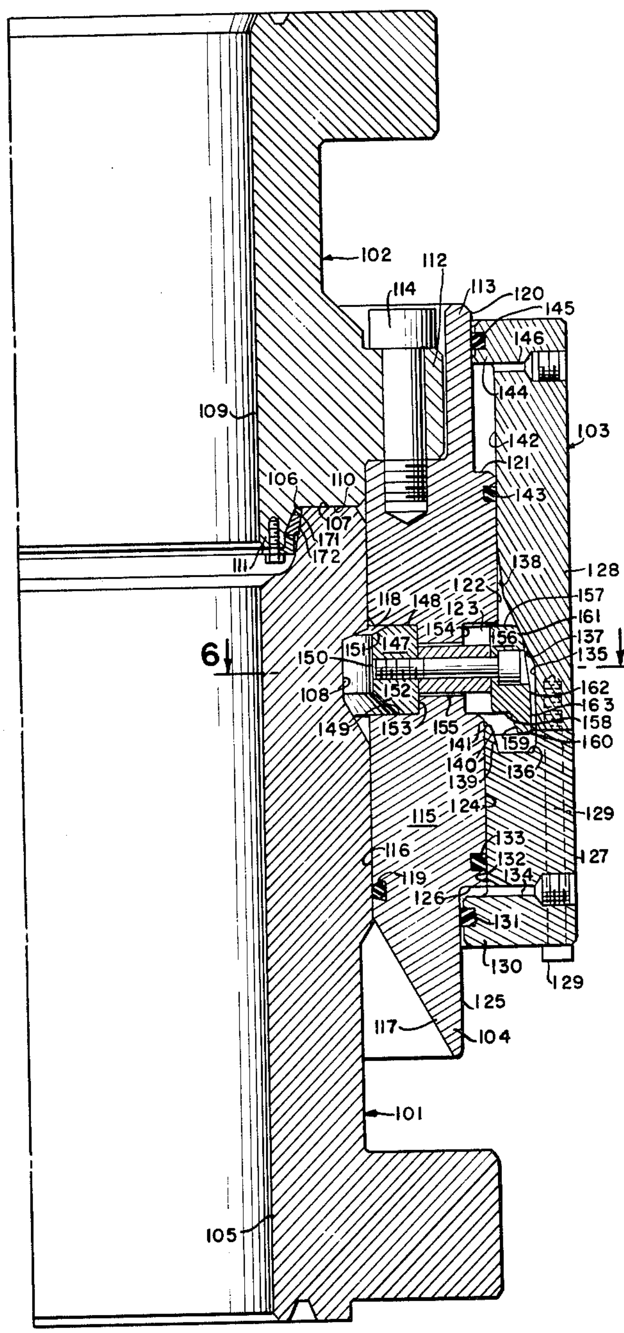

FIG.5.

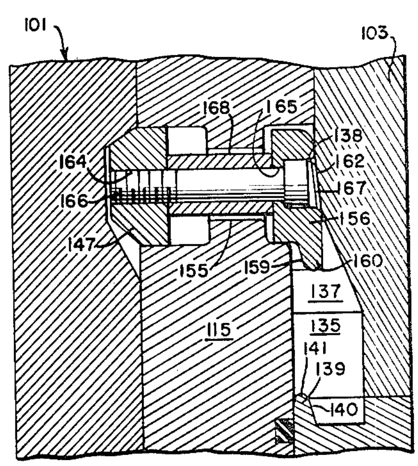

FIG.7.

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3,228,715
WELLHEAD CONSTRUCTIONS

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7 Claims. (Cl. 285—313)

This invention relates to wellhead constructions and, more particularly, to such constructions which are especially adapted for installation at substantial depths under water.

In recent years, the petroleum industry has found it practical to drill wells in earth formations lying beneath bodies of water of a considerable depth. In present-day practice, it is not unusual to drill wells in formations under water up to several hundred feet deep, and drilling operations have already been carried out under thousands of feet of water. In underwater wells generally, and particularly in many subsea operations, the site of the wellhead is at such a depth as to preclude diving operations, unless complicated and expensive diving vessels, operated in conjunction with a caisson or the like, are employed. There is accordingly an active demand for a practical wellhead construction which can be successfully installed without the presence of a human operator at the wellhead site.

Drilling and production requirements are such that underwater remotely assembled wellhead constructions require at least one, and frequently more than one, coupling between upright wellhead body members. Typically, there must at least be one wellhead body member serving to support casing and tubing strings, and at least one Christmas tree body member. Such body members are separately installed and must, of course, be coupled together in fluid-tight relation. Though it might at first appear that the provision of remotely operated couplings suitable for joining the wellhead body members would not be an unusually difficult task, the problem has proved to be extremely difficult because of the adverse conditions encountered in making underwater installations.

In a typical underwater driling operation, for example, a lower wellhead body member may be used to support the casing strings and, ultimately, the tubing string or strings, and the next higher members of the wellhead may be a coupling and the blowout preventer stack, a riser being coupled to the blowout preventer stack. In such an installation, the blowout preventer stack is typically 10–15′ in height and represents a mass on the order of 50,000 pounds. The riser may be of tubing having an inner diameter of 13⅝ inches and a length of 150 feet, for example. The supplier of the wellhead components must, therefore, provide couplings which are capable of handling truly great loads. This problem is greatly complicated by the fact that, when the components are assembled at the wellhead site, the assembly will be subjected to currents up to eight knots and stronger, with the strength of the currents varying at different depths and the direction of the currents also varying. Thus, even without considering forces which result from drilling and like operations carried out via the equipment, it is obvious that the wellhead will be subjected to tremendous bending forces which must be taken across the joint maintained by each coupling. Because of the height of the blowout preventer stack and the riser, the bending couples which may result from wave action and from movement of the drilling vessel act through a long moment arm. On the other hand, the opposing couple, provided by the coupling, acts only through a very short moment arm equal to the radius of the bore at the coupling plus a small increment.

In ability of the coupling to provide a joint capable

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of withstanding the large bending moments resulting from wave action, for example, can result in various kinds of wellhead failure, including failure of the seal or seals at the joint, and failure of support elements, even including the body members themselves. The difficulties arising from such failures vary and can be so severe as to require that the well be abandoned. Despite the fact that experimental, semiexperimental and commercial drilling operations in underwater locations have now been carried out for a relatively long period, the art has heretofore been unable to provide a truly satisfactory coupling for remotely assembled wellhead constructions.

The problem of providing a practical coupling in such circumstances is made more difficult by the fact that the coupling must maintain a satisfactory joint over a prolonged time period. In the case of a coupling at the base of the Christmas tree, for example, the requirement frequently is that the joint be maintained for the life of the well. On the other hand, it is essential that such couplings be capable of being readily disconnected, by remote manipulation, and failure of the coupling to disconnect can lead to great difficulties, even requiring abandoning the well.

A general object of the invention is to provide, in wellhead constructions of the type described, improved coupling means which can be operated remotely and is capable of establishing joints effective to withstand the forces encountered even in deep water installations.

Another object is to provide, in an underwater wellhead construction, means for coupling wellhead members together in such fashion that a truly adequate axial clamping force is established at the joint between the coupled members.

A further object is to provide such a wellhead construction wherein the coupling can be operated, after the joint has been established, to assure that the axial clamping force at the coupled joint will be maintained during use of the wellhead.

Yet another object is to provide an improved, fully practical power operated coupling means for underwater wellhead constructions.

A still further object is to devise a remotely operated wellhead coupling structure which provides maximum assurance of successful establishment and disengagement of the coupled joint solely by remote operation, without requiring diver assistance.

Another object is to provide a remotely operated wellhead coupling structure including power operated means for establishing the coupled joint and wherein the power operated means itself assures against accidental disengagement of the coupling.

A further object is to devise such a structure wherein metal or equivalent sealing rings can be employed under axial pressure to establish effective sealing of the joint.

A still further object is to provide a remotely operated, power actuated coupling for wellhead members so arranged that the power actuated means serves both to accomplish engagement and disengagement of the coupling, and purely mechanical means is available for effecting disengagement of the coupling in the event that power-actuated disengagement cannot be accomplished.

In order that the manner in which these and other objects are attained in accordance with the invention can be understood in detail, reference is had to the accompanying drawings, which form a part of this specification, and wherein:

FIGS. 1 and 2 are views, partly in side elevation and partly in vertical section, of a portion of a wellhead apparatus constructed in accordance with one embodiment of the invention, the two views showing parts of the apparatus in different positions;

FIG. 3 is a view, partly in top plan and partly in transverse section, taken generally on line 3—3, FIG. 1; and

FIG. 4 is an enlarged fragmentary vertical sectional view illustrating details of locking mechanism employed in the apparatus of FIGS. 1–3.

FIG. 5 is a vertical sectional view of one half of a wellhead apparatus constructed in accordance with another embodiment of the invention;

FIG. 6 is a transverse sectional view taken on line 6—6, FIG. 6; and

FIG. 7 is a fragmentary vertical sectional view showing certain elements of the structure of FIG. 5 in different operational positions.

Turning now to the drawings in detail, and first to FIGS. 1–4, it will be seen that this embodiment of the invention comprises a lower body member **1**, such as a casing head, an upper body member **2**, such as a tubing head, and a lock actuating member **3** in the form of a two-piece sleeve. Since the invention is concerned primarily with the manner in which the body members **1** and **2** are engaged and locked together, only the upper portion of member **1** and the lower portion of member **2** are shown, it being understood that the remainder of the wellhead construction can be of conventional form.

Body member **1** is generally cylindrical, having an upright plain cylindrical through bore **4**. At its top, body member **1** has a downwardly and inwardly tapering frusto-conical annular surface **5** which extends transversely of the body member and is concentric with bore **4**. The top edge of surface **5** joins a circular end surface or seat **6** lying in a plane at right angles to the axis of bore **4**. The radial width of surface **6** is less than that of the relatively thick wall **7** of the body member, and a downwardly and outwardly slanting shoulder **8** surrounds that end portion of the member which presents surface **6**.

Body member **1** has an outer cylindrical surface portion **9**, extending downwardly from shoulder **8**, and another outer cylindrical surface portion **10**, portion **10** having a slightly larger diameter than portion **9** and the two portions being separated by a transverse annular upwardly facing shoulder **11**.

Below shoulder **8**, surface portion **9** of the lower body member is interrupted by an outwardly opening transverse annular locking groove **12**. Groove **12** is defined by a downwardly and inwardly slanting top wall **13**, a cylindrical inner wall **14** coaxial with bore **4**, and a downwardly and outwardly slanting lower wall **15**.

Below shoulder **11**, body member **1** carries a locater pin **16** projecting radially outwardly from surface portion **10**.

Upper body member **2** has an upright through bore **17** the lower end of which is encircled by a circularly extending transverse flange **18** having a downwardly and inwardly tapering frusto-conical outer surface **19**. Surrounding flange **18**, and joining surface **19** at the root thereof, is a circularly extending flat surface or seat **20** lying in a plane at right angles to the axis of bore **17**. The diameter of surface **19** is substantially less than the diameter of surface **5** so that, when body member **2** is lowered toward body member **1**, with bores **4** and **17** aligned, flange **18** can enter the space defined by surface **5**, surface **20** coming to rest in face-to-face engagement with end surface **6**, as will be clear from FIG. 2.

The angle at which frusto-conical surface **19** slants inwardly and downwardly is materially greater than the corresponding angle for surface **5**. A metal sealing ring **21** embraces surface **19**, being held in place by a retaining ring **22** secured to the tip of flange **18**, as by screws **23**. Sealing ring **21** is advantageously of the type disclosed in U.S. Patent 2,687,229, issued August 24, 1954, to Laurent, and is made of a metal materially softer than that used in fabricating body members **1** and **2**. The inner and outer surfaces of sealing ring **21** are disposed to at least generally conform to surface **19** and surface **5**, respectively. Accordingly, as flange **18** enters the space defined by surface **5**, the sealing ring is wedged between surfaces **5** and **19**, the sealing ring being sufficiently deformed, when surface **20** comes into engagement with surface **6**, to assure a good fluid-tight seal between the two body members.

Upper body member **2** is provided with an integral cylindrical dependent skirt indicated generally at **24** and disposed concentrically with respect to bore **17** and surface **19**. Skirt **24** projects for a substantial distance below flange **18** and terminates in a downwardly and outwardly tapering frusto-conical guiding surface **25**. Immediately above surface **25**, skirt **24** has an inner diameter slightly greater than the diameter of surface **10** of body member **1**, so that a distinct clearance **26** will be afforded between surface **10** and the inner surface of skirt **24** when the upper body member is seated on the lower body member. When the two body members are engaged in this fashion, the inner surface of skirt **24** extends in plain cylindrical fashion to a point well above shoulder **11**. Here, skirt **24** is provided with a downwardly facing, inwardly extending shoulder **27**. Above shoulder **27**, the inner surface of the skirt is cylindrical and of such diameter as to closely embrace surface portion **9** of body member **1**. Immediately above shoulder **27**, skirt **24** is provided with an inwardly opening, transversely extending groove in which is disposed a sealing ring **28**.

Assuming that body member **2** is so manipulated as to approach the top of body member **1** while bores **4** and **17** are in at least approximate alignment, guiding surface **25** will engage the top of the lower body member and cause the upper body member to be properly centered. Skirt **24** then descends along surface portions **9** and **10** of the lower body member, sealing ring **28** engaging surface portion **9** in substantially fluid-tight relation. Assuming that the installation is being made under water, it is clear than an initial body of water will be trapped in the annular space **29** between shoulders **11** and **27**, this body of water being forced out through clearance **26** as the upper body member descends. Accordingly, a dash-pot action occurs, causing the movement of the upper body member to be slowed to such an extent that, as the upper body member comes into final, seated position, the sealing ring **21** will not engage surface **5** with sufficient force to cause damage to either the surface **5** or the ring.

Above the location of flange **18**, skirt **24** extends as a thickened portion **29** of the main wall **30** of upper body member **2**. Skirt **24** has upper and lower coaxially arranged plain cylindrical outer surfaces **31** and **32**, respectively, separated by an intermediate, outwardly projecting, annular portion **33**. Surfaces **31** and **32** have the same diameter while intermediate portion **33** presents an outer surface of materially larger diameter. Upper surface portion **31** joins intermediate portion **33** at an outwardly projecting, upwardly facing transverse annular shoulder **34**, FIG. 1, while portion **32** joins intermediate portion **33** at an outwardly projecting, downwardly facing transverse annular shoulder **35**.

Lock actuating sleeve **3** comprises a lower portion **36** and an upper portion **37**. Portion **36** includes a cylindrical main body **38** which slidably embraces intermediate portion **33** of skirt **24** and is provided at its top with a flat, transversely extending annular end face **39** and at its bottom with an inwardly projecting transverse annular flange **40**. Portion **37** is in the form of a ring having a flat bottom face engaged in face-to-face contact with the top end face of body **38**, the ring being secured to the body in any suitable fashion, as by studs **41**. While the outer face of portion **37** extends as a continuation of the outer face of body **38**, portion **37** projects inwardly to such a degree that the cylindrical inner face thereof closely embraces surface **31** of skirt **24**. Similarly, the cylindrical inner face of bottom flange **40** closely embraces surface **32** of skirt **24**. It will thus be apparent that, assuming that the actuating sleeve **3** is not otherwise restrained, the sleeve can be moved, axially of the body member **2**, between an upper position, illustrated in FIG. 1, and a lower position, such as that shown in FIG. 2. When the sleeve is in its uppermost position, flange **40** engages the bottom of intermediate portion **33** of skirt **24**, and there is a cylindrical space **42**, FIG. 1, between the top of intermediate portion **33** and ring **37**. In lowered positions of sleeve **3**, there is a cylindrical space **43**, FIG. 2, between the bottom of portion **33** and flange **40**.

Immediately above the bottom of ring **37**, the inner face of the ring is provided with a transverse annular groove accommodating a sealing ring **44** engaged with upper surface portion **31** of skirt **24**. The top of body **38** is provided with an annular upwardly opening groove accommodating a sealing ring **45** which is effective to seal between body **38** and the bottom face of ring **37**. Immediately below its upper end, intermediate portion **33** of the skirt is provided with a transverse annular groove in which is disposed a sealing ring **46** effective to provide a seal between the skirt and body **38**.

Immediately above its lower end, intermediate portion **33** of the skirt has a transverse annular groove accommodating a sealing ring **47** which seals between the skirt and body **38**. Bottom flange **40** is provided with an inwardly opening groove retaining a sealing ring **48** which is engaged with lower surface portion **32** of the skirt.

Skirt **24** is provided with two bores **49** and **50** extending downwardly from the top of the skirt and communicating respectively with spaces **42** and **43**. Bores **49** and **50** are provided at their upper ends with suitable fittings (not shown) for connection of flexible hydraulic conduits to extend between the operator's position and the remote location of the installations.

It is accordingly apparent that spaces **42** and **43**, being sealed in fluid-tight relation for all positions of the actuating sleeve **3**, are effective as expansible chambers, and that the bores **49** and **50** can be employed to supply and exhaust fluid under pressure to the spaces **42** and **43** in order to accomplish movement of actuating sleeve **3** upwardly or downwardly, as desired. It will be understood that the hydraulic lines connected to bores **49** and **50** can be controlled by suitable valves and thus selectively connected to act either to supply fluid or exhaust fluid, depending upon the direction of motion of the sleeve desired.

In a location spaced below flange **18**, skirt **24** is provided with an inwardly opening, circularly extending, transverse groove **51**. The location of groove **51** is such that, when sealing ring **21** is properly engaged with surface **5**, and surfaces **6** and **20** are in mutual engagement, groove **51** will be substantially aligned with groove **12**. Groove **51** has a rectangular transverse cross section. In the same location, skirt **24** is provided with four angularly spaced, radially extending openings **52** each comprising an outer cylindrical portion **53** of larger diameter and a short inner cylindrical portion **54** of smaller diameter. Portions **53** open through the outer surface of intermediate portion **33** of the skirt, while portions **54** open inwardly into groove **51**.

For each of openings **52**, there is provided a lock member indicated generally at **55**. All four of the lock members are identical and only one will be described in detail. As seen in FIGS. 1 and 3, the lock member **55** is made in two parts, one being an arcuately extending locking segment **56** and the other being a cam extension comprising a cylindrical stem **57** and a cam follower portion **58**, portions **57** and **58** being integral with each other.

Locking segment **56** has arcuate inner and outer faces **59** and **60**, respectively, and flat upper and lower faces **61** and **62**, faces **61** and **62** being spaced by a distance such that they are disposed in slidable engagement with the upper and lower walls of groove **51**, respectively. Faces **59** and **61** are joined by a downwardly and inwardly slanting face **63** disposed at the same angle as upper wall **13** of groove **12**. Faces **59** and **62** are connected by an upwardly and inwardly slanting face **64** disposed at the same angle as lower wall **15** of groove **12**.

At its center, segment **56** is provided with a stud portion **65**, FIG. 4, which projects radially outwardly and is exteriorly threaded. Stem **56** is provided at its inner tip with an axially aligned interiorly threaded bore in which stud **65** is threadedly engaged to secure the two parts of the lock member **55** rigidly together. As seen in FIG. 1, stem **57** projects through the corresponding opening portion **54** and thence outwardly through the larger opening portion **53**. The wall of each portion **54** is provided with an inwardly directed transverse annular groove in which is retained a sealing ring **66** disposed to engage the outer surface of stem **57** to afford a fluid-tight seal between groove **51** and the corresponding opening **52**.

Cam follower portion **58** has a circular transverse cross section, the diameter thereof being only slightly smaller than the diameter of portion **53**. The outer tip of portion **58** is spherical. At its inner end, portion **58** presents a flat annular surface, lying in a plane at right angles to the longitudinal axis of stem **57**, this flat annular surface being opposed to and spaced from the shoulder between opening portions **53** and **54**. A helical compression spring **67** is engaged between the flat annular inner face of portion **57** and the shoulder just mentioned and serves to bias the lock member **55** normally to the position seen in FIG. 1, with the lock segment **56** retracted and housed completely in groove **51** and cam follower portion **58** projecting outwardly from the outer surface of intermediate portion **33** of the skirt. Thus, when all of the lock members **55** occupy the normal position just described, the lock members do not interfere in any way with lowering of the skirt over the upper end portion of body member **1**.

At a point intermediate its ends, body **38** of lower portion **36** of the lock actuating sleeve is provided with an inwardly opening transverse cam groove indicated generally at **68**. As best seen in FIG. 4, cam groove **68** has a transverse bottom shoulder **69**, a plain cylindrical surface portion **70**, an intermediate frusto-conical surface portion **71** which slants upwardly and inwardly at a larger angle, and an upper frusto-conical surface portion **72** which slants upwardly and inwardly at a smaller angle. Cam groove **68** is so located that, when flange **40** engages the bottom end of intermediate portion **33** of the skirt, the cylindrical cam surface portion **70** is disposed opposite openings **52**, so that biasing spring **67** can urge the lock members outwardly into their normal positions, cam follower portions **58** engaging the cam surface **70**. Upon downward movement of the lock actuating sleeve **3** on skirt **24**, cam follower portions **58** are engaged successively by cam surface portions **71** and **72**. Since surface portion **71** is disposed at a relatively larger angle, engagement of the cam follower portions with this surface will result in a relatively large radial inward movement of the lock members. Such movement cannot occur, unless the groove **51** has been substantially aligned with groove **12**, it being understood that this initial radial inward movement of the lock members serves to accomplish a preliminary engagement of segments **56** in groove **12**. Further downward travel of lock actuating sleeve **3** causes surface portion **72** to ride over cam follower portions **58** and results in further radial inward movement of the lock members, this further movement being small as compared to the initial movement resulting by engagement of the cam follower portions with cam surface **71**. The purpose of the two-stage cam actuation of lock members **55** will be discussed in detail hereinafter.

Adjacent the top of thickened portion **29**, there are provided four outwardly opening recesses **73** spaced equally about the central axis of body member **2**. Recesses **73** are radially directed and there is provided in each recess a latch element indicated generally at **74** and biased outwardly by a compression spring **75**. The latch elements are identical and only one will be described. The inner end portion of latch element **74** has a rectangular transverse cross section matching that of the corresponding recess **73**, so that the latch element is slidable in the recess and is restrained to a predetermined radial orientation. The latch element has a flat outer tip portion **76** disposed in a plane at right angles to the axis of body member **2**. The upper surface of the latch element includes a downwardly and outwardly slanting portion **77** which joins the flat upper face of tip **76**. Similarly, the lower surface of the latch element includes an upwardly and outwardly slanting portion **78** which joins the lower face of tip **76**. The inner face of ring **37** is provided with an inwardly opening, relatively shallow transversely extending groove **79** having a flat upper wall lying in a plane at right angles to the central axis of actuating sleeve **3**. As will be clear from FIG. 1, when flange **40** engages the shoulder presented by the bottom end of intermediate portion **33** of skirt **24**, groove **79** is so located that outward movement of latch elements **74** will result in engagement of the upper faces of tips **76** beneath the flat upper wall of groove **79**, so that the entire actuating sleeve **3** is retained in its uppermost position by the latch elements. The radial length of the latch elements, and the characteristics of the biasing springs **75**, is such that the biasing springs are effective to move the latch elements outwardly through a distance sufficient to cause tips **76** to engage properly with groove **79**. FIG. 1 illustrates the actuating sleeve latched in its uppermost position and it will be understood that this is the position in which the sleeve is disposed when upper body member **2** is lowered to engage body member **1**.

It will be understood that the latch elements **74**, springs **75** and groove **79** cooperate to form a releasable latch for retaining the sleeve **3** in its uppermost position. In accordance with this embodiment of the invention, release of this latching arrangement is accomplished automatically in response to seating of the upper body member on the lower body member. Adjacent each of the recesses **73**, thickened portion **29** is provided with a downwardly and inwardly slanting bore **80**. All of bores **80** are identical and are arranged in identical fashion with respect to its adjacent recess **73**, and only the single bore seen in FIG. 1 will be described in detail. The lower end portion of bore **80** is of smaller diameter, while the remaining upper portion of the bore is of larger diameter, a transverse shoulder **81** being provided between the two bore portions. The angle of inclination of the bore is such that, when body member **2** is aligned coaxially with body member **1**, as seen in FIG. 1, the axis of bore **80** extends at right angles to the downwardly and outwardly slanting frusto-conical surface **8** at the top of body member **1**.

Slidably disposed in bore **80** is a latch release pin **82** having an intermediate portion **83** of larger diameter and end portions **84** and **85** of smaller diameter. An exteriorly threaded plug **86** is provided in the upper end of bore **80** and has a central bore accommodating upper portion **84** of the latch release pin. A helical compression spring is engaged between the upper end of intermediate portion **83** of the pin and the lower face of plug **86**, so that the spring **87** serves to bias the pin downwardly until the lower end of intermediate portion **83** engages shoulder **81**. With the latch release pin in this normal position, lower end portion **85** thereof projects well below the tip of flange **18**, while upper end portion **84** projects a short distance above the lower wall of the adjacent recess **73**. Hence, biasing spring **75** forces the latch elements **74** outwardly until lower slanting surface portion **78** of the latch element is engaged against the tip of upper portion **84** of the latch release pin. With the parts in these positions, latch element **74** projects outwardly far enough to engage beneath the upper wall of groove **79**.

The locations and inclinations of bores **80**, and the dimensions of latch pins **82**, are such that, with body member **2** spaced slightly above body member **1**, and with the latch pins occupying their normal positions as above described, the lower tips of the latch pins are arranged in a circle which registers with surface **8**. Hence, lowering of the upper body member into proper seated relation will cause the latch pins to come into engagement with surface **8**, so that all of the latch pins are forced upwardly in their respective bores **80**. Such upward movement of the latch pins causes the upper tips thereof to ride along the respective upwardly and outwardly slanting surfaces **78** of the latch elements. Hence, the latch elements are simultaneously shifted radially inwardly to such a degree that tips **76** are withdrawn completely from groove **79** and lock sleeve **3** is accordingly freed for movement downwardly relative to skirt **24**.

The lower portion of the inner surface of skirt **24** is provided with an axially extending locator groove **88** having an outwardly flaring open lower end and so dimensioned as to slidably receive locator pin **16**. The combination of pin **16** and groove **88** serves automatically to orient upper body member **2** in a given rotational position (about the common axis of the two body members) so that wellhead elements (not shown) will be properly oriented. It is to be noted that no special rotational orientation is required for proper operation of the locking means of this invention or for proper operation of the latching means, since locking groove **12**, cam groove **68** and latch groove **79** are all continuous annular grooves which serve their purposes in any relative rotational positions of body member **1**, skirt **24** and sleeve **3**.

Those skilled in the art will understand that lower body member **1** is first installed at the top of the borehole in conventional fashion, being fixed in place rigidly, and that this installation may be made under water at depths up to many thousands of feet. Body member **2** is lowered toward the top of body member **1** in any conventional fashion. For this phase of the operation, guide lines (not shown) of a type now well known in the art are ordinarily employed to achieve approximate centering of body member **2** relative to body member **1**, so that, as the upper body member approaches its final position, frusto-conical guiding surface **25** engages the top of body member **1** and accomplishes precise alignment of body member **2** coaxially with body member **1**. It will be understood that, when body member **2** is prepared for lowering into place, sleeve **3** is in its uppermost position and is retained in that position by engagement of tips **76** of latch elements **74** beneath the upper shoulder of groove **79**, pins **82** being biased to their lowermost positions, seen in FIG. 1, by springs **87**. Accordingly, cam groove **68** is so disposed that lock members **55** are allowed to occupy their normal outermost positions, leaving the internal bore of skirt **24** free and unimpeded to slide over the upper end portion of lower body member **1**.

As sealing ring **28** comes into engagement with surface **9**, a dash-dot action occurs, the water trapped between shoulders **11** and **27** being forced out through clearance **26**. This dash-pot action slows the downward travel of the upper body member sufficiently to assure that parts which come into abutting engagement during final movement of the upper body member will not be damaged. As the dash-pot action commences, the upper body member is rotated until pin **16** enters groove **88**. Downward motion of the upper body member continues, the lower tips of pins **82** coming into engagement with surface **8**, so that continued descent of body member **2** causes the pins **82** to be raised, the upper ends of the pins then camming latch elements **74** inwardly by reason of the fact that the upper ends of the pins ride along slanting surfaces **78** of the latch elements. Tips **76** of the latch elements are thus withdrawn from groove **79**, freeing sleeve **3** for downward movement relative to skirt **24**. Since sleeve **3** is of very substantial weight, downward movement thereof may commence by gravity. In this connection, it is to be noted that the sleeve **3** may weigh several thousand pounds for wellhead constructions of conventional size. Initial downward movement of the sleeve at this time is not disadvantageous, since such movement will not occur until groove **51** has passed below surface **8**, so that such initial inward movement of lock members **55** as may result can only cause the inner faces **59** of the locking segments to engage surface **9**. If desired, gravitational movement of sleeve **3** can be prevented by maintaining adequate hydraulic pressure in cylindrical space **42**.

Further downward movement of upper body member **2** brings metal sealing ring **21** into engagement with surface **5**, the relatively great weight of the upper body member causing ring **21** to be engaged between surfaces **5** and **19** in wedging fashion so that a good fluid-tight seal is obtained between the two body members. The positions of surfaces **5** and **19** and the shape and dimensions of ring **21** are such that, as the sealing ring becomes finally seated, when adequate clamping force is applied to members **1** and **2**, surface **20** is allowed to come into full face-to-face engagement with surface **6**, so that upper body member **2** is seated directly on lower body member **1**.

When upper body member **2** has thus been seated on the lower body member **1**, groove **51** is, because of the relative dimensions of the parts of the apparatus, substantially aligned with lock groove **12**. As seen in FIG. 4, it is advantageous that, at this stage of the operation, the upper wall of groove **51** be disposed slightly above the outer edge of wall **13** of lock groove **12**. Hydraulic pressure is now applied via bore **50**. The pressure fluid enters betwen flange **40** and shoulder **35**. Accordingly, sleeve **3** is forced downwardly. Downward movement of sleeve **3** first causes cam surface portion **71** to slide simultaneously over the outer ends of all four cam follower portions **58**, causing lock members **55** to be forced radially inwardly, with segments **56** entering groove **12**. Further descent of sleeve **3** causes the uppermost cam surface portion **72** to engage all of the cam follower portions **58**. Since cam surface portion **72** is disposed at a relatively smaller angle, and is of a smaller average diameter than portion **71**, a correspondingly smaller radial inward movement of the lock members **55** results. As seen in FIG. 4, descent of only a part of cam surface portion **72** past the point of engagement with cam followers **58** causes surface portion **63** of segments **56** to be solidly wedged beneath upper wall **13** of groove **12**.

Such wedging action applies an axially clamping force effective to secure body members **1** and **2** rigidly together, with surfaces **6** and **20** engaged. It is to be noted that application of this clamping force involves a simple and direct load circle including the upper end portion of body member **1**, the segments **56**, and the integral structure comprising the upper portion of skirt **24** and the lower portion of body **2**. Independent of the load circle involved in energization of sealing ring **21**, the clamping load circle is such that the clamping force does not act through threaded or bolted joints, and the opportunities for loosening of the coupling once segments **56** are engaged in groove **12** are minimized.

Even though surfaces **6** and **20** are clamped in direct engagement, and the clamping load circle mainly involves solid metal bodies, it is still highly advantageous to provide for increasing of the wedging action of segments **56** in groove **12** subsequent to installation of the coupling. In this regard, it is to be noted from FIG. 4 that, after the coupling has been engaged initially, space still remains between inner wall **14** of groove **12** and faces **59** of segments **56** to allow further radial inward movement of the locking members and space also still remains between portion **33** and ring **37** and, therefore, additional wedging action between surfaces **63** and wall **13** can be accomplished as a result of further descent of actuating sleeve **3**, causing further travel of cam surface portion **72** over the follower portions **58**. At least to some degree, this further downward movement can be allowed to result solely by gravitational action, particularly where the weight of sleeve **3** is large. Alternatively, this additional movement can be accomplished positively, simply by increasing the hydraulic pressure applied via bore **50** to cylindrical space **43**.

The ability to provide additional wedging action between surfaces **63** and wall **13** after the wellhead has been installed is particularly important, since the wellhead assembly can be satisfactory only if the high clamping force applied to body members **1** and **2** is preserved. During use after installation, the wellhead is subjected to vibration, shock and the severe bending moments hereinbefore discussed and, in many instances, the high clamping force established when the coupling is made up will not persist unless further wedging of the segments in the locking groove can be effected.

Surface **72**, constituting a "slow taper" portion of cam groove **68**, also coacts with followers **58** to provide a frictional lock-down capable of preventing accidental upward displacement of ring **3**. In this regard, surface **72** tapers toward the axis of the assembly at an angle so small that the tangent thereof is materially less than the coefficient of friction between surface **72** and followers **58** under the conditions of pressure and lubrication employed. Thus, for example, surface **72** can extend at an angle of approximately 4°45′, to the wellhead axis. With ring **3** and followers **58** formed of steel, and with suitable lubrication, the coefficient of friction at surface **72** is decidedly greater than the tangent of the angle at which surface **72** is disposed, and even rather large upward forces on ring **3** are successfully resisted by the frictional engagement between the followers **58** and surface **72**.

It will be apparent that, at any time after installation, the two body members can be unlocked simply by relieving the hydraulic pressure in chamber **43** and applying adequate hydraulic pressure via bore **49** to chamber **42**. This results in upward movement of actuating sleeve **3** relative to skirt **24** and this movement can be continued until flange **40** engages shoulder **35**. Such upward movement brings cam grooves **68** again into full registry with openings **52**, so that springs **67** can again move locking members **55** radially outward to an extent such that segments **56** are completely withdrawn into groove **51**. Such withdrawal of locking members **55** allows upper body member **2** to be raised and detached from body member **1**. As body member **2** is moved upwardly away from the top of body member **1**, pins **82** are again moved downwardly by springs **87** and, assuming sleeve **3** to be held in its uppermost position, the tips **76** of latching elements **74** again engage in groove **79** to latch sleeve **3** in its raised position.

Use of the exterior ring **3**, coacting with skirt **24** to form chambers **42** and **43**, offers distinct advantages. This construction can ge manufactured with relative ease and at relatively low cost, without requiring that strength be sacrificed. Also, being fully exposed, ring **3** can be actuated mechanically to release the coupling in the event of failure of the hydraulic system. In this regard, mechanical actuation of the ring **3** can be accomplished with an overshot ring (not shown), or simply by use of jerk lines (not shown) attached to the ring in any suitable fashion. Finally, ring **3** in no way interferes with the application of the clamping force to members **1** and **2**.

FIGS. 5–7 illustrate another embodiment of the invention, again in the form of a wellhead construction comprising a lower body member **101**, an upper body member **102** and a locking member in the form of a two-piece sleeve 103, an annular member 104 being secured rigidly to and depending from upper body member 102.

Member 101 is a cylindrical tubular member having a through bore 105 and, at its top, a transverse annular downwardly and inwardly tapering frusto-conical surface 106. Surface 106 joins a circular transversely extending end surface 107 lying in a plane at right angles to the axis of bore 105. The upper portion of member 101 has a plain cylindrical outer surface interrupted by an outwardly opening transverse annular locking groove 108 which is spaced below the location of surfaces 106 and 107.

Upper body member 102 is generally cylindrical, having a through bore 109, a flat, circularly extending transverse end face 110, and a dependent annular flange 111 which has an outer downwardly and inwardly slanting frusto-conical surface 171 so disposed as to be spaced concentrically inwardly from surface 106 when the end face 110 of member 102 is seated upon end face 107 of member 101.

Member 102 has an outwardly projecting annular flange 112 having a cylindrical outer face embraced by an uptsanding tubular projection 113 on annular member 104. Flange 112 has a flat bottom face and member 104 is correspondingly provided with a flat face enclosed by projection 113 and disposed to be engaged directly by the bottom face of flange 112. Member 104 is rigidly secured to member 102, as by screws 114.

The main body 115 of member 104 has a plain cylindrical inner surface 116 of a diameter to slidably embrace the outer surface of the upper portion of body 101. At its lower end, surface 116 joins an outwardly and downwardly slanting frusto-conical guide surface 117. In a location to be aligned with locking groove 108 when member 102 is seated on member 101, cylindrical surface 116 is interrupted by an inwardly opening transverse annular groove 118 having flat top and bottom walls and a cylindrical outer wall. An annular seal 119, retained in a suitable groove provided in surface 116 adjacent surface 117, is employed to effect a fluid-tight seal between members 101 and 104.

Projection 113 has a cylindrical outer surface 120 terminated at its lower end by an outwardly projecting transverse annular shoulder 121. Shoulder 121 also determines the upper end of a cylindrical outer surface portion 122 of larger diameter than surface 120. At its bottom end, surface portion 122 terminates at the upper wall of an outwardly opening transverse annular groove 123. Below groove 123, member 104 has outer cylindrical surface portions 124 and 125 which are separated by a downwardly facing transverse annular shoulder 126, surface portion 124 having a larger diameter than does surface portion 125 and a somewhat smaller diameter than surface portion 122.

Locking sleeve 103 comprises a lower portion 127 and an upper portion 128 rigidly secured together, as by screws 129. At its bottom end, member 103 has an inwardly projecting transverse annular flange 130 having a grooved cylindrical inner surface, the groove retaining a suitable seal 131. The diameter of the inner surface of flange 130 is such that the seal 131 is maintained in slidable fluid-tight sealing engagement with surface portion 125. Immediately above flange 130, member 103 presents a cylindrical inner surface portion 132 which closely embraces surface portion 124 of member 104. Surface portion 124 is provided with a groove immediately above shoulder 126, and a seal 133 is disposed in this groove to provide a fluid-tight seal between members 103 and 104 at this point. Flange 130, shoulder 126, surface portion 125 and surface portion 132 define an expansible chamber, and a suitable duct 134 is provided in member 103 for the supply and exhaust of fluid from this chamber.

Immediately above inner surface portion 132, member 103 is provided with a cam groove comprising a cylindrical outer surface portion 135, a transverse bottom wall 136 and two upwardly and inwardly slanting surface portions 137 and 138. Surface portion 137 joins outer wall 135 and slants inwardly at a relatively larger angle which may, for example, be 24°. Upper slanting surface portion 138 joins surface portion 137 and slants inwardly at a markedly smaller angle which may, for example, be slightly in excess of 4°.

Bottom wall 136 of the cam groove does not extend completely to surface portion 132 but is terminated by an upwardly directed tubular projection 139 which is defined by the upper portion of surface 132, an outer wall 140, and a rounded upper edge 141.

Above the cam groove member 103 has an inner cylindrical surface portion 142 of a diameter to closely embrace outer surface portion 122 of member 104. Surface portion 122 is grooved, immediately below shoulder 121, to accommodate a seal 143 for effecting a fluid-tight seal between surfaces 142 and 122 in this location. At its upper end, member 103 is provided with an inwardly directed transverse annular flange 144 which presents a cylindrical inner surface of a diameter to closely embrace tubular projection 113. The inner face of flange 144 is suitably groved to retain a seal 145, so that a fluid-tight seal is effected between flange 144 and the outer cylindrical surface 120 of projection 113. The lower face of flange 144, shoulder 121, surface 122 and surface 142 combine to define an expansible chamber with which a duct 146 communicates for the supply and exhaust of pressure fluid.

Groove 118 in member 104 slidably retains a plurality of identical locking segments 147. Segments 147 are arculate and arranged end-to-end in a circular series, as will be clear from FIG. 6. Each segment 147 has a flat upper face 148, a flat lower face 149, and an arcuate face 150. Upper face 148 is joined to arcuate face 150 by a downwardly and inwardly slanting face 151 and an upwardly and inwardly slanting face 152 is provided between lower face 149 and arcuate face 150. Each segment also has an arcuate outer face 153, the distance between faces 150 and 153 being somewhat less than the radial depth of groove 118. The height of each segment 147 is such that surfaces 148 and 149 slidably engage the upper and lower walls, respectively, of groove 118.

Grooves 118 and 123 are separated by an annular wall 154 provided with a plurality of radially directed cylindrical bores 155, there being one bore 155 for each of the locking segments 147.

Groove 123 slidably accommodates a plurality of identical cam follower segments 156 which are equal in number to the locking segments 147. Segments 156 are arcuate and arranged end-to-end in a complete circular series, as will be clear from FIG. 6. Each segment 156 has a flat upper surface 157 and a flat lower surface 158 which, at its outer edge, joins the downwardly and outwardly slanting arcuate surface 159 of a dependent cam flange 160. The outer face of each follower segment 156 is designed to cooperate with the inwardly facing cam surfaces presented by the locking sleeve 103. The outer face of each follower segment includes a rounded upper portion 161, a downwardly and outwardly slanting intermediate portion 162, and a cylindrical lower portion 163.

As will be clear from FIG. 7, each cooperating pair of locking and follower segments is provided with radially aligned bores 164 and 165, respectively, bore 164 being threaded for engagement with a retaining screw 166. The follower segment 156 is recessed, as indicated at 167, to accommodate the head of the retaining screw. A spacer sleeve 168 surrounds the screw 166 and has its ends in respective engagement with the adjacent faces of segments 147 and 156, the diameter of the sleeve 168 being such that the sleeve is freely accommodated in the corresponding bore 155 through wall 154.

As will be clear from FIG. 6, each follower segment 156 is provided with a pair of cup-shaped recesses 169 which are located each on a different side of bore 156 and open toward wall **154**, the recesses having flat bottoms and cylindrical side walls. In each recess, there is disposed a helical compression spring **170**, one end of the spring engaging wall **154** and the other end of the spring engaging the bottom of the recess. Springs **170** are held in compression between the follower segments **156** and wall **154** and are operative to normally urge the follower segment **156** outwardly into the cam groove presented by locking ring **103**. Assuming that the cam groove is positioned to accommodate the follower segments, springs **170** are effective to move the follower and locking segments, coupled together by screws **166**, radially outwardly until outer face **153** of each locking segment engages the corresponding face of wall **154**, as seen in FIG. 5. With the parts in this position, the locking segments **147** are fully withdrawn from locking groove **108**. Downward movement of locking ring **103** relative to member **104** causes cam surfaces **137** and **138** to ride over the rounded surface portion **161** of the follower segments, until cam surface portion **138** lies in face-to-face engagement with surface portion **162**. With the parts in this position, as illustrated in FIG. 7, the downwardly and inwardly slanting upper faces **151** are engaged beneath the upwardly and outwardly slanting wall of groove **108** in wedging fashion, so that members **101** and **102** are clamped axially together with end surfaces **107** and **110** in direct face-to-face contact with each other.

Referring particularly to FIG. 7, it will be noted that surface portions **162** of followers **156** taper inwardly and upwardly at the same angle as does surface portion **138** of the cam groove in ring **103**. Hence, when the ring has been actuated inwardly by downward movement of cam surface portion **137** past followers **156**, the surface portions **162** come into flush, face-to-face engagement with cam surface portion **138**. As compared to the corresponding structure in the embodiment of FIGS. 1–4, the followers **156**, with their specially disposed surface portions **162**, afford a greater area of engagement with the cam surface and, therefore, a superior ability to provide a frictional lock-down action for ring **103**.

When ring **103** is again moved upwardly, so that portion **135** of the cam groove is opposite the follower segments, springs **170** are normally effective to urge the follower and locking segments outwardly, causing the locking segments to be withdrawn from groove **108**. Should the segments be frictionally held or otherwise jammed in place to such an extent that the springs **170** are ineffective to accomplish such movement, the upwardly directed tubular projection **139**, located at the bottom of the cam groove in ring **103**, moves upwardly between dependent flange **160**, on the follower segments, and surface **124**. As will be clear from FIG. 7, the parts are so dimensioned that, during such upward movement, the rounded nose **141** of projection **139** engages surface **159** of flange **160** and cams the follower segment outwardly, freeing the same so that the springs **170** will become effective.

Selective actuation of the ring **103**, upwardly and downwardly on member **104**, is accomplished by controlled admission of power fluid under pressure via ducts **134** and **146**. With the parts in the relative position seen in FIG. 5, it will be understood that introduction of power fluid via duct **134** provides fluid pressure in the expansible chamber defined by shoulder **126**, flange **130** and surfaces **125** and **132**, this fluid pressure being effective to move the ring **103** downwardly. During such movement, any fluid contained within the chamber defined by shoulder **121**, surfaces **120** and **142**, and flange **144** is exhausted via ducts **146**. It will be obvious that, with the ring **103** in its lowermost position, introduction of power fluid via duct **146** is effective to raise ring **103**.

Dependent flange **111** on upper body member **102** presents a downwardly and inwardly tapering frusto-conical surface **171** which opposes surface **106** when faces **110** and **107** are in engagement. A suitable metallic sealing ring **172**, retained by ring **173**, provides a fluid-tight seal between surfaces **106** and **171** when the upper body member **102** is properly seated on lower body member **101**.

Both embodiments of the invention provide a practical solution to the problem of establishing by remotely operated means the necessary high axial clamping force between the wellhead body members, and for maintaining this force throughout the life of the wellhead assembly. Both embodiments also make it possible to employ metal sealing rings, such as the Laurent-type rings **21** and **172**, in underwater, remotely asembled wellhead constructions.

While particularly advantageous embodiments of the invention have been chosen for illustration, it will be understood by those skilled in the art that various changes and modifications can be made therein without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. In a well apparatus for installation at an underwater location, the combination of

an upright lower metal member having
- an axial through bore,
- a cylindrical outer surface and an outer downwardly directed transverse annular locking shoulder,
- a transverse annular upper end face, and
- an upwardly exposed annular seat spaced outwardly from said through bore,
- said shoulder, said end face and said seat being concentric with said through bore;

an upright upper metal member having
- an axial through bore,
- a transverse annular lower end face, and
- a downwardly exposed annular seat spaced outwardly from said through bore of said upper member,
- said lower end face and said downwardly exposed seat being concentric with said through bore of said upper member;

dependent tubular means rigidly carried by said upper member concentric with said through bore thereof;

a metal sealing ring;

a plurality of locking devices carried by said dependent tubular means and arranged in a circular series,
- each of said locking devices having an outer cam follower portion and an inner portion having an upwardly exposed downwardly and inwardly slanting surface;

means yieldably biasing said locking devices outwardly toward positions in which said inner portions are retracted and said cam follower portions are outwardly exposed;

said upper member being disposed on said lower member with said end faces in direct mutual engagement and said dependent tubular means surrounding the upper end portion of said lower member,
- said sealing ring being disposed between and engaged by said annular seats,
- said locking devices being disposed with said downwardly and inwardly slanting surfaces facing said locking shoulder;

an annular member carried by said dependent tubular means for axial movement relative thereto between a first position and a second position,
- said annular member having inwardly facing cam means comprising a first, sharply tapering frusto-conical cam surface and a second adjacent frusto-conical cam surface, said first and second cam surfaces tapering axially of said annular member in the same direction, said second cam surface tapering at a markedly smaller angle and being of a smaller average diameter than said first cam surface,
- movement of said annular member from said first position toward said second position causing said

first and second cam surfaces to engage said cam follower portions and force said locking devices radially inwardly and cause said downwardly and inwardly slanting surfaces of the inner portions of said locking devices to wedge beneath said locking shoulder and so establish an axial clamping force effective to secure said upper and lower members rigidly together; and

remotely operated power means for driving said annular member,

the dimensions and locations of said locking shoulder, said second frusto-conical cam surface, and said locking devices being such that, when said annular member has been moved axially toward said second position to such an extent that the wedging action of said downwardly and inwardly slanting surfaces beneath said locking shoulder establishes said axial clamping force, said locking devices are still capable of further inward movement, as a result of further axial movement of said annular member, to preserve solid metal-to-metal contact between said end faces, and between said seats and said sealing ring, even though the well apparatus has been subjected to vibration, shock and bending forces which would otherwise cause loss of such solid metal-to-metal contact.

2. Well apparatus according to claim **1**, wherein

said lower and upper members are wellhead members.

3. Well apparatus according to claim **1**, wherein

said dependent tubular means comprises a generally cylindrical metal member having an internal diameter such as to closely surround said lower member in the location of said locking shoulder when said end faces are mutually engaged, said cylindrical metal member having

a transverse annular inwardly opening groove, and

a plurality of radial openings extending outwardly from said groove and spaced apart in an annular series,

said groove having an upper wall which is disposed slightly above said locking shoulder when said end faces are mutually engaged; and

each of said locking devices comprises

a rigid stem extending through one of said radial openings and interconnecting said cam follower portion and said inner portion of the locking device,

said inner portion of each of said locking devices being in the form of an arcuate segment slidably disposed in said inwardly opening groove,

the radial depth of said inwardly opening groove being sufficiently greater than the radial dimension of said segments to allow said segments to be retracted completely within said groove.

4. Well apparatus according to claim **3**, wherein

said cylindrical metal member also is provided with an outwardly opening transverse annular groove,

said radial openings communicating between said inwardly opening and outwardly opening grooves; and

said cam follower portion of each of said locking devices is in the form of an arcuate segment slidably disposed in said outwardly opening groove.

5. Well apparatus according to claim **4**, wherein

each of said cam follower segments is provided with an outwardly facing downwardly and outwardly slanting surface disposed to come into face-to-face engagement with said second frusto-conical surface of said annular member as said annular member is moved toward said second position.

6. Well apparatus according to claim **3**, wherein

said cylindrical metal member has an intermediate portion of larger outer diameter, and upper and lower portions of smaller outer diameter,

said inwardly opening groove being in said intermediate portion, and said radial openings extending outwardly through said intermediate portion; and

said annular member slidably embraces said intermediate portion of said cylindrical metal member and includes upper and lower transverse annular inwardly extending portions which respectively embrace said smaller diameter upper and lower portions of said annular member,

said annular member and said cylindrical metal member cooperating to define upper and lower expansible chambers to which pressure fluid can be supplied selectively to drive said annular member.

7. Well apparatus according to claim **1**, wherein

said seats are frusto-conical surfaces which converge axially of said upper and lower members, and

said sealing ring is wedged between said seats.

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