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Mitchell et al.(10) **Pub. No.: US 2014/0174755 A1**(43) **Pub. Date: Jun. 26, 2014**(54) **VALVE****Publication Classification**(76) Inventors: **Craig Mitchell**, Aberdeen (GB); **Keith Taylor**, Inverurie (GB); **Alistair Tennant**, Aberdeen (GB)(51) **Int. Cl.****E21B 34/04** (2006.01)**E21B 33/035** (2006.01)(52) **U.S. Cl.**CPC **E21B 34/04** (2013.01); **E21B 33/035** (2013.01)USPC **166/368**; 137/343; 137/15.01(21) Appl. No.: **14/131,515**(22) PCT Filed: **Jul. 24, 2012**(86) PCT No.: **PCT/GB2012/051769**

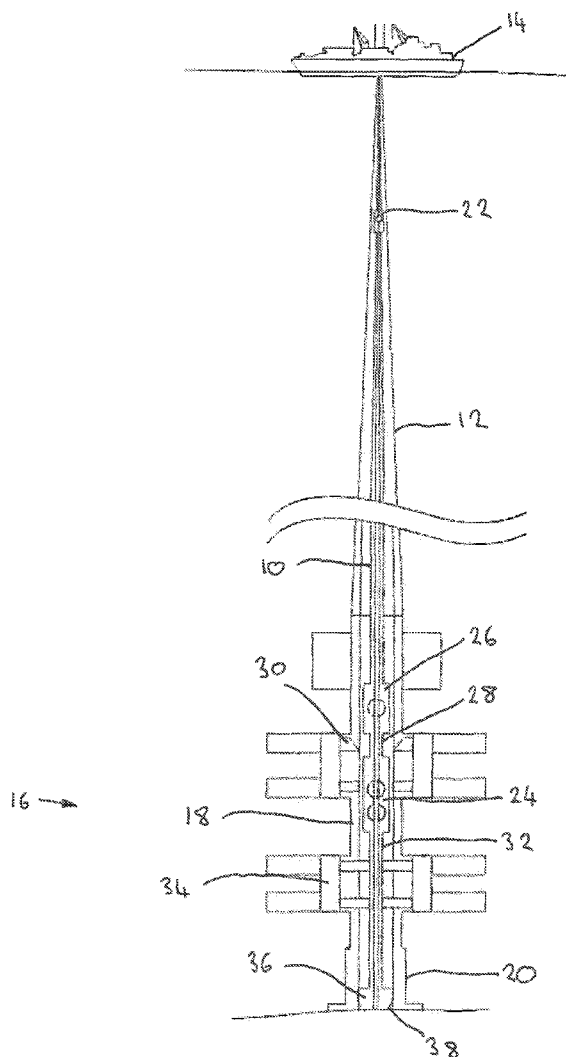
§ 371 (c)(1),

(2), (4) Date: **Mar. 12, 2014**(57) **ABSTRACT**

A valve comprises a valve mechanism located within a housing arrangement, wherein the housing arrangement comprises an outer housing configured to be mechanically secured with a fluid conduit system, and an inner housing located within the outer housing and configured to contain pressure.

(30) **Foreign Application Priority Data**

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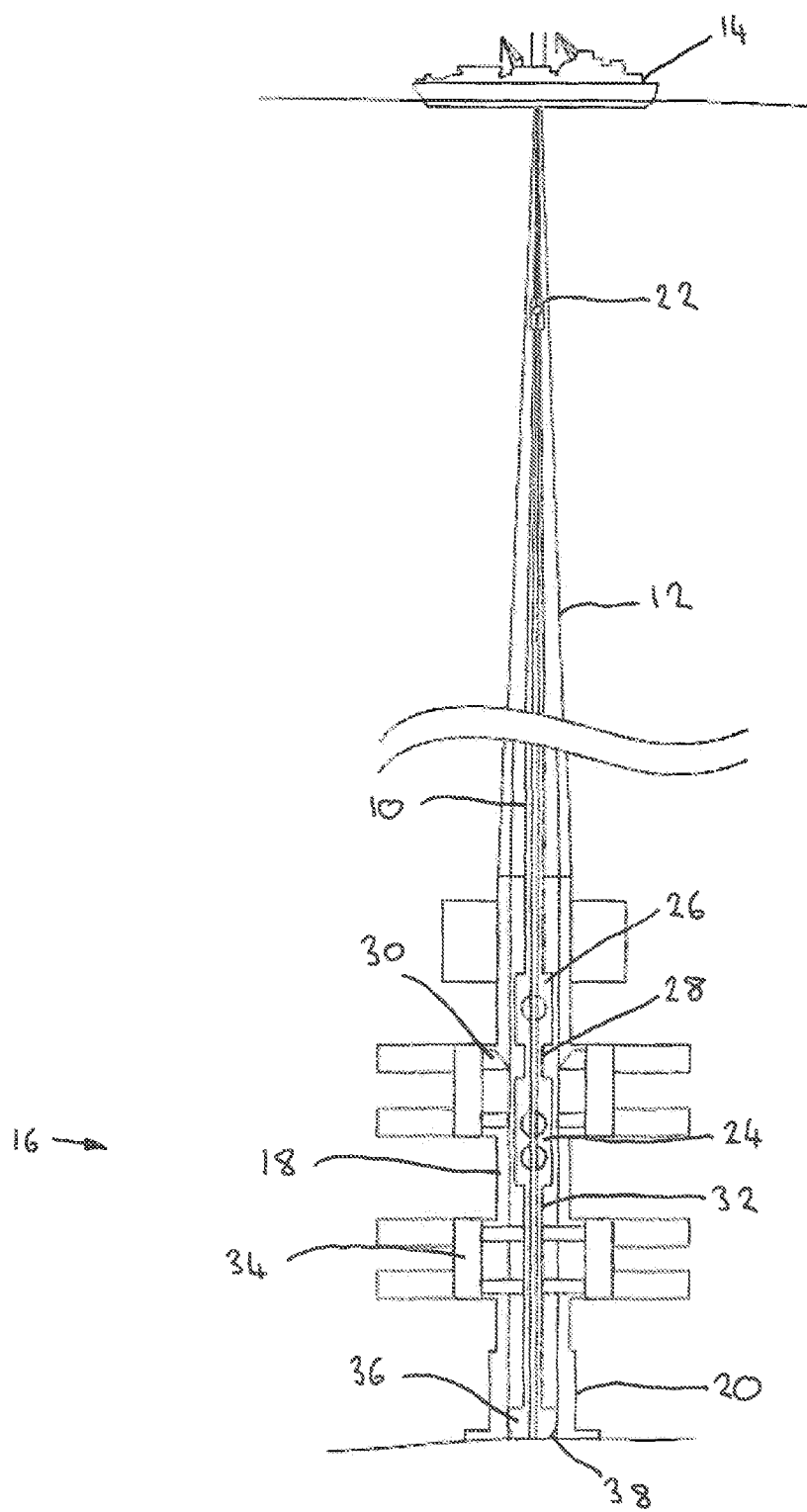


FIG. 1

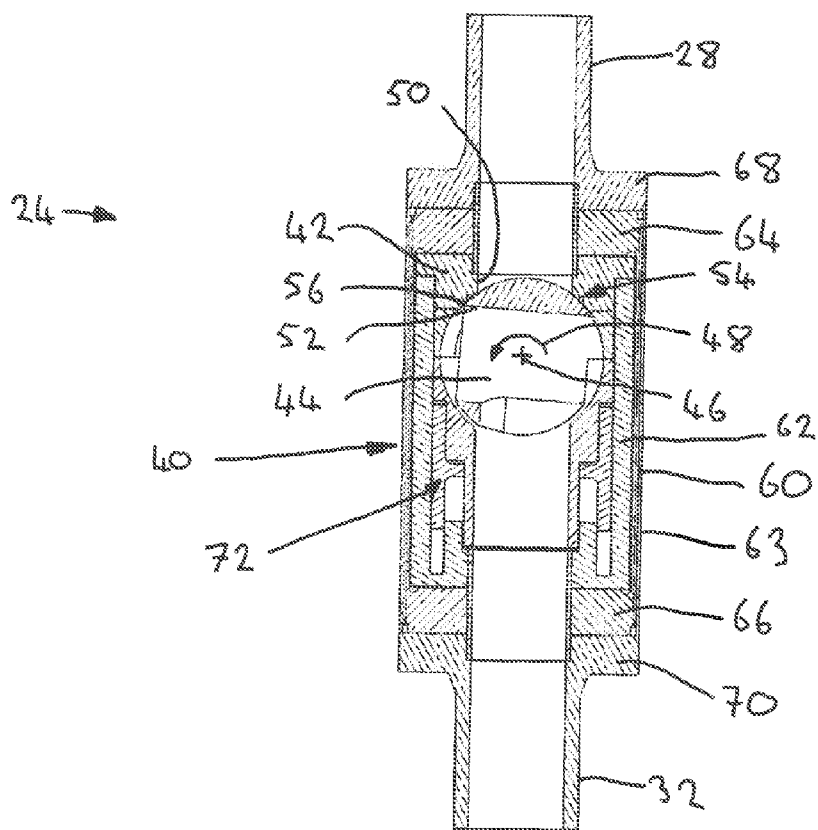


FIG. 2

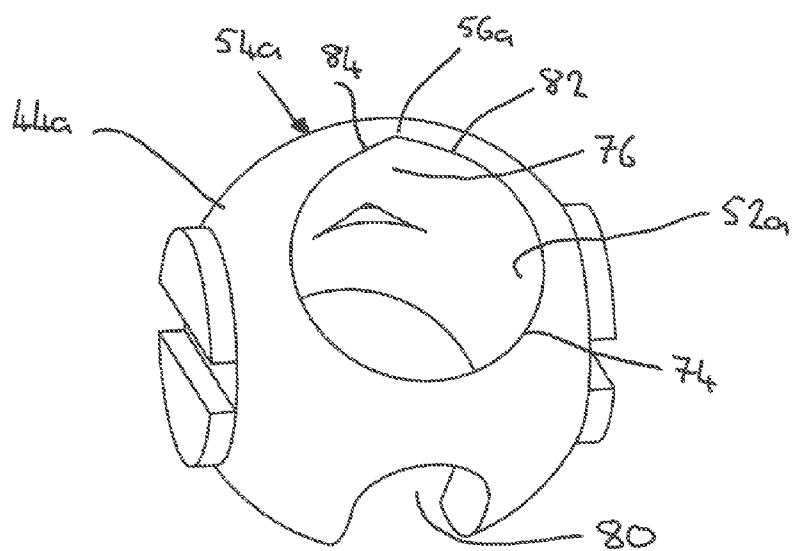


FIG. 3

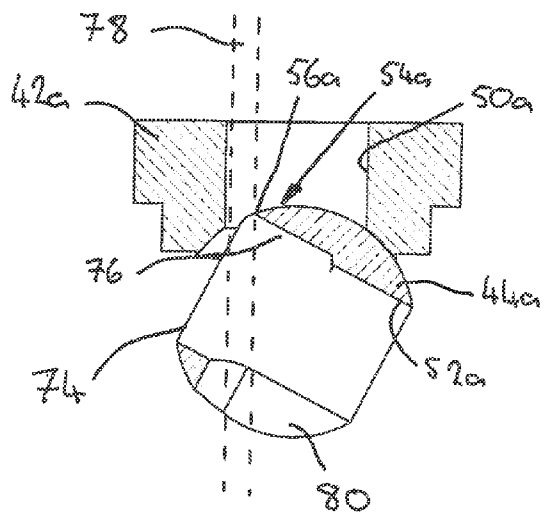


FIG. 4

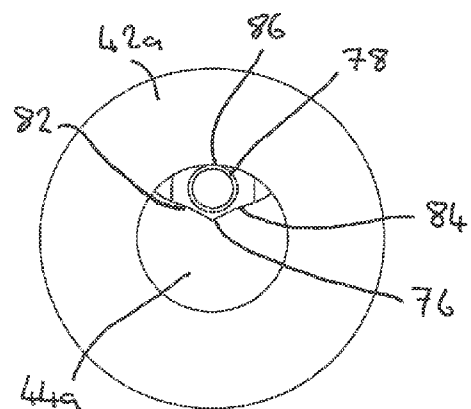


FIG. 5

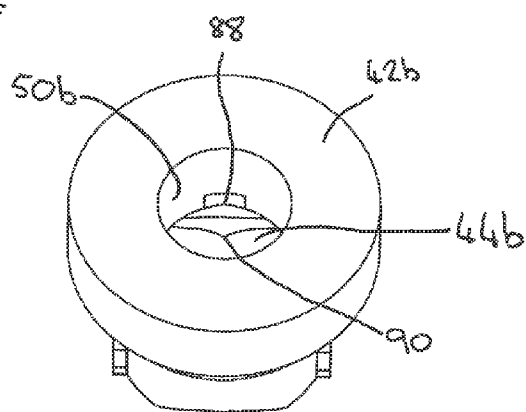


FIG. 6

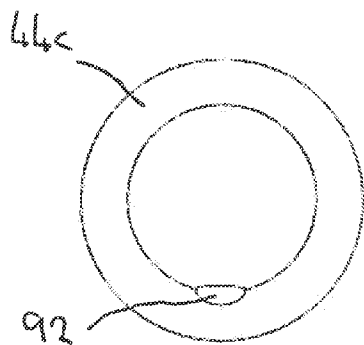


FIG. 7

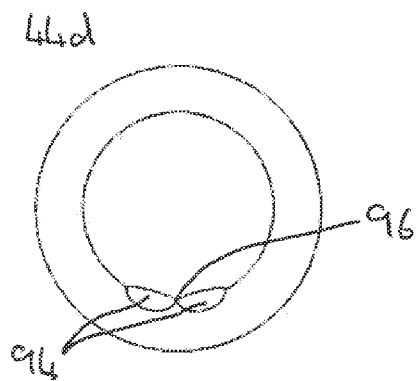


FIG. 8

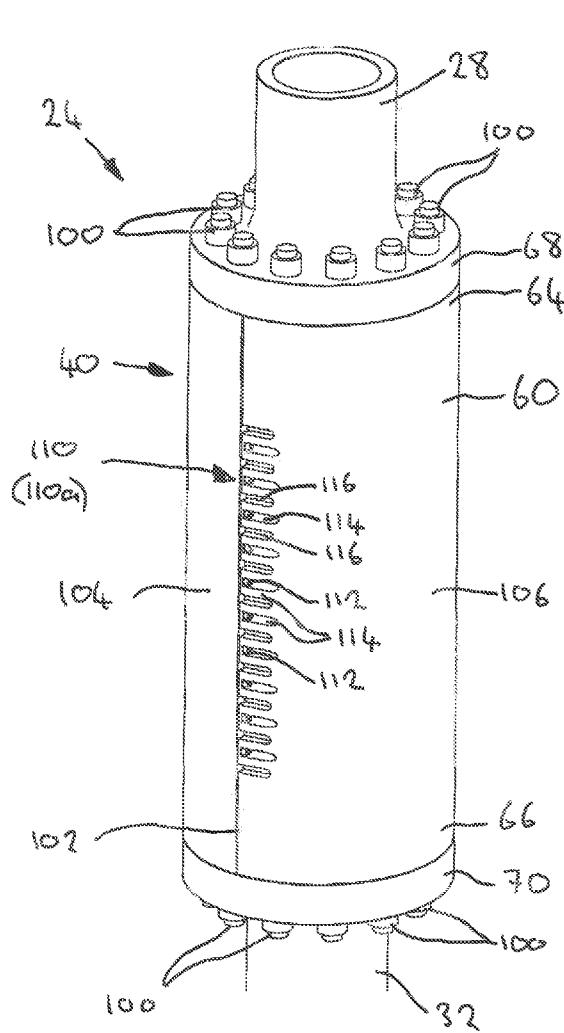


FIG. 9

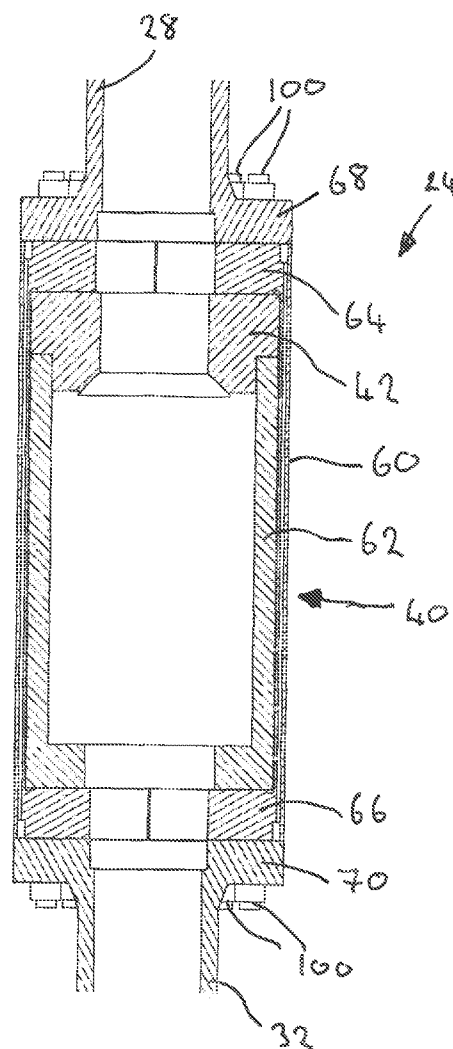
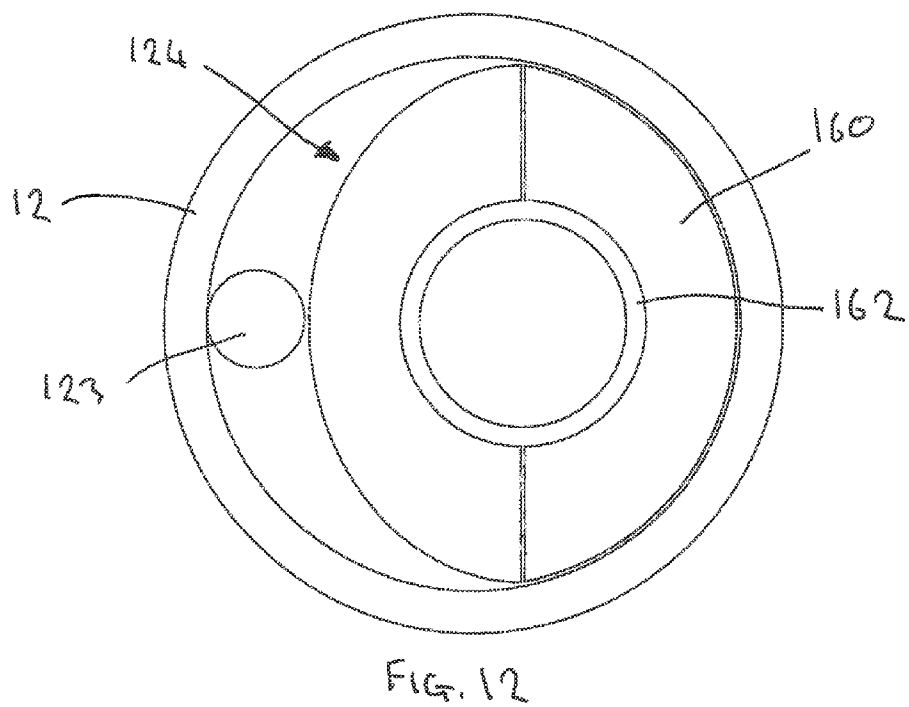
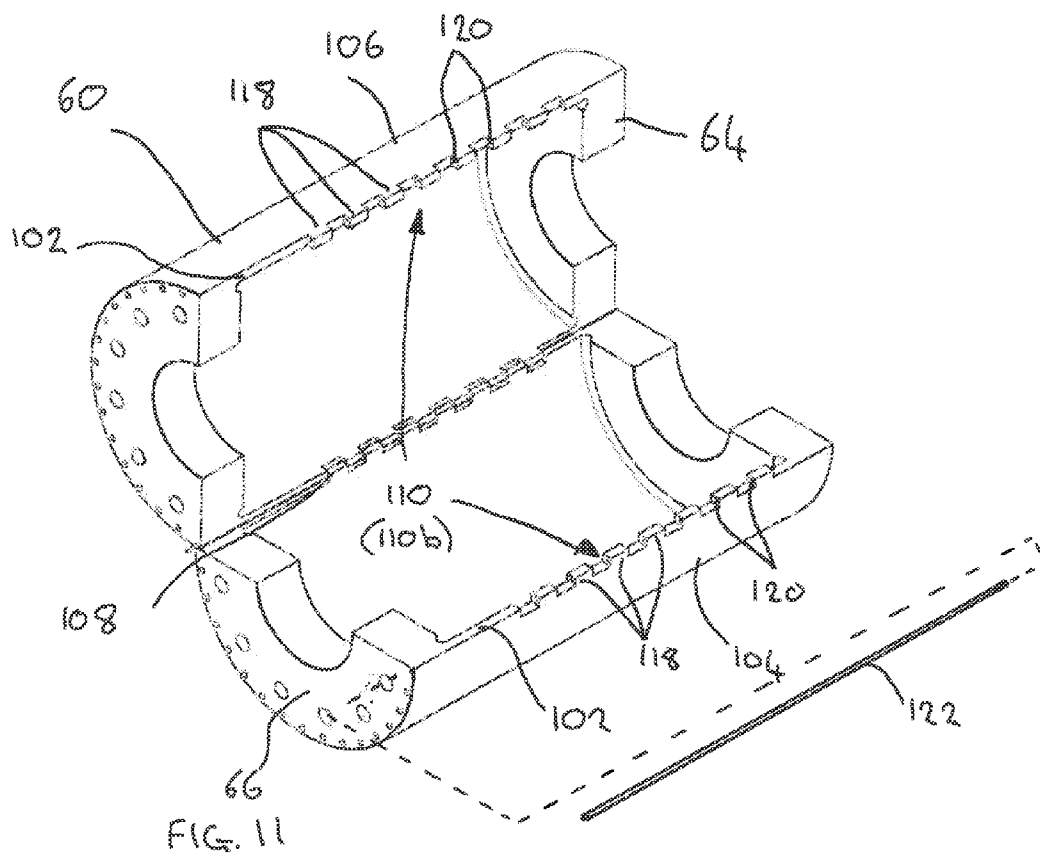


FIG. 10



VALVE

FIELD OF THE INVENTION

[0001] The present invention relates to a valve, and in particular, but not exclusively, to a valve for use in a landing string arrangement, for example for use within a subsea test tree.

BACKGROUND TO THE INVENTION

[0002] Landing strings are used in the oil and gas industry for through-riser deployment of equipment, such as completion architecture, well testing equipment, intervention tooling and the like into a subsea well from a surface vessel. When in a deployed configuration the landing string extends between the surface vessel and the wellhead, for example a wellhead Blow Out Preventor (BOP). While deployed the landing string provides many functions, including permitting the safe deployment of wireline or coiled tubing equipment through the landing string and into the well, providing the necessary primary well control barriers and permitting emergency disconnect while isolating both the well and landing string.

[0003] Wireline or coiled tubing deployment may be facilitated via a lubricator valve which is located proximate the surface vessel, for example below a rig floor.

[0004] Well control and isolation in the event of an emergency disconnect is provided by a suite of valves which are located at a lower end of the landing string, normally positioned inside the central bore of the BOP. The BOP therefore restricts the maximum size of such valves. The valve suite includes a lower valve assembly called the subsea test tree (SSTT) which provides a safety barrier to contain well pressure, and an upper valve assembly called the retainer valve which isolates the landing string contents and can be used to vent trapped pressure from between the retainer valve and SSTT. A shear sub component extends between the retainer valve and SSTT which is capable of being sheared by the BOP if required.

[0005] As noted above, the landing string may accommodate wireline and/or coiled tubing deployed tools. In this respect the various valve assemblies, such as in the SSTT, must define sufficiently large internal diameters to permit unrestricted passage therethrough. However, the valve assemblies also have outer diameter limitations, for example as they must be locatable within the wellhead BOP. Such conflicting design requirements may create difficulty in, for example, achieving appropriate valve sealing, running desired tooling through the valves and the like.

[0006] Furthermore, the landing string must be capable of cutting any wireline or coiled tubing which extends therethrough in the event of an emergency disconnect. It is known in the art to use one or more of the valves to shear through the wireline or coiled tubing upon closure. However, providing a valve with the necessary cutting capacity may be difficult to achieve within the geometric design constraints associated with the landing string. For example, the valve actuators must be of sufficient size to provide the necessary closing/cutting forces, which may be difficult to accommodate within the restricted available size.

[0007] The landing string must also be designed to accommodate the significant in-service loadings, such as the global tension from a supported lower string (e.g., a test string, completion or the like), bending loads, valve actuation loading, internal and external pressures and the like. As the indus-

try continues to move into fields with increasing formation and water depths, the resulting structural demands on the landing string also become more extreme. For example, landing string global tension requirements far in excess of 4.5 MN (1,000,000 lbf) and wellbore pressures which can exceed 690 bar (10,000 psi) are typical. Such loadings must be accommodated across regions including the various valve assemblies, such as the SSTT. It is therefore necessary to design the valve housings and appropriate end connections to be capable of accommodating the global applied tension, bending loads, valve actuation loading and pressures. This results in the use of thick walled valve housings, which can compromise the achievable valve internal diameters and sealing integrity. Furthermore, current industry standards call for all connections through such landing string valve assemblies to be configured to avoid separation during use to improve fatigue performance. Such connections may include bolted connections of the valve housings into the landing string. This typically requires significant upsizing of the connections and establishes further difficulties in achieving sufficiently large internal diameters within the outer diameter constraints, such as dictated by the BOP.

[0008] Issues such as those described above are not unique to valves within landing string applications. For example, there is a general desire in the art to minimise the size of valves, for example to provide minimal valve housing dimensions while still maximising the inner diameter to accommodate appropriate valve mechanisms and the like.

SUMMARY OF THE INVENTION

[0009] According to a first aspect of the present invention there is provided a valve comprising a valve mechanism located within a housing arrangement, wherein the housing arrangement comprises an outer housing configured to be mechanically secured with a fluid conduit system, and an inner housing located within the outer housing and configured to contain pressure.

[0010] In use, the outer housing may permit the valve to be secured with a fluid conduit system while the inner housing provides an appropriate pressure barrier for pressure internally and/or externally of the valve/fluid conduit system, wherein the valve mechanism permits control of flow along the fluid conduit system.

[0011] The outer housing may be configured to be secured in-line with a fluid conduit system.

[0012] The valve may be configured to form part of a fluid conduit system.

[0013] The fluid conduit system may be defined by one or more tubing components, flow equipment such as other valves, flow meters, shear-sub components or the like.

[0014] The valve may have numerous applications as might readily be understood by those of skill in the art. In some embodiments the valve may be configured for use within a landing string assembly. For example, the valve may define or form part of a Subsea Test Tree (SSTT), a retainer valve, a lubricator valve or the like. In such an arrangement a landing string may define a fluid conduit system.

[0015] The outer housing may be defined as a structural housing. That is, the outer housing may be provided primarily to accommodate mechanical forces, such as axial and bending forces, associated with the fluid conduit system while providing minimal or no pressure containment, for example of internal and/or external pressures. The inner housing may be defined as a pressure housing. That is, the inner housing

may be provided primarily for pressure containment, for example of internal and/or external pressures, while providing minimal or no contribution to accommodating mechanical loading associated with the fluid conduit system. This arrangement may permit each individual housing to be designed and/or selected to meet more focussed or specific operational requirements.

[0016] These divided roles of the outer and inner housings may provide a number of advantages, such as reduction in wall thickness, weight, costs and the like. In particular, the provision of an outer structural housing and a separate pressure containing inner housing may permit a reduction in the global housing wall thickness to be achieved. That is, as the outer housing is not intended to be pressure containing, the wall thickness of this can be significantly reduced. Furthermore, as the inner housing is intended for pressure containment, and not, for example, to accommodate significant tensile and bending loads, this too can have a minimal wall thickness for its limited function. As such, the combined wall thickness can be reduced relative to a single structure which is designed to be exposed to both mechanical and pressure loading.

[0017] Reducing the overall wall thickness of the housing may permit a larger housing inner diameter to be available. This may provide a number of advantages, such as assisting to maximise the viable size of the valve mechanism, permitting larger equipment to be deployed through the valve, valve sealing area and the like. Furthermore, such dimensional advantages may be achieved without increasing, or without significantly increasing material usage. For example, being able to provide a thinner global wall thickness across separate outer and inner housings relative to a single housing design may permit an increased inner diameter to be achieved without also requiring an increased outer diameter. This may have advantage in applications in which the valve must be located within an outer constraining structure, such as a pipeline, borehole, casing string, wellbore, riser, BOP or the like.

[0018] By the outer housing being mechanically secured, for example in-line, with a fluid conduit system mechanical forces, such as tensile forces and bending forces, may be transmitted across the outer housing. Such mechanical forces may originate from the fluid conduit system, such as from the weight of the fluid conduit system or the like.

[0019] The outer housing may comprise a connection arrangement for permitting mechanical connection with a fluid conduit system. The connection arrangement may comprise first and second connectors for securing with a fluid conduit system, for example in-line with a fluid conduit system. The first and second connectors may be configured to be secured to similar components, such as tubing, for example. The first and second connectors may be configured to be secured to different components. For example, one connector may be configured to be secured to tubing, and one connector may be configured to be secured to flow equipment such as another valve, flow meter, tubing hanger, choke, manifold, or the like.

[0020] At least one of the first and second connectors may comprise a flange connector.

[0021] At least one of the first and second connectors may define a preloaded connector. Such preloading may be achieved by use of one or more preloaded bolt connections, clamp assemblies or the like. Such preloading may permit the point of connection from separating during use, for example due to axial and bending forces. As the inner housing is

located internally within the outer housing and does not include any direct mechanical connection with the fluid conduit system, any requirement to provide such a preloaded connector with the inner housing is eliminated. That is, only the connection between the outer housing and the fluid conduit system may require preloading, for example to meet required or preferred industry standards.

[0022] The inner housing may be axially contained within the outer housing. In such an arrangement any axial loading experienced by the inner housing, for example due to internal pressures, valve actuation forces and the like may be transferred to the outer housing. The inner housing may be axially contained between first and second connectors of the outer housing. At least a portion of the valve mechanism may be axially located, for example secured, between the outer and inner housings. For example, at least a portion of the valve mechanism may be secured between one of the first and second connectors and the inner housing, for example an axial end face of the inner housing.

[0023] The outer housing may comprise an axially extending wall section configured to encapsulate the inner housing. As pressure forces are contained primarily by the inner housing, the wall thickness of the axially extending wall section of the outer housing may be minimised.

[0024] The outer housing may define a barrel-type housing.

[0025] The outer housing may be split to permit access to install, remove, replace, inspect or the like the inner housing and/or the valve mechanism. In one embodiment the outer housing may be longitudinally split, that is, split along its length. The outer housing may comprise at least two housing segments. The housing segments may be hingedly connected together. The housing segments may be configured to be secured together when in a closed configuration. For example, the housing segments may be secured together in a closed configuration when the outer housing is secured to a fluid conduit system, for example via first and second connectors. The housing segments may be secured along a length of separation, for example along the length of the split defined between the different segments. This arrangement may provide or establish appropriate hoop stiffness within the outer housing which may be required to resist bending forces, for example.

[0026] The housing segments may be secured together by a bolting arrangement. The bolting arrangement may be provided along one or more sides or regions of separation between different segments.

[0027] The housing segments may be secured together via one or more tangential bolts.

[0028] Adjacent housing segments may comprise one or more connecting portions extending at least partially along the length of split defined between the adjacent segments, wherein opposing connecting portions of each segment may be secured together, for example via bolting. A plurality of connecting portions may be provided on each adjacent segment. Axially adjacent connecting portions on a single segment may be separated by a slotted region, such as a laterally extending slot. Such separation between axially adjacent connecting portions may permit appropriate redirection of stress, for example due to tensile loading, around and across this area of connection between segments.

[0029] The housing segments may be secured together via one or more axially extending connecting members, such as a connecting rod, bolt or the like. In such an arrangement adja-

cent housing segments may comprise interleaving portions which are held together via such an axially extending connecting member.

[0030] As the outer housing is not intended to be pressure containing any sealing, or at least any significant sealing arrangements, may not be required between individual housing segments when secured together. However, in some embodiments a sealing arrangement may be provided between different segments of the outer housing. In other embodiments no sealing arrangement between different segments may be provided. This may permit equalisation of pressure internally and externally of the outer housing, thus assisting to eliminate or minimise any stress, for example hoop stress, applied via effects of pressure.

[0031] At least a portion of the outer housing may define a generally cylindrical outer profile.

[0032] At least a portion of the outer housing may define a generally non-cylindrical outer profile having different dimensions in mutually perpendicular lateral directions. For example, at least a portion of the outer housing may define a generally oval outer profile, elliptical outer profile or the like. Such an arrangement may permit umbilicals or the like to be accommodated between the valve housing and an outer constraining structure, such as an outer pipeline, borehole, casing section, riser, BOP or the like.

[0033] In some embodiments a connection arrangement, such as a flange connection arrangement of the outer housing may define a non-cylindrical profile.

[0034] At least a portion of the outer housing may define a generally cylindrical inner profile.

[0035] The outer housing may define one or more axial holes, such as gun drilled holes, which may accommodate fluid communication, for example across the entire length of the housing, to provide hydraulic power to the valve mechanism or the like.

[0036] The inner housing may define a generally cylindrical profile.

[0037] The inner housing may be isolated from mechanical connection with a fluid conduit system. For example, the inner housing not be exposed, or may be exposed to a far lower proportion of mechanical loading associated with the fluid conduit system as the outer housing. This lack of connection thus eliminates any requirement for a preloaded connection with the fluid conduit system, for example as may be required or preferred by industry standards. This permits space saving to be achieved, for example in terms of available internal diameter thus allowing a larger valve mechanism to be utilised.

[0038] The inner housing may be defined by a pressure containing sleeve.

[0039] At least a portion of the valve mechanism may define part of the inner housing.

[0040] Any suitable valve mechanism as would readily be selected by a person of skill in the art may be utilised. Such valve mechanisms may comprise, for example, a ball valve, butterfly valve, poppet valve, needle valve, check valve, choke valve, gate valve, piston valve or the like. The valve mechanism may generally comprise a valve seat and a valve member configured to cooperate with the valve seat to provide flow control.

[0041] The valve mechanism may comprise an actuator, for example an actuator to displace a valve body. The actuator may comprise a hydraulic actuator, electrical actuator,

mechanical actuator, thermal actuator, pressure differential actuator or the like. The actuator may comprise a piston arrangement.

[0042] The valve mechanism may be configured to cut a body extending at least partially through the valve. This arrangement may permit full closure of the valve mechanism to be achieved without impedance from the body. Further, such cutting may be provided not only where full closure is required. For example, the valve mechanism may be utilised to cut a body and then return to an open configuration thereafter.

[0043] The valve mechanism may be configured to cut an elongate body, such as tubing, coiled tubing, wireline, slick-line, a tool string or the like.

[0044] The ability to maximise the inner diameter of the housing by use of separate housing components may permit the valve mechanism to be appropriately configured, for example in terms of size, available cutting force and the like, to cut through a body.

[0045] In one embodiment the valve mechanism may comprise a ball valve mechanism which includes a ball seat and a ball member, wherein the ball member is rotatable relative to the ball seat to provide flow control.

[0046] The ball seat may be axially contained between the inner housing, for example an axial end of the inner housing, and the outer housing, for example a connecting portion of the outer housing. Such an arrangement may provide a simple modular construction, permitting ease of assembly while ensuring sufficient retention of the ball seat within the ball valve. Furthermore, such an arrangement may eliminate the requirement to provide a mechanical connection of the ball seat within the ball valve, providing advantages in terms of, for example, space saving.

[0047] The ball seat and ball member may define respective through bores each having a bore edge.

[0048] The respective through bores of the ball seat and ball member may define a flow path through the valve. The ball member may be rotated relative to the ball seat to misalign the respective through bores to prevent or restrict flow through the valve, and may be rotated relative to the ball seat to align, for example coaxially align, the respective through bores to permit or increase flow through the valve.

[0049] The bore edge of at least one of the ball seat and ball member may be configured to cut a body extending at least partially through the valve upon closure of the ball member.

[0050] The bore edge of at least one of the ball seat and ball member may define a recessed cutting region for cutting a body.

[0051] Both the ball seat and ball member may define a recessed cutting region. In such an arrangement the respective recessed cutting regions may be configured similarly, or differently. Respective recessed cutting regions of the ball seat and ball member may be generally aligned with each other. Such alignment may be considered to exist in a plane which is perpendicular to a rotational axis of the ball member. In other embodiments the respective recessed cutting regions of the ball seat and ball member may be misaligned.

[0052] Only one of the ball seat and ball member may define a recessed cutting region. This arrangement may be advantageous in that the component which does not comprise a cutting recess may hold the body being cut in a more central position relative to the ball seat and ball member, presenting the body in a better position to be cut. In one embodiment only the ball member may define a recessed cutting region.

[0053] A recessed cutting region may be recessed relative to an associated through bore. That is, the recessed cutting region may be outwardly recessed relative to an associated through bore.

[0054] A recessed cutting region may be configured to at least partially receive a body to be cut. The recessed cutting region may be configured to entirely receive a body to be cut. In some embodiments, large bodies, for example large diameter bodies may only partially be received within the recessed cutting region.

[0055] A recessed cutting region may be provided in a leading edge of one or both of the ball seat and ball member. In this respect the leading edges of the ball seat and ball member may be considered to be those edges of the respective through bores which initially pass each other upon closure of the ball member relative to the seat.

[0056] Upon closure of the ball member the bore edge of the ball member through bore may engage and displace a body which at least partially extends through the valve until said body is engaged between the ball member bore edge and the ball seat bore edge and at least partially received within a recessed cutting region, such that further rotational movement of the ball member towards a closed position permits cutting of the body, typically by a shearing action, by the recessed cutting region.

[0057] A recessed cutting region may define a cutting edge. The cutting edge may be formed continuously with the edge of an associated through bore edge.

[0058] A recessed cutting region may define at least two cutting edges configured to permit simultaneous cutting into separate regions of a body, for example upon initial contact with the body. A recessed cutting region may be arranged to define at least two points of cutting contact with a body during cutting thereof. During initial contact with the body during cutting thereof the at least two points of cutting contact may be offset from a central region of the body. During initial contact with the body the at least two points of cutting contact may be offset from a central region of the recessed cutting region. This arrangement may permit the force of cutting to be divided between the different points of cutting contact, assisting to prevent adverse compression, collapsing or the like of the body. Furthermore, this arrangement may prevent large cutting forces being applied initially centrally of a body which may assist to prevent collapse of the body, for example. Also, this arrangement may require less torque through the ball member to cut the body. Such reduced loading is anticipated to reduce damage to the components of the ball valve which may assist in preventing or reducing any damage to sealing regions. During cutting of a body, the at least two points of cutting contact with the body may converge together. That is, the at least two points of cutting contact may propagate relative to the body until converged together.

[0059] The at least two cutting edges may be defined by two distinct cutting edges. In some embodiments the at least two cutting edges may be defined by separate regions of a single cutting edge.

[0060] The at least two cutting edges may be aligned substantially obliquely relative to a rotation axis of the ball member.

[0061] At least one cutting edge may be generally straight. At least one cutting edge may be curved, for example arcuate.

[0062] A recessed cutting region may be defined by a notch extending into the edge region of an associated through bore.

[0063] A recessed cutting region may be generally v-shaped, for example defined by a v-shaped notch.

[0064] A recessed cutting region may be arcuate, for example.

[0065] The bore edge of at least one of the valve seat and ball member may define a single recessed cutting region. The bore edge of at least one of the valve seat and ball member may define at least two recessed cutting regions. In such an arrangement at least two cutting regions may be separated from each other. At least two cutting regions may merge or overlap each other.

[0066] A recessed cutting region may comprise a projection, for example a central projection, which may function to pierce the body, for example centrally of the body.

[0067] A recessed cutting region may comprise a serrated edge.

[0068] The ball valve may comprise one or more inserts located within a recessed cutting region. The insert may define a cutting edge. Such an insert may facilitate easier maintenance and the like. For example, to re-establish a sufficient cutting edge only the insert need be replaced, rather than the entire ball.

[0069] The ball member may define a sealing area which cooperates with an appropriate sealing area of the ball seat, at least when the valve is in a closed configuration. The ball seal area is rotationally offset from the ball through bore. The recessed cutting region may be defined within the ball member, wherein said cutting region is recessed towards the sealing area.

[0070] According to a second aspect of the present invention there is provided a method of controlling flow along a fluid conduit system, comprising:

[0071] securing a valve housing arrangement to a fluid conduit system, wherein the valve housing arrangement includes an outer housing which provides mechanical connection to the fluid conduit system and an inner housing located within the outer housing and which contains pressure; and

[0072] controlling flow along the fluid conduit using a valve mechanism located within the valve housing.

[0073] According to a third aspect of the present invention there is provided a sub sea test tree comprising:

[0074] a housing arrangement; and

[0075] a valve mechanism located within a housing arrangement,

[0076] wherein the housing arrangement comprises an outer housing configured to be mechanically secured with a fluid conduit system, and an inner housing located within the outer housing and configured to contain pressure.

[0077] The housing arrangement may be configured to be located within a Blow Out Preventor (BOP).

[0078] According to a fourth aspect of the present invention there is provided a landing string assembly comprising a valve, wherein the valve comprises:

[0079] a housing arrangement; and

[0080] a valve mechanism located within a housing arrangement,

[0081] wherein the housing arrangement comprises an outer housing configured to be mechanically secured with a landing string fluid conduit system, and an inner housing located within the outer housing and configured to contain pressure.

[0082] The valve may define a sub sea test tree.

[0083] The outer housing may be mechanically secured in-line with a fluid conduit system.

[0084] Features defined in relation to one aspect defined above may be associated with any other aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0085] These and other aspects of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0086] FIG. 1 illustrates a landing string arrangement which includes features according to embodiments of aspects of the present invention;

[0087] FIG. 2 is a cross-sectional view of a ball valve in accordance with an embodiment of the present invention;

[0088] FIG. 3 is a perspective view of a ball member which may be utilised in the ball valve of FIG. 2, in accordance with an embodiment of the present invention;

[0089] FIG. 4 is a cross-sectional view of the ball member of FIG. 3 shown in combination with an associated ball seat;

[0090] FIG. 5 is an top elevational view of the ball member, ball seat and coiled tubing shown in FIG. 4;

[0091] FIG. 6 is a perspective view of a ball member and ball seat of a ball valve according to a modified embodiment of the present invention;

[0092] FIGS. 7 and 8 are top elevational views of alternative embodiments of a ball member according to the present invention;

[0093] FIG. 9 is a perspective view of a split outer housing component of a valve according to an embodiment of the present invention, wherein the split housing component is shown in a closed configuration and coupled within a flow-line;

[0094] FIG. 10 is a cross-sectional view of a valve assembly which incorporates the split outer housing of FIG. 9;

[0095] FIG. 11 is a perspective view of a split outer housing component of a valve according to an alternative embodiment of the present invention, wherein the split housing component is shown in an open configuration; and

[0096] FIG. 12 is a top elevational view of a ball valve shown located within a riser, in accordance with a modified embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0097] Aspects of the present invention relate to a valve. Such a valve may be used in numerous applications. However, one specific exemplary application will be described below.

[0098] A landing string assembly 10 is diagrammatically illustrated in FIG. 1, shown in use within a riser 12 and extending between a surface vessel 14 and a subsea wellhead assembly 16 which includes a BOP 18 mounted on a wellhead 20. The use and functionality of landing strings are well known in the art for through-riser deployment of equipment, such as completion architecture, well testing equipment, intervention tooling and the like into a subsea well from a surface vessel.

[0099] When in a deployed configuration the landing string 10 extends through the riser 12 and into the BOP 18. While deployed the landing string 10 provides many functions, including permitting the safe deployment of wireline or coiled tubing equipment (not shown) through the landing string and into the well, providing the necessary primary well control barriers and permitting emergency disconnect while isolating both the well and landing string 10.

[0100] Wireline or coiled tubing deployment may be facilitated via a lubricator valve 22 which is located proximate the surface vessel 14.

[0101] Well control and isolation in the event of an emergency disconnect is provided by a suite of valves which are located at a lower end of the landing string 10 inside the BOP 18. The valve suite includes a lower valve assembly called the subsea test tree (SSTT) 24 which provides a safety barrier to contain well pressure, and also functions to cut any wireline or coiled tubing which extends through the landing string 10. The valve suite also includes an upper valve assembly called the retainer valve 26 which isolates the landing string contents and can be used to vent trapped pressure from between the retainer valve 26 and SSTT 24. A shear sub component 28 extends between the retainer valve 26 and SSTT 24 which is capable of being sheared by shear rams 30 of the BOP 18 if required. A slick joint 32 extends below the SSTT 24 which facilitates engagement with BOP pipe rams 34.

[0102] The landing string 10 may include an interface arrangement for interfacing with other oil filed equipment. For example, in the present embodiment the landing string 10 includes a tubing hanger 36 at its lowermost end which engages with a corresponding tubing hanger 38 provided in the wellhead 20. When the landing string 10 is fully deployed and the corresponding tubing hangers 36, 38 are engaged, the weight of the lower string (such as a completion, workover string or the like which extends into the well and thus not illustrated) becomes supported through the wellhead 20. However, during deployment of the lower string through the riser 12 all the weight and other forces associated with the lower string must be entirely supported through the landing string 10. Furthermore, when deployed a degree of tension is conventionally applied to the landing string 10, for example to prevent adverse compressive forces being applied, for example due to the weight of the landing string 10, which can be significant in deep water. The landing string 10 must thus be designed to accommodate significant in-service loadings, such as the global tension and bending loads from a supported lower string. Such in-service loadings, which may also include valve actuation loading, internal and external pressures and the like, must be accommodated across the various valve assemblies, such as the SSTT 24. It is therefore necessary to design the valve housings and appropriate end connections to be capable of accommodating the global applied tension, bending loads, valve actuation loading, pressures and the like.

[0103] A cross sectional view of a valve in accordance with an embodiment of the present invention is shown in FIG. 2. The valve, which in the current embodiment is a ball valve, may be provided for various functions, but for the purposes of the present description the ball valve may define a SSTT 24 of the landing string 10 shown in FIG. 1. It should be noted that although the SSTT 24 is illustrated in FIG. 1 as a dual ball valve, the arrangement shown in FIG. 2 is a single ball valve assembly for purposes of clarity.

[0104] The ball valve 24 includes a housing arrangement, generally identified by reference numeral 40 which is secured between the upper shear sub component 28 and the lower slick joint 32. As such, the ball valve 24 is installed in-line with the landing string 10 which can be considered to be a fluid conduit system. The housing 40 accommodates a valve mechanism which comprises a ball seat 42 and a ball member 44, wherein the ball member 44 is rotatable about axis 46 to selectively close the ball valve 24 and control flow through the

landing string. In the embodiment shown the ball member **44** is rotatable in the direction of arrow **48** to close the ball valve **24**. The ball seat **42** and ball member **44** define respective through bores **50**, **52** which when aligned define a flow path through the valve **24** and when misaligned (as shown in FIG. 2) prevent or restrict flow through the valve. When the ball member **44** is closed a sealing area **54** is defined between the ball seal **42** and ball member **44**.

[0105] As will be discussed in further detail below, a leading edge **56** of the ball member **44** and/or ball seat **42** is configured to cut through a body (not shown), such as wireline, coiled tubing or the like which extends through the valve **24** and landing string **10** (FIG. 1) upon closure of the ball member **44**.

[0106] As will also be discussed in further detail below, the housing arrangement **40** comprises an outer housing **60** configured to be mechanically secured in-line with the landing string **10** (FIG. 1), and an inner housing **62** located within the outer housing **60** and which is configured to contain pressure. The outer housing component **60** comprises a thin-walled, non-pressure containing cylindrical portion **63** which extends between axially opposing end flange connectors **64**, **66** which are configured to be secured to flange components **68**, **70** of the shear sub **28** and slick joint **32**, respectively. In such an arrangement the outer housing **60** may be defined as a structural housing. That is, the outer housing **60** may be provided primarily to accommodate mechanical forces, such as axial and bending forces, associated with the landing string **10** and any supported lower string while providing minimal or no pressure containment, for example of internal and/or external pressures.

[0107] The inner housing **62** comprises a generally cylindrical portion or sleeve and does not include any mechanical connection to the landing string **10** (FIG. 1). In such an arrangement the inner housing **62** may be defined as a pressure housing. That is, the inner housing **62** may be provided primarily for pressure containment, for example of internal and/or external pressures, while providing minimal or no contribution to accommodating mechanical loading associated with the landing string **10** and/or supported lower string.

[0108] This split role arrangement may permit each individual housing **60**, **62** to be designed and/or selected to meet more focussed or specific operational requirements, providing a number of advantages, such as permitting a reduction in the global wall thickness of the housing which can increase the available internal housing diameter.

[0109] The valve mechanism further includes an actuator assembly, generally identified by reference numeral **72** for use in actuating the ball member **44** to rotate relative to the ball seat **42** between open and closed positions. In the present example the actuator assembly **72** comprises a piston arrangement.

[0110] Various forms of ball member **44** and ball seat **42** may be provided within the scope of the present invention. Some exemplary embodiments are described below with reference to FIGS. 3 to 8.

[0111] Reference is initially made to FIGS. 3 and 4. FIG. 3 shows a perspective view of a ball member, in this case identified by reference numeral **44a**, according to an exemplary embodiment of the present invention, and FIG. 4 shown a cross-sectional view of the ball member **44a** of FIG. 3 in combination with an embodiment of a ball seat, in this case identified by reference numeral **42a**. Ball member **44a** and seat **42a** have many features in common with ball member **44**

and seat **42** shown in FIG. 2 and as such like features share like reference numerals, suffixed with the letter "a".

[0112] The ball member **44a** defines a through bore **52a** having a bore edge **74**, wherein a leading edge **56a** defines a recessed cutting region **76** which is configured to receive and cut through a body, such as coiled tubing **78**, shown in broken outline in FIG. 4 extending through the through bore **52a** of the ball member **44a** and a through bore **50a** of the ball seat **42a**. That is, rotation of the ball member **44a** towards a closed position causes the coiled tubing **78** to become engaged between the edge of the ball seat **42a** and the recessed cutting region **76** of the ball member **44a**, with further rotation effecting cutting of the coiled tubing **78** primarily by a shearing action. The ball member **44a** includes a slotted region **80** which accommodates the lower portion of the coiled tubing **78** during rotation of the ball member **44a**.

[0113] The recessed cutting region **76** encroaches into the sealing area **54a** which is defined between the ball member **44a** and ball seat **42a**. In some embodiments the recessed cutting region may define a relatively shallow recess such that sealing area **54a** may not be compromised. However, in other embodiments the ability to utilise a thinner walled housing arrangement **40** by use of separate outer and inner housings **60**, **62** (having different roles, namely structural and pressure containing) facilitates use of a larger ball member **44a** and ball seat **42a** such that even with the presence of the recessed cutting region **76** the sealing area **54a** may be sufficiently large to retain sealing integrity.

[0114] In the present embodiment the recessed cutting region **76** is generally v-shaped. Such a v-shaped cutting region **76** is also shown in FIG. 5 (reference to which is also made) which is a top elevation view of the ball seat **42a** and ball member **44a**. Such a profile defines two cutting edges **82**, **84** which provide simultaneous initial cutting into separate regions of the tubing **78**. In this way, during initial contact two points of cutting contact are created which are offset from a central region of the tubing **78** and which propagate together as cutting continues. This arrangement may permit the force of cutting to be divided between the different points of cutting contact provided by each cutting edge **82**, **84**, assisting to prevent collapsing of the tubing **78** which the present inventors have discovered can render cutting very difficult. Also, this arrangement may require less torque through the ball member **44a** to cut the tubing **78**. Such reduced loading is anticipated to reduce damage to the components of the ball valve which may assist in preventing or reducing any damage to sealing regions, such as sealing area **54a**.

[0115] As illustrated most clearly in FIG. 5, in the present embodiment, the leading edge **86** of the ball seat **42a** does not include any recessed region. However, in other embodiments, the ball seat may also (or alternatively) include a recessed region. Such an embodiment is illustrated in FIG. 6 which is a perspective view, from below, of a ball seat **42b** and ball member **44b** which both include recessed cutting regions **88**, **90**.

[0116] In the exemplary embodiments described above the recessed cutting region is generally v-shaped. However, other arrangements are possible. For example, a ball member **44c** (or a corresponding ball seat) may include a generally arcuate recessed region **92** as shown in FIG. 7. Furthermore, in the exemplary embodiments described above a single recessed cutting region is provided. However, in other arrangements multiple recessed regions may be provided. For example, a ball member **44c** (or corresponding ball seat) may include a

pair of (or more) recessed regions **94** as shown in FIG. **8**. In such an embodiment a projection **96** may be defined between each recessed region **94** which may function to pierce a body, such as coiled tubing, to assist in initiating cutting while minimising adverse collapse or the like. Such a projection may be provided within embodiments including a single recess.

[0117] A perspective view of the ball valve **24** illustrated in FIG. **2** is shown in FIG. **9**, reference to which is now made, along with FIG. **10** which shows a further cross-sectional view of the ball valve **24** with the ball member **44** and actuator **72** removed for clarity.

[0118] As described above, the housing arrangement **40** of the valve **24** includes an outer housing **60** and a separate inner housing **62**, wherein the outer housing **60** includes opposing flange connectors **64**, **66** which are secured to the respective flange components **68**, **70** of the shear sub **28** and slick joint **32**. Each flange connection **64**, **68** and **66**, **70** is made via a plurality of bolts **100**, wherein one or more of the bolts **100** may be pre-tensioned to provide a degree of preloading through the connections.

[0119] The inner housing **62** is axially retained between the flange connectors **64**, **66** of the outer housing **60**. Furthermore, the ball seat **42** is interposed between the upper flange connector **64** and the upper end of the inner housing **62**.

[0120] The inner housing **62** defines a unitary cylindrical component, whereas the outer housing **60** is longitudinally split along a line of separation **102** such that the outer housing **60** is formed from two half segments **104**, **106**. Referring also to FIG. **11**, this split arrangement permits the outer housing **60** to be opened to provide access to install, inspect, repair, replace or the like the inner housing **62** and other components, such as the ball seat **42**. Splitting a housing of a valve is generally not attempted in the art. However, the present invention permits the outer housing **60** to be split as this does not need to provide any sealing or pressure retaining function, which instead is provided by the unitary inner housing **62**.

[0121] The segments **104**, **106** are hinged together along one side **108** and once closed may be retained closed upon connection of the respective flange connectors **64**, **66** to the flange components **68**, **70** of the shear sub **28** and slick joint **32**. Additionally, a longitudinal connecting arrangement **110** is provided which longitudinally secures the segments **104**, **106** together when closed. In an alternative embodiment no hinge connection may be provided and instead both sides may be bolted to secure together the different segments **104**, **106**. Providing such a longitudinal connection arrangement **110** establishes appropriate hoop stiffness within the outer housing **60** which may be required to resist bending forces, for example.

[0122] The longitudinal connection arrangement **110** may be provided in a number of forms. In this respect one such form is illustrated in FIG. **9** (identified by reference numeral **110a**), whereas an alternative form is illustrated in FIG. **11** (identified by reference numeral **110b**).

[0123] The longitudinal connection arrangement **110a** of FIG. **9** comprises a plurality of tangential-type bolts or cap screws **112** which extend through respective flange fingers or ribs **114** on one housing segment **106** and engage threaded holes (not illustrated) in the opposing housing segment **104**. Each adjacent flange finger or rib **114** is separated by a slotted region **116**. This geometry assist to redirect stress along this region of connection to, for example, prevent high stresses at the locations of the cap screws **112** during tensile loading.

[0124] The longitudinal connection arrangement **110b** illustrated in FIG. **11** comprises a plurality of interleaving components **118** on each segment which are interleaved with each other when the segment halves **104**, **106** are closed. Each interleaving component **118** comprises an axially extending bore **120** which become aligned when the segment halves **104**, **106** are closed. An elongate connecting member **122** is provided which is received within the aligned bores **120** to thus secure the segment halves **104**, **106** together.

[0125] In the embodiments described above, such as with reference to FIGS. **2** and **9** to **11**, the outer housing defines a generally cylindrical outer profile. However, in other embodiments a non-cylindrical outer profile may be provided, as illustrated in FIG. **12**. In this embodiment a valve, generally identified by reference numeral **124**, includes a split outer housing **160** and a unitary inner housing **162**, in a similar manner to the embodiments described above for similar reasons. However, in the present embodiment the outer housing **160** defines a generally oval outer profile. This arrangement permits other components, such as the illustrated umbilical **123** to be accommodated between the valve **24** and an outer constraining component, such as a riser **12**.

[0126] It should be understood that the embodiments described herein are merely exemplary and that various modifications may be made thereto without departing from the scope of the present invention. For example, the disclosed valve embodiments are not solely for use within a landing string, and may be used in many other applications as would be understood by a person of skill in the art. Furthermore, the multiple component housing arrangement may also be used in combination with different valve types, and is not limited solely for use in ball valve applications.

1. A valve comprising a valve mechanism located within a housing arrangement, wherein the housing arrangement comprises an outer housing configured to be mechanically secured with a fluid conduit system, and an inner housing located within the outer housing and configured to contain pressure.

2. The valve according to claim 1, wherein the outer housing is securable in-line with a fluid conduit system.

3. The valve according to claim 1, defining or forming part of at least one of a Subsea Test Tree (SSTT), a retainer valve and a lubricator valve.

4. The valve according to claim 1, wherein the outer housing comprises a connection arrangement for permitting mechanical connection with a fluid conduit system.

5. The valve according to claim 4, wherein the connection arrangement comprises first and second connectors for securing with a fluid conduit system.

6. The valve according to claim 5, wherein at least one of the first and second connectors comprises a flange connector.

7. The valve according to claim 5, wherein at least one of the first and second connectors defines a preloaded connector.

8. The valve according to claim 1, wherein the inner housing is axially contained within the outer housing.

9. The valve according to claim 8, wherein the outer housing comprises a connection arrangement comprising first and second connectors for securing with a fluid conduit system, wherein the inner housing is axially contained between the first and second connectors of the outer housing.

10. The valve according to claim 1, wherein at least a portion of the valve mechanism is axially located between the outer and inner housings.

11. The valve according to claim 1, wherein the outer housing comprises an axially extending wall section to encapsulate the inner housing.

12. The valve according to claim 1, wherein the outer housing is split.

13. The valve according to claim 1, wherein the outer housing is longitudinally split.

14. The valve according to claim 1, wherein the outer housing comprises at least two housing segments.

15. The valve according to claim 14, wherein the housing segments are hinged together.

16. The valve according to claim 14, wherein the housing segments are secured together when the outer housing is secured to a fluid conduit system.

17. The valve according to claim 14, wherein the housing segments are secured along a length of separation defined between the different housing segments.

18. The valve according to claim 14, wherein the housing segments are secured together by a bolting arrangement.

19. The valve according to claim 18, wherein the bolting arrangement is provided along one or more sides or regions of separation between different housing segments.

20. The valve according to claim 14, wherein the housing segments are secured together via one or more tangential bolts.

21. The valve according to claim 14, wherein adjacent housing segments comprise one or more connecting portions extending at least partially along the length of split defined between the adjacent housing segments, wherein opposing connecting portions of each segment are arranged to be secured together.

22. The valve according to claim 21, wherein a plurality of connecting portions are provided on each adjacent housing segment.

23. The valve according to claim 22, wherein axially adjacent connecting portions on a single housing segment are separated by a slotted region.

24. The valve according to claim 1, wherein at least a portion of the outer housing defines a generally cylindrical outer profile.

25. The valve according to claim 1, wherein at least a portion of the outer housing defines a non-cylindrical outer profile having different dimensions in mutually perpendicular lateral directions.

26. The valve according to claim 1, wherein the inner housing is isolated from mechanical connection with a fluid conduit system.

27. The valve according to claim 1, wherein the inner housing is defined by a pressure containing sleeve.

28. The valve according to claim 1, wherein at least a portion of the valve mechanism defines part of the inner housing.

29. The valve according to claim 1, wherein the valve mechanism comprises a ball valve mechanism.

30. The valve according to claim 1, wherein the valve mechanism is operable to cut a body extending at least partially through the valve.

31. The valve according to claim 1, wherein the valve mechanism is operable to cut an elongate body including at least one of tubing, coiled tubing, wireline, slickline and a tool string.

32. The valve according to claim 1, wherein the valve mechanism comprises a ball valve mechanism which includes a ball seat and a ball member, wherein the ball member is rotatable relative to the ball seat to provide flow control.

33. The valve according to claim 32, wherein the ball seat and ball member define respective through bores each having a bore edge and the bore edge of at least one of the ball seat and ball member is configured to cut a body extending at least partially through the valve upon closure of the ball member.

34. The valve according to claim 33, wherein the bore edge of at least one of the ball seat and ball member defines a recessed cutting region for cutting a body.

35. A method for controlling flow along a fluid conduit system, comprising:

securing a valve housing arrangement to a fluid conduit system, wherein the valve housing arrangement includes an outer housing which provides mechanical connection to the fluid conduit system and an inner housing located within the outer housing and which contains pressure; and

controlling flow along the fluid conduit using a valve mechanism located within the valve housing.

36. A sub sea test tree comprising:

a housing arrangement; and

a valve mechanism located within a housing arrangement, wherein the housing arrangement comprises an outer housing configured to be mechanically secured with a fluid conduit system, and an inner housing located within the outer housing and configured to contain pressure.

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