Nov. 29, 1966 B. J. WATKINS 3,288,472

METAL SEAL

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FIG. 1.

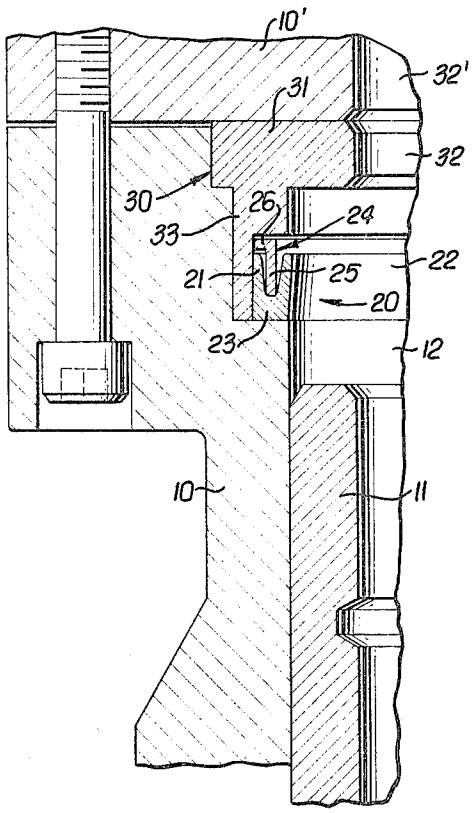


FIG. 3.

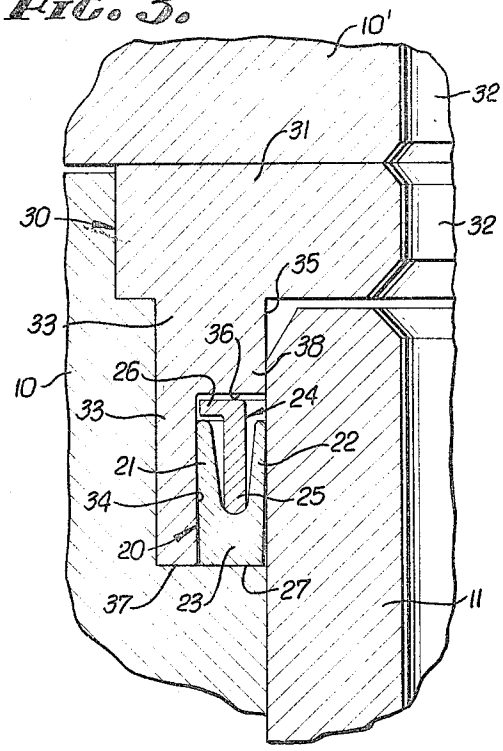


FIG. 2.

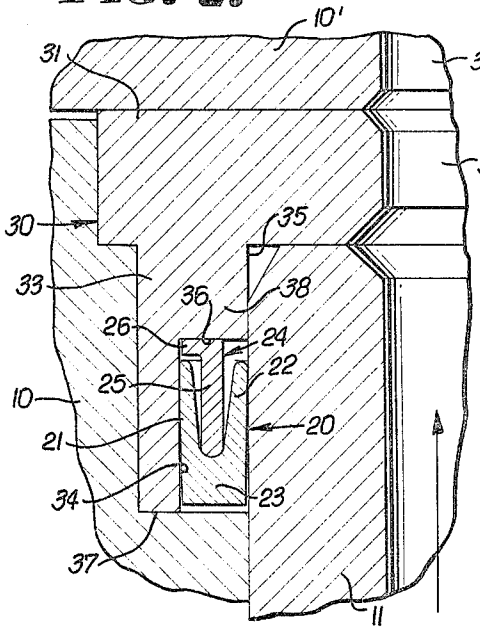
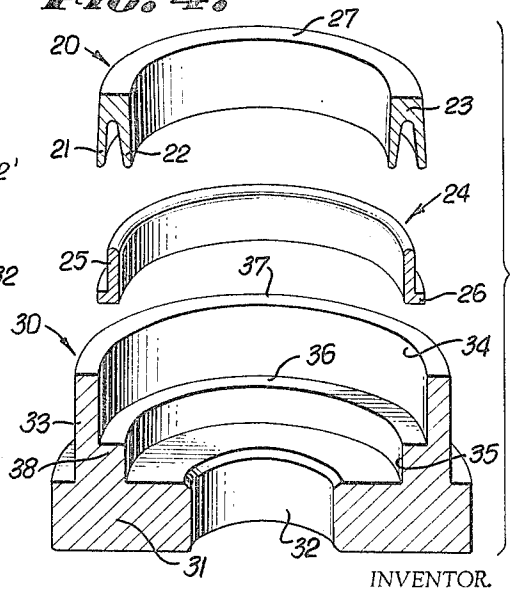


FIG. 4.



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FIG. 5.

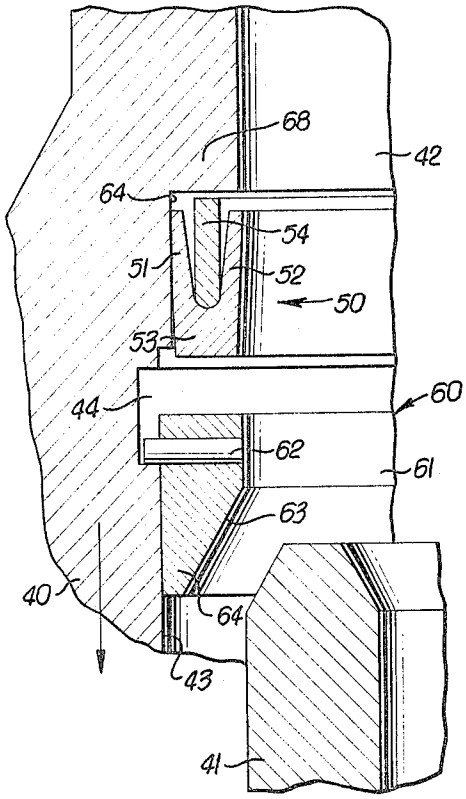


FIG. 6.

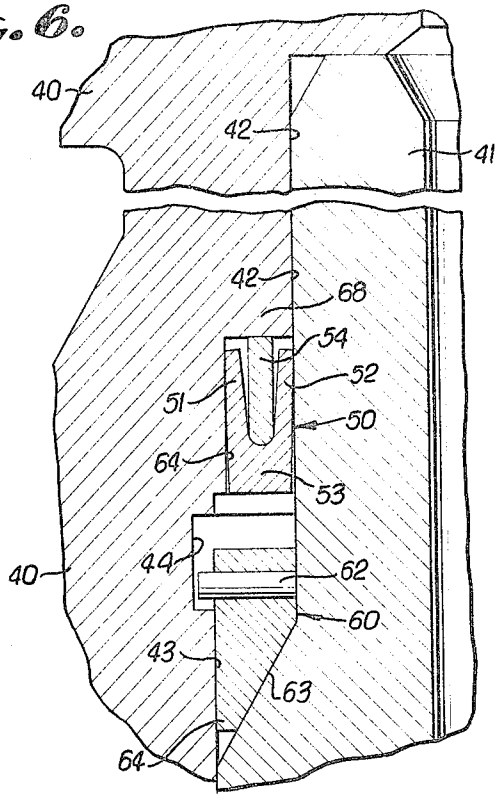


FIG. 7.

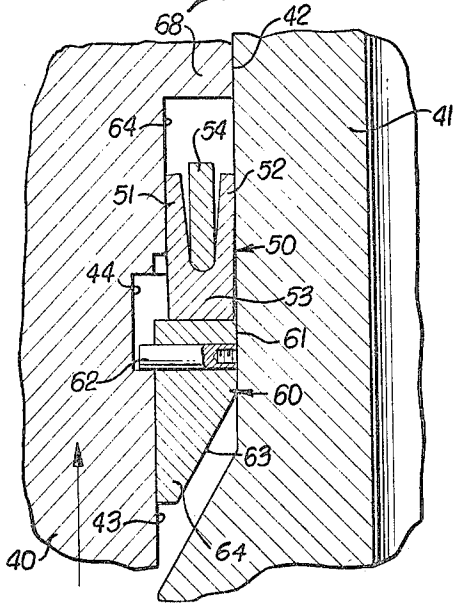
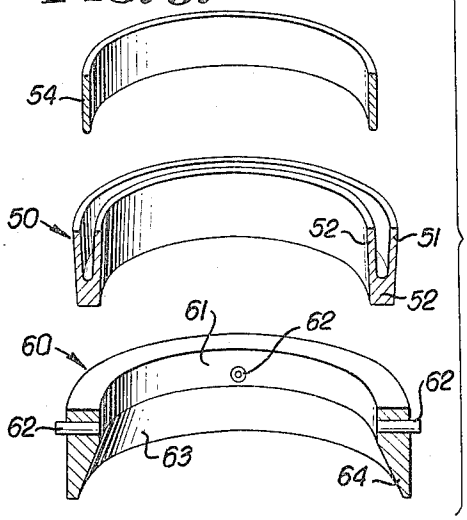


FIG. 8.



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3,288,472

METAL SEAL

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Filed July 1, 1963, Ser. No. 291,723
3 Claims. (Cl. 277—11)

This invention relates in general to an apparatus and method of effecting a fluid tight surface seal between an oil well drilling casing and an inner casing or mandrel member upon running of the casing over the mandrel member. More particularly, this invention relates to an apparatus and method of effecting such a high pressure metal seal particularly adapted for use in subsea oil well drilling which is deformable within its elastic limit to provide a surface seal between coaxial casing members without the application of additional external or internal sealing forces.

With the increase in off-shore or subsea oil well drilling from stationary platforms and floating vessels, there has developed a need for apparatus and methods of effecting high pressure seals between coaxial casing members capable of use in subsea locations at an appreciable distance from the well rig. Further, in undersea drilling the repeated entry and re-entry of a well for the various drilling and producing operations at water depths of several hundreds of feet has created a demand for a seal that is reusable indefinitely and effected merely upon the running of an outer casing over an inner casing or mandrel member. For example, in drilling a subsea well, after the surface casing has been landed on the conductor pipe casing set in the well, a drilling bonnet is run down over the surface casing head and latched thereto. In order to maintain well pressure within the casing, while drilling the production casing hole, a high pressure seal must be effected between the bonnet and surface casing head, preferably upon the running of the bonnet over the casing head.

Previously employed seals have not been suitable for use in a subsea environment and have not been reusable. Pressurized seals and annular rings of different shapes, fitted together in stacks or nests, have been employed unsatisfactorily. Such seals, made of synthetic rubber, fiber composition and soft metal have all tended to deform permanently on their first use. Prior rubber seals have provided only a lip seal, depended on internal well pressure for sealing forces and deteriorated from the associated gases and the presence of sea water. Prior metal seals, such as disclosed in United States Letters Patent No. 2,766,829 have required the application of external forces, as by clamps and bolted flanges, to effect a seal. Such metal seals incorporated with conduit connections cannot operate to effect a seal on running of a casing member over a mandrel and thus are not suited for use in the repeated engagement and disengagement of mating parts in drilling operations beneath the sea.

It is a primary object of this invention, therefore, to disclose and provide apparatus for and a method of effecting a high pressure metal-to-metal seal between a casing and an inner mandrel member upon the running of the casing over the mandrel member.

It is also an object of this invention to disclose and provide a metal seal assembly adapted to be used in subsea oil well drilling and producing operations which will not deteriorate in the subsea well drilling environment, which is reusable and is easily assembled within an oil well casing to be run over an inner casing or mandrel member.

It is a further object of this invention to disclose and provide a metal seal assembly to be preassembled within a casing which is self-energizing upon running of the casing over the mandrel to effect a fluid tight seal between the casing and a mandrel without the application of additional internal or external forces.

It is another object of this invention to disclose and provide a method of effecting a fluid tight surface seal between a casing and a mandrel member upon running a casing over a mandrel member without the application of internal well pressures or external clamping pressures to effect the seal which is easily employed on subsea drilling and producing operation and insures repeated use of the sealing apparatus for an indefinitely long period of time.

It is a still further object of this invention to disclose and provide a novel apparatus and method of orienting a metal sealing means within a recess within an oil well casing to unfailingly provide an effective fluid tight surface seal between the sealing means and an inner casing or mandrel member over which the casing is run and insure its retention within the casing upon removal of the casing from the mandrel member.

It is also another object of this invention to disclose and provide a method of spacing a single metal seal ring within a casing recess during its elastic deformation by the passing of a mandrel member therethrough upon the running of a casing member over an inner casing or mandrel member to prevent binding, undue wearing and deterioration of the metal seal ring within the casing.

Generally stated, the apparatus according to the present invention comprises a metal seal assembly including an annular sealing means made of metal with an upwardly opening annular channel therein. The channel is formed by spaced divergent walls having outer surfaces provided with a downward taper, a taper of approximately two degrees in the preferred embodiment. The sealing means is adapted to be inserted within a recess within a casing member with its tapered outer wall elastically deformed therein and its inner tapered annular wall protruding into the bore of the casing. An annular spacer means is associated with the aforementioned channel to abut portions of the casing recess and portions of the sealing means to space the sealing means from an overhead portion of the recess. Such spacing is provided in accordance with the invention to insure unfailing, reliable operation of the sealing means upon running of the casing over the mandrel member. Also, annular seal retainer means are provided to insure the proper positioning of the spacer means and sealing means within the casing and their retention within the casing upon relative movement between the casing and mandrel member. Two exemplary embodiments of apparatus within the invention will be subsequently described in detail.

Generally stated, the method according to the present invention comprises: the placing of an annular metal spacer ring in a selected location within an internal recess in an oil well casing; press fitting an annular metal sealing ring into the recess over the annular sealing means and elastically deforming an outer wall thereof against a side wall of the casing recess; running the casing, spacer ring and sealing means over an inner casing or mandrel member to provide a fluid tight surface seal through elastic deformation of an inner wall of the sealing means against the mandrel; and concurrently with said running step, spacing the sealing ring from an overhead portion of the recess positioning the sealing ring and insuring uniform elastic deformation of such inner wall. Thereafter, the casing may be backed off of or withdrawn from the mandrel while retaining the sealing ring within the casing recess ready for the next application of the method.

Further objects and various advantages will become apparent and a better understanding of the apparatus and method of the present invention will be obtained from a consideration of the following detailed description of

exemplary embodiments of the metal seal assembly and method of effecting same. Reference will be made to the appended sheets of drawings in which:

FIG. 1 is a section view of a portion of an oil well drilling casing containing an exemplary embodiment of the metal seal and seal assembly in accordance with the present invention prior to the running of the casing completely over the running mandrel member;

FIG. 2 is a section view of the casing, metal seal and assembly and inner casing or mandrel member of FIG. 1 with the casing run over the mandrel member and the metal seal providing a metal-to-metal surface seal between the casing and mandrel member;

FIG. 3 is a section view of the casing, metal seal and assembly and inner casing or mandrel member of FIGS. 1 and 2 with the casing member being backed off of the inner casing or mandrel member;

FIG. 4 is an exploded view of the exemplary embodiment of metal seal assembly of FIGS. 1 through 3 shown in inverted position prior to its assembly;

FIG. 5 is a section view of an alternative exemplary embodiment of a casing, metal seal assembly according to the invention and inner casing or mandrel member prior to the complete running of the casing over the mandrel member;

FIG. 6 is a section view of the casing, alternative exemplary embodiment of metal seal assembly and inner casing or mandrel member of FIG. 5 with the casing completely run down over the mandrel member;

FIG. 7 is a section view of the casing, metal seal assembly and inner casing or mandrel member of FIGS. 5 and 6 with the casing being backed off of the inner casing or mandrel member; and

FIG. 8 is an exploded view of the alternative exemplary embodiment of metal seal assembly of FIGS. 5 through 7.

Referring first to the exemplary embodiment of a metal seal, according to the present invention, that is shown in FIGS. 1 through 4, a casing **10** and inner casing or mandrel member **11** are shown at the time the casing **10** is being run over mandrel **11**, but prior to engagement between the exemplary metal seal, indicated generally at **20**, and the mandrel member **11**. The metal seal, indicated generally at **20**, is pre-assembled within a recess in the casing **10** so that the running of the casing down over the mandrel will bring the metal seal into a metal-to-metal fluid tight surface seal with the mandrel **11**. In the exemplary embodiment of FIGS. 1 through 4, the recess in the casing **10** which receives the metal seal, indicated generally at **20**, is provided by an annular seal retainer means which comprises part of the metal seal assembly in accordance with the present invention. Such metal seal assembly comprises generally an annular sealing means for mounting within a recess within the casing **10**, recessed relative to the casing bore **12**; spacer means associated with the sealing means for limiting movement thereof within the recess in casing **10**; and an annular seal retainer means for mounting within the casing adjacent the sealing means to retain it withinin the casing during relative movement of the casing **10** and mandrel **11**.

Annular sealing means for mounting within a recess within casing **10**, recessed relative to the casing bore **12**, in the exemplary embodiment of FIGS. 1 through 4 is an annular metal sealing ring, indicated generally at **20** having spaced divergent channel walls **21** and **22** interconnected by a bight portion **23**. The outer wall **21** and inner wall **22** with the bight portion **23** form an upwardly opening annular channel within the annular metal sealing ring. The inner surface of the annular metal sealing ring, indicated generally at **20**, provided by wall **22** is downwardly tapered preferably approximately two degrees. The outer wall of the annular metal sealing ring provided by wall **21** is also similarly downwardly tapered preferably at an angle of approximately two degrees. It has been found that a taper of about two degrees in the sealing ring inner and outer surfaces of the present invention provides a desired surface seal between the sealing ring and mandrel.

Spacer means associated with the channel of the annular sealing means for limiting the movement of such sealing means within the casing, in the exemplary embodiment of FIGS. 1 through 4, is provided by the annular metal spacer ring indicated generally at **24**. Such spacer ring has a generally L-shaped cross section with a longer wall portion **25** and the shorter wall portion **26**. The radius of the annular longer wall portion **25** approximates that of the annular channel formed by walls **21** and **22** in the annular sealing ring **20**, and is of a height greater than the depth of such channel so that a part of wall **25** protrudes from within the channel. As shown in FIGS. 1 through 3, the shorter annular wall **26** disposed at generally right angles to the longer wall **25** is spaced above the annular metal sealing ring **20** by wall **25** and below a retainer means. As best seen in FIGS. 2 and 3, the combined axial height of the spacer ring and the bight portion of the sealing ring into which the spacer ring is assembled is less than the axial height of the recess **34** allowing limited axial movement of the assembled spacer ring and sealing ring during movement of the mandrel relative to the casing as hereinafter more fully described.

Annular seal retainer means for mounting within the casing adjacent the sealing means to retain it within the casing **10** when the casing **10** is moved relative to the mandrel **11** is provided in the exemplary embodiment of FIGS. 1, 2, 4 by an annular metal retainer ring, indicated generally at **30**. The annular metal retainer ring is provided with a head portion **31** having a chamfered bore **32** to align with the bore **32'** of the prior casing **10'**. A depending annular wall portion **33** has a recess **34** and a mandrel receiving bore **35**. The mandrel receiving bore **35** is of the same diameter as bore **12** of the casing **10**, while the recess **34** is of a larger diameter to receive the metal sealing ring. The flat or seat **36** in the retainer ring, indicated generally at **30** between the bore **35** and recess **34** may be of the same width as the bottom surface **27** of the sealing ring, indicated generally at **20**. The sealing ring therefore may be inserted within the recess **34** in the retainer ring with only so much of the inner wall protruding into the bore **12** of casing **10** as is provided by the taper of inner wall **22**. As subsequently described, the taper of outer wall **21** may not effect the metal-to-metal interference between the metal seal **20** and the mandrel **11** due to elastic deformation of wall **21** upon its assembly to the casing recess.

The method of effecting a fluid type surface seal between casing **10** and mandrel **11**, in accordance with the present invention, is accomplished as follows. The annular metal seal retaining ring, indicated generally at **30**, is initially inverted to the position shown in FIG. 4 to present recess **34** opening upwardly to receive the metal spacer ring **24**. The spacer ring **24** is then selectively placed within the recess **34**, which is to provide an internal recess in the oil well casing **10**, with the shorter wall **26** lying on the flat or seat **36** of retainer **30**. The outer diameter of wall **26** is slightly less than the inner diameter of recess **34** to allow a loose fit therein. Wall **26** fitting within recess **34**, serves to selectively position or locate the annular metal longer wall **25** within recess **34** to receive the metal sealing ring, indicated generally at **20**. The annular metal sealing ring, as shown in FIG. 4, is then inverted and press fitted over the annular wall **25** of spacer ring **24**. Since the bottom surface **27** is of approximately the same width and inner and outer diameters as the flat or seat **36** in the retainer ring, there is interference between the outer wall **21** of the sealing ring and the recess **34** in the retainer ring. In the preferred embodiment, the outer surface of outer wall **21** is provided with a taper of approximately two degrees, such that it is elastically deformed (deformed within the elastic limit) on fitting within the annular recess **34**. The sealing ring is forced down over the spacer ring **24** until

most of the wall **25** of the spacer ring has been received in the annular channel formed by walls **21** and **22** of the sealing ring. This is accomplished when the bottom surface **27** of the sealing ring is approximately level with the bottom surface **37** of the retainer.

The assembled sealing ring, indicated generally at **20**; spacer ring, indicated generally at **24**; and retainer ring, indicated generally at **30**; are then placed right side up within the casing **10** as shown in FIGS. 1 through 3. The assembly of the metal sealing ring to the casing is thus greatly facilitated by the pre-assembly of the sealing ring, spacer ring and retainer prior to insertion in the casing **10**. The retainer, indicated generally at **30**, may be threaded to screw into the casing **10** or, as shown in FIGS. 1 through 3, merely be confined within the casing by the abutment with the next casing section **10'**.

The casing **10** with the metal seal assembly, including the metal sealing means, contained in a recess therein is then run over an inner casing or mandrel member having an outer diameter less than the bore of the casing, but greater than the smallest undeformed inner diameter of the inner wall of the annular metal sealing ring. In the exemplary embodiment, as shown in FIG. 1, the outer diameter of mandrel member **11** is less than the diameter of bore **12** to allow the mandrel to fit within casing **10**. However, since bottom surface **27** of the sealing ring, indicated generally at **20**, is approximately equal to the flat or seat **36** of the retainer ring, wall **21** protrudes into the bore **12** of casing **10** due to its taper. The smallest inner diameter of the metal sealing ring occurs at the upper edge of inner wall **22**. Preferably, in accordance with the present invention, the outer diameter of mandrel **11** equals the inner diameter of wall **22** at a point thereon approximately midway between the bottom and the top of wall **22**. Put another way, the inner diameter of wall **22** varies from approximately the diameter of bore **12** at the bottom to a smaller diameter at the top of wall **22** due to the taper of wall **22**. It has been found that a taper of about two degrees on the outer wall of the sealing ring, when used with conventional casing and mandrel members in oil well drilling and producing operations, produces an interference between wall **22** and mandrel **11** such that a surface seal rather than a mere lip seal is effected therebetween. It is specifically contemplated within the present invention that the seal effected is a surface seal along at least a third of the wall **22** as opposed to a mere lip seal or theoretical line contact between the top edge of wall **22** and mandrel **11**. Thus, inner wall **22**, according to the present invention, is deformed within its elastic limit against the mandrel to effect the surface seal therebetween upon the running of the casing **10** over mandrel **11** without the application of additional external or internal sealing forces or pressures. Such surface seal is shown in FIG. 2.

As the casing is run down over the inner casing or mandrel member elastically deforming the inner wall of the metal sealing ring against the outer wall of the inner casing or mandrel member, it is contemplated within the present invention that the metal sealing means be spaced from overhead portions of the recess within the casing against which the sealing means might abut and interfere with. As shown in FIG. 2, casing **10** has been almost completely run down over the inner casing or mandrel member **11** and the inner wall **22** of the metal sealing ring has been elastically deformed to provide a surface seal against the mandrel **11**. As the mandrel member **11** passes through the annular metal sealing ring elastically deforming the inner wall **22**, it imparts an upward force to the sealing ring which might cause it to ride upward within the recess **34** within casing **10** until interference occurred between the free ends of the sealing ring channel walls **21** and **22** and the overhead portion **38** of the recess. Such interference between the elastically deforming inner wall **22** of the sealing ring with the overhead portion **38** of the recess **34** is to be avoided since it may cause deformation of wall **22** beyond its elastic limit

and consequent premature deterioration of the seal as well as perhaps immediate breaking of the surface seal being effected between wall **22** and mandrel member **11**. Therefore, in accordance with the method of the present invention, concurrently with the step of running the casing over the mandrel and deforming the sealing means elastically, spacing of the divergent walls of the sealing ring from the overhead portion of the recess is provided. In the exemplary embodiment of apparatus, shown in FIGS. 1 through 4, for effecting the seal according to the present method, the spacer ring, indicated generally at **24**, spaces the sealing ring from the overhead portion **38** during the running of the casing over the mandrel. As shown in FIGS. 2 and 3, the combined height of the assembled spacer ring, indicated generally at **24**, and the sealing ring, indicated generally at **20**, is less than the height of the recess **34**. As mandrel **10** engages the sealing ring, deforming the inner wall **22** elastically, upward movement of the sealing ring is arrested after an initial movement thereof due to the abutment of the shorter leg **26** of the spacer ring with the overhead portion **38**. An upward force upon the sealing ring is thus transmitted to the longer annular leg or wall **25** of the spacer ring and through the shorter annular leg or wall **26** to the retainer. Annular wall **25** is provided with a bottom radius approximating that of the bottom radius of the channel formed in the sealing ring by walls **21** and **22** to allow transmission of load therebetween without effecting the free deformation of the walls **21** and **22** during the aforedescribed operations.

An alternative exemplary embodiment of apparatus to effect a fluid tight surface seal according to the method of the present invention is shown in FIGS. 5 through 8. Referring first to FIG. 5, a casing **40** is shown with an alternative exemplary embodiment of metal seal, indicated generally at **50** contained in a recess therein prior to the complete running of the casing down over an inner casing or mandrel member **41**. In this embodiment, the recess within the casing **40** is formed in an inner wall of the casing at **64**.

Annular metal sealing means for mounting within the recess within the casing **40**, recessed relative to the casing bore **42**, is provided in the alternative exemplary embodiment of FIGS. 5 through 8 by the annular sealing ring, indicated generally at **50**. As in the prior embodiment of FIGS. 1 through 4, the annular metal sealing ring, indicated generally at **50**, is provided with upwardly opening spaced divergent inner and outer walls **52** and **51**, respectively interconnected by a bight portion **53**. Inner and outer walls **52** and **51**, as in the prior embodiment, are tapered downwardly, preferably at an angle of approximately two degrees, and form an annular upwardly opening channel therebetween in the sealing ring.

Spacer means associated with the channel of the annular sealing means for limiting the movement of the sealing means within the casing recess when the casing is run over the mandrel member in this alternative exemplary embodiment comprises the annular spacer ring **54**. Spacer ring **54**, as in the prior embodiment, is provided with a height greater than the depth of the channel formed in the annular metal sealing ring to protrude therefrom a distance sufficient to space the sealing ring from an overhead portion of the recess within casing **40** when assembled therein.

Annular seal retainer means for mounting within the casing adjacent the sealing means to retain it within the casing during relative movement of the casing to the mandrel, in the alternative exemplary embodiment, comprises the annular metal retainer ring **60**. Retainer ring **60** is provided with an outer diameter slightly less than that of recess **64** and is adapted to loosely slide within an enlarged bore **43** within casing **40** to the recess **64**. It may be seen in FIG. 7, that mandrel member **41** is multi-diameter with an upper portion of a diameter slightly less than that of the bore **42** of casing **40** and a larger

diametered lower portion having a diameter slightly less than the enlarged bore portion **43** of casing **10**. Positioning pins **62** in the head portion **61** of retainer **60** are provided to slideably mount retainer **60** within the enlarged bore portion **43** of casing **40**. As shown in FIG. 5, for example, a channel **44** may be provided in the bore **43** of casing **40** to receive the plurality of pins **62** after the retainer ring **60** has been assembled to the casing in accordance with the present method. Further, in this exemplary embodiment annular seal retainer ring **60** includes a downwardly facing mandrel guide means to guide the mandrel **41** through the annular sealing means upon running of the casing over the mandrel. Such guide means includes the provision of the downwardly facing and tapered surface **63** on tail portion **64** to receive and guide the mandrel member **41** through the retainer and into aligned engagement with the annular metal sealing ring thereabout.

In accordance with the method of the present invention, with the casing **40** inverted, the annular metal spacer ring **54** is placed within the internal recess **64** in the oil well casing **40** in a selected, generally centered location within recess **64**. The outer diameter of ring **54** is less than the diameter of the recess **64** to allow the positioning of outer wall **52** of the sealing ring therebetween. Next, the annular metal sealing ring, indicated generally at **50**, is inverted and press fitted into the recess **64** over the annular metal spacer ring **54**, as previously described with regard to the prior embodiment, elastically deforming the outer wall **52** of the sealing ring against the side wall of recess **64**.

Annular metal retaining ring **60** is then inverted and assembled within the casing into alignment with channel **44** and the plurality of pins **62** are inserted to hold the retainer ring within the casing while allowing limited vertical sliding movement thereof below the sealing ring indicated generally at **50**. When the casing is in upright position as shown in FIG. 5, the retainer ring **60**, because of its loose mounting within the casing, rides therein below and spaced from the annular sealing ring indicated generally at **50** with the pins **62** bearing on bottom surfaces of channel **44**.

The casing **40** with the material seal assembly contained in a recess therein, is then run down over the inner casing or mandrel member **41**. If mandrel **41** is not in exact alignment with bore **61** of retainer **60**, the guide surface **64** will direct the mandrel through the bore **61** to the annular sealing means indicated generally at **50**. During such guiding of the mandrel member by the retainer **61** it may slide upwardly with the casing until it abuts the bottom of the sealing means. As the mandrel penetrates the bore of the sealing means elastically deforming the inner wall **51** of the sealing ring, as previously described, the sealing ring end spacer will tend to ride upwardly within recess **64**.

According to the present method, concurrently with the running of the casing down over the inner casing or mandrel member, elastically deforming the inner wall of the metal sealing ring against the outer wall of the inner casing or mandrel member, the metal sealing means is spaced from overhead portions of the recess within the casing by metal spacer means. In FIG. 6, the casing is shown completely run down over the inner casing or mandrel member **41** with the divergent walls **51** and **52** of the sealing ring being spaced from the overhead portion **68** of recess **64** by the spacer ring **54**. Since retainer ring **60** is under no load at this time, it merely comes to rest upon the mandrel member **41** with its tapered surface **63** abutting a chamfered portion of the mandrel member between its larger and smaller diameters.

Upon the backing off of casing **40** from the mandrel **41**, as shown in FIG. 7, the frictional forces on the exemplary sealing ring, shown generally at **50**, are reversed causing it to move downwardly relative to casing **40**. In FIG. 7 the exemplary metal sealing ring is shown immediately after its contacting the retainer ring prior to relative movement between retainer ring **60** and mandrel **41**. Upon further relative movement between the casing and mandrel with the backing off of casing **40**, the pins **62** of retainer ring **60** engage the lower surface of channel **44**, retaining the annular sealing ring and annular spacer ring within recess **64** upon the complete backing off of the casing **40**.

It may be seen from the foregoing detailed description of the method and two exemplary embodiments of apparatus according to the present invention that an effective high pressure fluid tight surface seal may be effected between an outer casing and an inner casing or mandrel member merely upon the running of the casing member down over the mandrel member. The seal of the present invention has been tested to 15,000 p.s.i. with no permanent deformation that would affect its continued use. Because of the seal's unique construction, and mode of operation, it can be formed of materials having low tensile strength such as stainless steel or hastelloy C. The metal seal effected is reusable indefinitely, is easily assembled within an oil well casing and does not require the application of additional external or internal forces or sealing pressures. It is thus a truly self-energizing seal. The novel method of effecting the aforedescribed seal including the orienting and spacing of the sealing means insures its continued uninterrupted use without deterioration due to uneven wearing of over-deforming the sealing means to cause a permanent set in the metal and consequent failure of the metal seal to operate effectively.

It should be understood that the foregoing detailed explanation of the exemplary embodiments and the method of the present invention are exemplary in nature and not intended to limit the invention in any way from covering alternative or equivalent embodiments and methods embodying the invention. For example, it is contemplated that the spacer means associated with the annular sealing means may be provided as an integral portion of the sealing means, as by a centrally positioned wall member extending upwardly above the sealing ring walls or an extension of part of the outer sealing ring wall itself. Further, the taper provided between the inner wall of the sealing ring and the mandrel member could be provided by a tapered recess receiving a sealing ring having non-tapered walls. The present invention is limited only and defined by the following claims.

I claim:

1. A metal seal assembly assembled within a casing recess to effect a fluid tight seal between a casing and a mandrel upon running of the casing over the mandrel without the application of additional external or internal sealing pressures which is resistant to deterioration in subsea applications, said metal seal assembly comprising:

annular metal sealing means for mounting within said casing recess, said sealing means having spaced divergent channel walls interconnected by a bight portion to define an annular channel therein;

annular metal spacer means received in said sealing means annular channel having a height greater than said channel for limiting movement of said sealing means within said casing recess when said casing is run over a mandrel and for spacing free ends of said divergent walls from overhead portions of the casing recess overlying said free ends the combined axial height of said sealing means and spacer means received therein being less than the axial height of said recess; and

annular metal retainer means for mounting within said casing adjacent said recess to retain said sealing means and spacer means within said casing when said casing is moved relative to said mandrel.

2. A metal seal assembly assembled within a casing recess having a predetermined axial height and inner sur-

face diameter to effect a fluid-tight seal between a casing and a mandrel run therein, said assembly comprising:

a resilient annular metal sealing ring to be mounted within said casing recess including an elastically deformable outwardly tapered outer wall to be elastically deformed by abutment with said recess inner surface on assembly of said ring within said recess, an elastically deformable radially inwardly tapered inner wall for elastically deformed sealing engagement about a mandrel run therein and a bright portion connecting said inner and outer walls and forming therewith an annular channel opening in an axial direction within said recess when said ring is mounted within said recess; and

a spacer ring to be received in said sealing ring channel between said sealing ring inner and outer walls on said bight portion, the axial height of said spacer ring being greater than the depth of said channel, and the combined axial height of said spacer ring and sealing ring bight portion being less than the axial height of said recess.

3. A metal seal assembly assembled within a casing to effect a fluid-tight seal between the casing and a mandrel on running of the casing over the mandrel which is not dependent in its operation upon external application of sealing pressures or internal casing hydraulic pressures, said assembly comprising:

annular sealing means for mounting within a recess within a casing, said sealing means being recessed relative to the casing bore and having an upwardly opening annular channel;

spacer means associated with said sealing means for allowing limited axial movement of said sealing means within said casing and for preventing engagement of said sealing means with an upper wall of said recess; and

annular seal retainer means for mounting within said casing adjacent said sealing means to retain said sealing means within said casing, said retainer means including a downwardly facing mandrel guide means to guide said mandrel through said annular sealing means upon running of said casing over said mandrel.

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