

SAFETY VALVE APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

The invention generally relates to a valve which may be used as a master valve for a production well, or alternatively as a safety or blowout preventer valve between a tubing head and a production (Christmas) tree. The invention also generally relates to valve apparatus providing complete control over a well during installation or workover of tubing in an oil or gas well.

More specifically, the invention, in its blowout preventer embodiment, is directed for use on offshore production platforms where a plurality of producing oil wells are disposed in close proximity to one another and where there is an emergency need to simultaneously shut in all the producing wells rapidly, safely, reliably, and economically while facilitating rapid resumption of production after the emergency has passed.

The invention may also serve as a substitute for a master valve in production wells where a vertical production tree is eliminated in favor of horizontal plane apparatus.

Description of the Prior Art

On marine production platforms there are often many producing wells in close proximity to one another. Each of the wells typically has a production wellhead from which production tubing extends from the well. The wellhead typically has a production or "Christmas" tree connected to it for controlling the gas or fluid flowing in the production tubing during production of the well. A master gate valve disposed in each production tree may be closed to shut off flow from the well, but such gate valves may be difficult to close rapidly during an

emergency due to their location, and indeed may not be available as where the production tree is removed from the wellhead during workover of the well.

Downhole safety valves may also be provided in each of the producing wells; but there is always the danger that a downhole safety valve may not be operable or in place during workover of the well. As indicated above, during workover, the production tree may have been removed in order to install a blowout preventer stack atop the production wellhead for control of the well during workover. Such a blowout preventer stack is of the kind used typically in drilling operations and includes one or more ram type blowout preventers and an annular blowout preventer. Until the blowout preventer is installed on the production wellhead and connected to its controls, well control in the past for the well has depended upon remotely installed plugs in the well. Such plugs have not always been reliable.

During an emergency on an offshore platform, for example, where a fire or leaking gas or fluid from one production tree endangers all of the wells and indeed the platform itself, there has developed the need for an apparatus and method for its installation and refurbishing which may be used to rapidly close off the flow path of the production tubing in each of the wells.

As indicated above, a shear ram blowout preventer similar to those used in marine blowout preventer stacks for drilling operations could be a candidate for satisfying such a need. The use of a shear ram blowout preventer has a major disadvantage in that the tubing above the tubing hanger must be replaced after it has been sheared before production can be resumed. Shear ram blowout preventers crush the production tubing which must be replaced before the well can be put back into operation. In order to replace the crushed tubing, the production tree must be removed and a drilling blowout

preventer and rig installed in order to remove the damaged tubing and replace it with new tubing.

Another disadvantage of using a shear ram blowout preventer similar to that used in drilling operations is that after the preventer crushes and shears the tubing, the well can only be controlled by pumping mud into it to control the pressure in the well. A plug typically cannot be installed through the tubing which has been crushed during the shearing by the preventer.

Identification of the Object of the Invention

10 Thus, it is an object of the present invention to provide a safety valve interconnectable with a wellhead and a Christmas tree which does not crush the tubing extending into the well.

Summary of the Invention

15 According to one aspect of the present invention there is provided a safety valve adapted for placement above a wellhead comprising a housing having a coaxial upper and lower vertical housing passages and at least one laterally disposed outlet, the diameter of the upper and lower passages being sufficiently large to pass a tubing hanger with tubing for landing in the wellhead, and control
20 element means disposed between said upper and lower vertical housing passages for preventing or allowing fluid flow through a passage smaller than the lower vertical housing passage and for providing full diametrical access via the upper housing passage to the lower housing passage.

25 According to another aspect of the present invention there is provided a ball adapted for use in a safety valve, the safety valve having a housing with coaxial lower and upper vertical passages disposed therein and at least one laterally disposed outlet and a chamber disposed between the ends of said outlet and passages,
30 the chamber adapted to accept said ball, wherein the ball comprises an outer part having an insert cavity along a central axis of the outer part with an inner diameter substantially the same as or less than the diameter of the upper passage of said housing, said outer part having a perpendicular passage extending from the insert cavity
35 to the exterior of the outer part, and a removable inner part disposed in the insert cavity and having an outer diameter substantially the same as that of the insert cavity of the outer part and having

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intersecting passages forming a "T" shape, the head passage of the "T" being along said central axis and the base passage of the "T" being aligned with the perpendicular passage of the outer part.

According to a further aspect of the present invention there
5 is provided a production tree for use with an oil and gas well comprising a master valve having a housing at least one lateral outlet, a vertical upper passage and a vertical lower passage coaxial with said vertical upper passage, each of the outlet and upper and lower passages being open to a chamber in the housing,
10 and a rotatable ball having an outer part with means for seating it within the chamber, said outer part having an insert cavity along a central axis of the outer part, the insert cavity having an inner diameter substantially the same as or less than that of the upper passage, said outer part having a perpendicular passage extending
15 from the insert cavity to the exterior of the outer part, a removable inner part disposed in said insert cavity and having an outer diameter substantially the same as that of the insert cavity of the outer part and having intersecting passages forming a "T" shape, the head passage of the "T" being along said central axis and the base passage
20 of the "T" being aligned with the perpendicular passage of the outer part, the housing of said master valve being connected to the tubing head of the well, means for coupling production tubing landed in the well with the lower passage of said master valve, and control valve means attached to said lateral outlet for controlling fluid
25 flow in the production tubing in the well.

Preferably means are provided for aligning the inner part with the outer part after the inner part is inserted into the outer part. The aligning means includes a spring loaded anti-rotation key means disposed on the exterior surface
30 of the inner part and a depression means in the interior surface of the insert cavity for angularly locking the inner part in the insert cavity of the outer part and alignment of the base bore of the "T" of the inner part with the perpendicular passage of the outer part but
35 allowing the inner part to move with respect to the outer part along the central axis.

Means are also preferably provided for axially aligning the inner part within the outer part whereby after the inner part is inserted into the outer part, the base bore of the "T" of the inner part may be axially aligned with the
5 perpendicular passage of the outer part. The axial aligning means comprises snap ring means disposed about the outer wall of the inner part and a groove means about the inner wall of the insert cavity of the outer part for cooperatively holding the inner part to the outer part on
10 axial alignment of the outer part with respect to the inner part after insertion of the inner part in the insert



cavity and for allowing the inner part to be pulled axially free from the outer part in one direction along the central axis of the outer part but not the other.

In an alternative embodiment of the safety valve of the invention, the housing includes two lateral outlets open to the chamber in the housing. Wing valves may be placed in the lateral outlets for either diverting flow from the production tubing or for serving to control flow from the tubing during production of the well. Such lateral outlets may also be used for "killing" the well.

The valve with the rotatable ball having a removable insert may serve as the master valve of a production tree and the wing valves may serve as the production control valves of the production tree. Vertical access to the tubing in communication with the lower passage is available via the upper passage when the removable insert is removed. A cap for the upper passage is used when the valve serves as the master valve in the normal production mode of the production tree.

Seating means for seating the exterior of the ball with the lateral outlet are provided for the valve. The seating means includes an arcuate annular surface about the opening of the lateral outlet, the curvature of the surface being substantially the same as the curvature of the ball. Preferably, an elastomeric member is disposed in a slot in the annular surface about the opening of the lateral outlet in order to seal the exterior of the ball with the lateral outlet.

After tubing has been landed in the lower passage below the ball, means are provided for seating the exterior of the ball with the lower conduit placed in the lower passage. Preferably, the lower conduit is a coupling member disposed in the lower passage of the housing and having an upwardly facing opening to the chamber. The coupling member is in fluid communication with tubing extending below from the lower passage of the housing and the seating means is an arcuate annular

surface about the opening of the coupling member. The curvature of the annular surface is substantially the same as the curvature of the ball. Spring means are provided for urging the annular surface of the coupling member against the exterior of the ball.

A closure member is provided for cooperatively acting with the seating means by which the ball is seated within the chamber for securing the outer part of the ball within the chamber and axially aligning the perpendicular passage of the outer part with the lateral outlet. Means are provided for seating the exterior of the ball with an upper conduit placed in the upper passage of the housing. The seating means for seating the upper conduit is an arcuate annular surface about the opening of the upper conduit wherein the curvature of the surface is substantially the same as the curvature of the rotatable ball. A sealing means for sealing the upper conduit to the exterior of the ball includes an elastomeric member in a slot in the annular surface about the opening of the upper conduit.

Means are provided for rotating the annular ball within the housing. The rotating means includes a ball stem means extending through the housing, one end of the ball stem means having a coupling means for rotatably coupling the ball stem to the ball. The other end of the ball stem means extends through the outer wall of the housing. Motive means are coupled to the other end of the ball stem for rotating the stem and the ball. The motive means includes an hydraulically driven rotary actuator coupled to the end of the shaft. The motive means additionally comprises a hand wheel removably mounted upon the end of the shaft. The valve further includes a shaft mounted position indicator means mounted on the end of the shaft for providing a visual indication of the shaft rotation and the position of the ball within the housing.

The safety valve according to the present invention preferably includes cutting means secured in the head passage of the "T"

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of the inner part for cutting a wireline cable when the cable extends through the head passage.

Thus, there is provided _____
apparatus for controlling flow in a wellhead in which a
5 ball is disposed in a housing having upper and lower
conduits and at least one laterally disposed outlet. The
ball includes a removable insert and three output ports
with flow paths in the interior of the ball communicating
with the three ports and an unported surface. The means
10 for rotating the ball is provided for rotation of the ball
among at least three positions. The first position is
where two of the ports in the ball are aligned
respectfully with the ends of the upper and lower conduits
disposed in the housing and a third port is aligned with
15 the outlet. When the ball is in the first position, a
flow path is established between ends of the lower and
upper conduits and the lateral outlet. The second
position is where one of the ports in the ball is aligned
with the outlet and a second of the ports in the ball is
20 aligned with the end of the lower conduit and the unported
surface is aligned with the end of the upper conduit.

When the ball is in the second position, a flow path
is established between the end of the lower conduit and
said outlet and flow is prevented to the end of the upper
25 conduit. In the third position, the unported surface is
aligned with the end of the lower conduit. When the ball
is in the third position flow is prevented to the lateral
outlet or to the upper conduit from the lower conduit.

The three output ports _____
30 with flow paths in the interior of the ball comprise a "T"
shaped bore in the removable insert and a hole in the
outer part substantially aligned with the bore in the
removable insert defining the base of the "T" shape.

A method of controlling a well during installation of
35 production tubing in a wellhead and attaching a Christmas
tree for production of the well is provided. A valve
housing preferably having at least one _____

lateral outlet, an upper passage and a lower passage is connected to the wellhead or is provided integrally with the wellhead. The lower passage of the housing communicates with the wellhead and each of the outlets of
5 in the upper and lower passages are opened to the chamber in the housing. Seated within the chamber of the housing is an outer part of a rotatable ball. The outer part has an insert cavity along a central axis of the outer part and the insert cavity has an inner diameter substantially
10 the same as or less than that of the upper passage. The outer part has a perpendicular passage extending from the insert cavity to the exterior of the outer part.

Atop the housing is a blowout preventer removably attached to the upper part of the housing with the
15 vertical flow path of the blowout preventer communicating with the upper passage of the valve housing. The diameter of the vertical flow path of the blowout preventer is substantially the same as or less than that of the upper passage of the valve housing, the inner diameter of the
20 insert cavity and the lower passage. The method comprises the steps of first setting tubing in the wellhead through the blowout preventer, through the upper passage, through the insert cavity of the outer part of the rotatable ball and the lower passage of the valve apparatus housing.

25 The next step includes installing an inner part of the rotatable ball within the insert cavity of the outer part of the rotatable ball. The inner part has an outer diameter substantially the same as that of the insert cavity of the outer part and has intersecting passages
30 forming a "T" shape. The head passage of the "T" is aligned with the perpendicular passage of the outer part.

The next step in the method includes rotating the ball within the safety valve housing to a position where flow from the tubing is prevented access to the upper
35 passage of the housing. The blowout preventer is then removed from the upper part of the housing and a Christmas tree is installed to the upper part of the housing. The



ball is then rotated within the valve housing to a position where the head passage of the "T" completes the vertical flow path from the tubing in the wellhead below to the Christmas tree above the safety valve housing.

- 5 Where the apparatus is to be used in a safety mode, the method includes the step of rotating the ball to a position where a portion of the external surface of the ball having no passage extending through it covers and sealingly blocks the flow path from the tubing in the
10 wellhead.

- The method further includes connecting a diverter or "wing" valve to the lateral outlet of the housing and the step of rotating the ball to prevent access to the upper passage of the housing includes rotating the ball to a
15 position where the head passage of the "T" is aligned with the lateral outlet of the housing and the base passage of the "T" is aligned with the tubing, and a portion of the external surface of the ball having no passage extending through it covers the flow path to the upper passage of
20 the housing.

- A control element may be a gate for controlling
25 flow in one or more tubing strings disposed in the wellhead below the valve. It may be connected to a lateral outlet and valve line via the gate.

- According to an alternative embodiment of the safety valve having a gate control element, a wellhead is _____
30 provided having an integral or a separate housing, with a diverter valve, for example, a gate valve, which has a removable insert such that in one position of the valve, the insert can be removed via a vertical housing passage to provide full bore access to the wellhead housing.

- 35 The gate of the gate valve has multiple positions wherein in a first position the gate has a _____

vertical passage having a diameter substantially the same as or less than the upper vertical passage and a second lateral portion with a second gate vertical passage having a diameter smaller than the first gate vertical passage.

- 5 The second gate vertical passage is preferably sized to cooperate with tubing landed in the wellhead below the valve housing. Preferably, a third lateral portion is provided in the gate having an "L" shaped passage or a "T" shaped passage having an opening in the bottom of the gate
- 10 to cooperate with tubing landed in the wellhead below and one or two openings in the side portions of the gate to cooperate with a lateral opening or openings in the valve housing.

- A hydraulically or manually operated gate valve is provided which may be incorporated in the same forging or casting as the wellhead or in a separate valve housing which may be secured to the wellhead. A means for landing a tubing hanger is provided within the valve housing or in the wellhead to which the valve housing may be attached.
- 15
- 20 An adapter or coupling means is provided for sealing flow continuity with the tubing in the tubing hanger. The valve gate has a diverter section with a bore diameter corresponding to that of the tubing landed in the wellhead. The bore in the diverter portion of the gate
- 25 can provide communication vertically in line with the well or laterally.

- Conveniently, the valve gate has a _____ vertical cavity in which is placed a removable insert
- 30 having a vertical bore within it. The insert includes a stepped external profile to locate it in a stepped opening in the vertical cavity of the gate. This latter stepped opening has an internal diameter at least as large as the internal diameter of the lower vertical passage of the
- 35 valve and of the wellhead.

The insert for the vertical gate cavity may be removed when the gate is in a position with the insert in

line with the tubing head. When the insert has been removed, the tubing hanger may pass through the enlarged bore of the gate thus revealed in the gate. The vertical passage in the insert preferably has a diameter equal to
5 that of the tubing.

In the safety valve embodiment _____
_____ in which the gate has no insert, a laterally movable gate is disposed in a lateral passage of a housing having a vertical housing passage and a lateral housing
10 passage where the vertical and lateral passages intersect one another. The gate has a first lateral portion with a first gate vertical passage having a diameter substantially the same as or less than the vertical housing passage. A second lateral portion is provided in
15 the gate having no vertical passage therethrough. A third lateral portion is provided with a second gate vertical passage having a diameter smaller than the first gate vertical passage. In this embodiment of the invention, when the gate is in a lateral position where the first
20 gate vertical passage is aligned with the vertical housing passage, full diameter access through the vertical housing passage and the first gate vertical passage is provided.

Means are provided for laterally moving the gate in the lateral housing passage between at least two
25 positions. The first position is where the gate is in a lateral position such that the first gate vertical passage is aligned with the vertical housing passage and full diameter access through the vertical housing and the first gate vertical passage is provided. The second position is
30 where the gate is in a second lateral position such that the second lateral portion of the gate is aligned with the vertical housing passage and the vertical flow path through the vertical housing passage is closed.

Means may be provided for disposing upper and lower
35 tubing members or conduits in the lower and upper vertical housing passages, the upper conduit having its lower end open to the intersecting vertical and lateral passages and

the lower conduit having its upper end open to the intersecting vertical and lateral passages. The lateral moving means is further adapted to move the gate among the two positions mentioned above and a third position. The
5 third position is where the gate is in a lateral position such that the second gate vertical passage is aligned with the upper lower end of the upper conduit and the open upper end of the lower conduit.

Preferably at least one lateral outlet is provided in
10 the housing where the lateral outlet is substantially perpendicular to the vertical housing passage and to the lateral housing passage and is open to the intersection of the lateral housing passage and the vertical housing passage. In this embodiment, the gate has a fourth
15 lateral portion with a gate "L" shaped passage therein having an opening in the bottom of the gate and an opening in the side portion of the gate. The lateral moving means is adapted to move the gate among the three positions mentioned above and a fourth position where the gate is in
20 a lateral position such that the gate "L" shaped passage has its opening in the bottom of the gate aligned with the upper end of the lower conduit in the lower vertical housing passage and its opening in the side portion of the gate aligned with the lateral outlet in the housing.

25 Two lateral outlets may be provided in the housing and the gate may include a fourth lateral portion with a "T" shaped passage. The lateral moving means may be adapted to move the gate among the three positions mentioned above and the fourth position where the gate is
30 in a lateral position such that the gate "T" shaped passage communicates with the lower conduit and the openings in the sides of the gate are aligned with respective lateral outlets in the housing. A single diverter valve may be attached to the single lateral
35 outlet for the "L" shaped passage _____
_____ or two diverter valves may be connected, one

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each to the two lateral outlets in the "T" shaped passage.

More specifically, a safety valve may be provided having a
5 housing with coaxial upper and lower vertical housing
passages and a lateral housing passage. The lateral
housing passage intersects the upper vertical housing
passage and the lower housing passage. A laterally
movable gate is disposed in the lateral passage where the
10 gate has a first lateral portion with a first gate
vertical insert cavity. The insert cavity has an inner
diameter substantially the same as or less than that of
the upper vertical housing passage. A removable inner
part is provided for placement in or removable from the
15 insert cavity. The inner part has an outer diameter
substantially the same as that of the insert cavity and
has in addition a vertical passage in it. When the gate
insert cavity of a first lateral portion of the gate is
aligned with the upper and lower vertical housing
20 passages, the removable inner part of the gate may be
removed from or inserted within the insert cavity via the
upper vertical housing passage.

Preferably, means are provided for laterally moving
the gate in the lateral housing passage between at least
25 two positions. The first position is where the vertical
passage of the inner part is aligned with the upper and
lower vertical housing passages thereby allowing fluid
communication between the upper and lower passages of the
housing. The second position is where a second lateral
30 portion of the gate having no passage extending through it
covers the lower housing passage thereby closing the flow
path from the lower passage to the upper passage of the
housing. In this alternative embodiment _____

_____ means are
35 provided for disposing upper and lower conduits,
respectively, in said upper and lower vertical housing
passages. The upper conduit has its lower end open to the

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intersecting lateral passage. The lower conduit has its open upper end open to the intersecting lateral passage.

In the first position of the gate mentioned above, the inner part disposed in the insert cavity is aligned
5 with the upper and lower conduits allowing fluid communication therebetween. At _____
least one lateral outlet is preferably provided in the housing. The lateral outlet is substantially
perpendicular to the vertical housing passage and to the
10 lateral housing passage and is open to the intersection of the lateral housing passage and the vertical housing passage.

The gate further may have a third lateral portion with a gate "L" shaped passage therein. The "L" shaped
15 passage has an opening in the bottom of the gate and an opening in the side portion of the gate. The lateral moving means is adapted to move the gate among the first and second positions mentioned above and a third position. In the third position, the "L" shaped passage has its
20 opening in the bottom of the gate aligned with the upper end of the lower conduit and its opening in the side of the gate aligned with the lateral outlet in the housing. Two lateral outlets may be provided in the housing and a
"T" shaped passage may be provided in the third lateral
25 portion of the gate as described previously with the first embodiment of the invention described previously.

The gate may be provided having no lateral position that completely covers the tubing. Rather, a
portion of the gate may have an "L" shaped or a "T" shaped
30 bore therein for diverting fluid from the tubing in the wellhead below.

Either of the embodiments _____
mentioned above may have means for cutting a wireline
extending through the upper and lower vertical passages
35 and through a gate vertical passage upon moving the gate away from the position where the gate vertical passage is aligned with the upper and lower vertical passages.

The gate may be laterally _____ moved within the lateral housing passage either by hydraulic or manual means. Preferably the gate is moved manually for non-emergency operations but a hydraulic
5 actuator is provided for emergency purposes to drive the gate to a full off or a divert position.

Whilst the safety valve may be used _____ between a tubing or wellhead and a blowout preventer stack or Christmas tree, the valve may also be
10 advantageously used as a production tree where the valve _____ may be used as the master valve of a tree and diverter valves connected with lateral outlets in the housing may serve as control valves of the tree.

15 One method of utilising _____ the apparatus described above for controlling a well during installation of production tubing and a Christmas tree in a well in production or during completion of a well for production requires tubing in the well to be set through a
20 blowout preventer in the upper passage of the safety valve, the insert cavity of the gate, and the lower passage of the safety valve housing. Next, an inner part of the gate is installed within the vertical insert cavity from the first lateral portion of the gate where the inner
25 part has an outer diameter substantially the same as that of the insert cavity of the first lateral portion. Next, the gate is laterally moved within the safety valve housing until flow from the tubing is prevented access to the upper passage of the housing. The blowout preventer
30 is then removed from the upper part of the housing and a Christmas tree is installed to the upper part of the housing. The gate is then laterally moved within the safety valve to a position where the vertical passage of the inner part of the insert completes the vertical flow
35 path from the tubing in the wellhead below to the Christmas tree above the safety valve housing.

Where the gate includes a portion with a "T" shaped passage therein, the method further includes the step of moving the gate within the housing to prevent flow from the tubing to the upper passage of the housing and
5 comprises the step of moving the gate laterally within the housing until the head passage of the "T" is aligned with the lateral outlets in the housing and the base passage of the "T" is aligned with the tubing below and a portion of the upper surface of the gate having no passage extending
10 through it covers the flow path to the upper passage of the housing.

Alternatively, the method described above may include the step of laterally moving the gate until the lateral portion of the gate having no passage extending through it
15 covers the lower passage of the housing such that flow from the tubing and access to the upper passage of the housing is prevented.

A similar method may be provided _____
_____ where the gate does not have a vertical
20 cavity and insert but rather has a first lateral position with a first gate vertical passage having a diameter substantially the same as the vertical passage and another portion with a second gate vertical passage having a diameter smaller than the first gate vertical passage and
25 another portion either having no vertical passage therethrough or an "L" shaped passage or "T" shaped passage therethrough. Thus, the method using the valve according to this embodiment gains access to the tubing in the lower vertical housing passage via the first gate
30 vertical passage of the first lateral portion.

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Therefore, there is provided apparatus for controlling the well during removal of a blowout preventer atop the apparatus and while it is being replaced with a Christmas tree.

An apparatus and method are also provided for controlling
5 the well at all times, in conjunction with a blowout preventer atop the apparatus, while installing or working over production tubing in the well.

Advantageously, continuous uninterrupted security is achieved for a well to which the valve is attached from the time prior to
10 running production tubing to the final abandonment of the well.

Preferably, the apparatus does not destruct part of the apparatus, and thus provides a safety means for operating personnel to use during operations on the well in which they do not hesitate to use for fear of having to later replace a part during a time
15 consuming procedure. Therefore, a safety valve is provided which is entirely reversable without destruction of tubing or valve parts.

Most Christmas trees are vertically oriented; that is, a master valve is provided in a spool attached to the wellhead. Control valves are then provided laterally from the spool above
20 the master valve. The well is produced and controlled through the control valves.

Some wells demand that the vertical height of the Christmas tree be minimized. For example, in a shallow subsea completion, it is desirable to minimize the height of the tree so that vessels
25 passing above will not contact the tree during extremely low tide conditions. Another example is where the tree height must be minimized for esthetic reasons, say in a city.

Conveniently, the apparatus may serve as a master valve of a production tree where control valves may be disposed at the same
30 height as that of the master valve.

A safety valve is therefore advantageously provided in which no element is replaced and in which the production tubing is not disturbed after the valve has been closed and which does not require that the production tree be removed after the valve has been closed.

35 The safety valve in a producing well can be immediately put back into production after the valve has been closed and access to the production tubing is available via a blowout preventer attached to its top.

Valve apparatus can be provided which enables the production tubing to be connected directly to a lateral valve line.

Apparatus can also be provided which is useful during loss of control over the well to regain control over the well by lateral
5 access to the production tubing in order to carry out any of a wide range of procedures such as circulation, bullheading, pressure relieving, killing, etc., prior to vertical re-entry of the well.

Conveniently an apparatus and method are provided for controlling the well during completion of the tubing into the well
10 or during workover at the time that the blowout preventer stack is removed in order to install the Christmas tree or vice versa.

Advantageously complete control is obtainable over the well during wireline operations at any stage of the operations in a production well.

15 BRIEF DESCRIPTION OF THE DRAWINGS

The objects, advantages and features of the invention will become more apparent by reference to the drawings which are appended hereto and wherein like numerals indicate like parts and wherein an illustrative embodiment of the invention is shown, of
20 which:

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Drawings Relating to Ball Control Element Embodiment of the Invention

Figure 1 is a cross-section of the valve according to the invention showing a housing, a rotatable ball and
5 removable insert member and upper and lower tubing members connected within upper and lower passages in the housing;

Figure 2 is a cross-section of the valve through section lines 2-2 of Figure 1 and showing the actuating means for rotating the ball;

10. Figures 3A and 3B illustrate in exploded views the rotatable ball and insert member;

Figure 4 shows hydraulic actuating means for rotating the ball;

Figure 5 illustrates a running tool inserted within
15 the insert member for inserting the insert member in the insert cavity of the outer ball;

Figure 6 illustrates the apparatus used as a safety valve between a tubing head and a blowout preventer stack during installation or workover of production tubing in
20 the tubing head through the insert cavity of the ball where the inner part of the ball has been removed or not yet installed;

Figure 7 illustrates the apparatus of Figure 6 after the inner part of the ball has been inserted, aligned and
25 latched within the outer part of the ball by means of the running tool of Figure 5;

Figure 8 illustrates the apparatus of Figure 7 after the ball has been rotated aligning the base of the "T" passages with the tubing and the head of the "T" passages
30 with the lateral outlets;

Figure 9 illustrates the apparatus of Figure 7 after the ball has been rotated 180° from that shown in Figure 8 to a position where a portion of the ball having no passage through it is aligned with the tubing;

35 Figure 10 illustrates an invention used in a master valve in a "short" or horizontal tree embodiment and

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showing a swab valve attached to the upper passage of the housing;

Figure 11 illustrates the safety valve of Figure 10 with a Christmas tree attached at its top and where the
5 valve has been rotated to completely shut off flow from the production tubing;

Figure 12 illustrates the valve of the invention used as a safety valve between a tubing head and a Christmas tree and further illustrating a swab valve and adapter
10 attached to the top of the tree;

Drawings Relating to Gate Control Element Embodiment of the Invention

Figure 13 is a cross-section through the valve
15 according to a gate control element embodiment of the invention;

Figure 14 is a cross-section of the valve taken through lines 14-14 along the center line of Figure 13 and further illustrating side outlets and lateral moving means
20 for moving the gate of the valve;

Figure 15 is a perspective view of the gate of gate control element embodiment of the invention;

Figure 16 is a schematic diagram of the valve of Figures 13-15 connected between a blowout preventer stack
25 and a wellhead and illustrates a different gate configuration from that illustrated in Figure 15;

Figure 17 is a cross-section illustration taken at right angles through the center of the valve from that illustrated in Figure 16 and further illustrates the
30 attachment of a Christmas tree to the top of the valve and a swab valve and adapter for wireline work attached to the top of the Christmas tree;

Figure 18 illustrates the valve according to the invention used in a horizontal production tree
35 configuration and illustrates a "T" shaped passage which may be provided in the gate illustrated in Figure 15;

Figure 19 illustrates the valve of Figure 17 with the second vertical gate passage aligned with upper and lower conduits;

5 Figure 20 illustrates still another element of the gate of Figure 15 which may be provided according to the invention;

10 Figure 21 illustrates an alternative gate control element embodiment of the invention wherein the gate has a removable insert provided in a vertical cavity of the gate;

Figure 22 illustrates in a cross-section along lines 22-22 of Figure 21, the valve according to the invention;

15 Figures 23, 24 and 25 show gates which may be used in the valve according to the alternative embodiment of the invention and illustrating in exploded views the removable insert which may be inserted into the vertical cavities of gates there illustrated;

20 Figure 26 shows the valve according to the second embodiment of the invention after an insert has been provided into the vertical cavity of the gate through a blowout preventer stack;

Figure 27 illustrates a hydraulic actuator mechanism for laterally moving the gate of the valve according to the invention; and

25 Figure 28 illustrates a tool for inserting or removing the insert in the vertical gate cavity of the alternative gate control element embodiment of the invention.

30 DESCRIPTION OF THE INVENTION

Description of Ball Control Element Embodiment of the Invention

35 Figure 1 illustrates in a cross-section view the valve apparatus 10 according to the invention. The valve apparatus includes a housing 11, the bottom portion which may be attached to a tubing head 5 by means of studs 3 and

nuts 2 in a conventional manner. A tubing hanger 4 may be landed in the tubing head 5 conventionally and extends upwardly into the lower passage 23 of the housing 11. A tubing hanger pack-off 6 is sealingly disposed between the lower part of the housing 11 and the tubing hanger 4. A conventional port 7 extends through the lower part of the housing 11 for communication with a passage in the tubing hanger for possible use with a downhole safety valve in the well.

10 As illustrated in Figure 1, the housing 11 defines a lower passage 23 and an upper passage 24 as well as lateral outlets 25 and 26. The upper and lower passages and the two lateral outlets are open to a central chamber 40 in which is disposed a ball 20.

15 The ball 20 comprises an outer part 21 and inner part 22 which are shown in exploded views in Figures 3A and 3B. The ball is seated within chamber 40 by means of lower seat 27 and lower seat spacer 30 on which the ball 20 rests within the lower part of the central chamber 40. As
20 illustrated in Figure 1, the lower part of the outer part of the ball 21 contacts the lower seat 27. As will be shown below, the ball 20 is adapted to rotate within housing 11 bringing different parts of the ball into contact with seat 27. On the upper part of the ball 20,
25 an upper seat 28 and an upper seat spacer 29 cooperate with a housing head 32 for securing the outer portion of the ball 20 within the central chamber 40. The housing head 32 is secured to the housing 11 by means of threaded surfaces 33 in a conventional fashion.

30 Advantageously, a perpendicular passage 38 is disposed in the outer part 21 of the ball 20, which is perpendicular to the central axis 20A of the ball 20. When the ball 20 is oriented as illustrated in Figure 1, the perpendicular passage 38 communicates with lateral outlet
35 25.

According to the invention, the inner part of ball 22 is insertable in and removable from the outer part of the

ball 21. The outer part of the ball 21 has an insert cavity 42, (see also Figures 3A, 3B) the diameter of which is substantially the same as the diameter of the upper passage 24 and the lower passage 23 of housing 11. Thus, 5 when the adapter flange 44 is not in place, the inner part of the ball 22 may be inserted through the upper passage 24 for landing within and securing to the outer part of the ball 21. The outer diameter of the inner part of the ball or "insert" is substantially the same as that of the 10 upper passage 24 and the insert cavity 42 of the outer portion of the ball 21. Of course the outer diameter of the insert 22 is slightly smaller than the inner diameter of upper passage 24 and the outer part of ball 21 to provide clearance for passage during insertion and 15 withdrawal.

As illustrated in Figures 1, 3A and 3B, the inner part of the ball 22 is inserted through the upper passage 24 into alignment and engagement with the outer part of the ball 21. An anti-rotation key 34 in the outer wall of 20 the inner part of the ball 22 serves to angularly align the inner part of the ball 22 with the outer part of the ball 21. Springs 48 serve to force the anti-rotation key 34 outwardly into groove 50 such that the inner part of the ball 22 may have its outlet 37 angularly aligned with 25 the perpendicular passage 38 of the inner part of the ball. The anti-rotation key 34 has inclined shoulders 34' which cooperate with complementary shoulders 34'' on the inner wall of the insert cavity allowing the inner portion of the ball to snap into the groove 50 or conversely allow 30 the inner part of the ball 22 to be removed from the insert cavity 42 of the outer part of the ball 21.

The upper snap ring 39 and lower snap ring 39' serve to axially align the inner part of the ball 22 within the outer part of the ball 21 such that the outlet passage 37 35 in the inner part of the ball 22 is axially aligned with the perpendicular passage 38 of the inner part of the ball 21. The upper and lower snap rings 39, 39' within grooves

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54 secure the inner part 22 to the outer part. The inclined surfaces 52 and 52' of snap rings 39 and 39' allow the inner part of the ball 22 to be pulled free from the outer part of the ball when the entire ball is rotated one hundred-eighty (180) degrees from that illustrated in Figure 1.

In the orientation illustrated in Figure 1 of the ball 20, the perpendicular shoulders 53 and 53' of the snap rings of the inner part of the ball 22 prevent the inner part of the ball 22 from being pulled or forced axially upwardly with respect to the outer part of the ball. In other words, the snap rings 39 and 39' serve to hold the inner part of the ball 22 within the outer part of the ball 21, yet allow the inner part of the ball 22 to be pulled out of the inner part of the ball when the entire ball is rotated one hundred-eighty (180) degrees. This feature of the invention facilitates servicing and access to the lower passage of the valve after the adapter flange 44 has been removed from the valve. Seals 41 and 41' seal the outer part of the ball with respect to the inner portion of the ball and may be elastomeric members installed in grooves about the periphery of the inner portion of the ball 22.

Figures 3A and 3B illustrate in perspective, the inner part of the ball 22 as it is being inserted downwardly into the insert cavity 42 of the outer part of the ball 21. Figure 3A shows a view of the inner portion of the ball 22 and the outer portion of the ball 21 rotated one hundred-eighty (180) degrees from that illustrated in Figure 3B. The views in 3A and 3B are exploded views showing the anti rotation key 34 and springs 48 inserted in an outer wall of the inner part of the ball 22. Upper and lower snap rings 39 and 39' are also illustrated. Ball stem 70 is also illustrated in the exploded view along with coupling means 71 and 72 for coupling the ball stem 70 to the outer portion of the ball 21.

Returning now to Figure 1, means are provided for coupling the tubing disposed in the tubing hanger 4 into the tubing head below with the ball 20. A coupling member 70 includes an upper member 72 and a lower member 71. The lower member 71 is inserted through the insert cavity 42 of the outer part of ball 21, where the inner part of the ball 22 has not yet been installed in the outer portion of the ball 21. The outer coupling member 71 is threadedly fastened to the tubing hanger 4 by means of complementary threads 73. The upper member 72 fits within an upper neck 78 of the lower coupling member 71 and rests against upwardly facing shoulders 79 of lower coupling member 71. Seal 75 seals the upper coupling member 72 to the lower coupling member 71. Spring 74 is provided by which the upper coupling member 72 is urged upwardly against the inner portion of the ball 22 once it is installed in the outer portion of the ball 21.

An upwardly facing arcuately shaped surface 77 of the upper portion of the coupling member 72 is adapted to engage the exterior part of the ball 20. A seal 76 comprising an elastomeric member in a slot in the upwardly facing arcuately shaped surface 77 serves to seal the opening 80 in the coupling member 70 with respect to any passage in the ball which may be aligned with the lower coupling member.

In a similar manner, an upper coupling member 90 is provided to couple the ball with a conduit extending upwardly and installed in the upper passage 24 within the housing 11 and the housing head 32. The upper coupling member comprises the downwardly facing coupling member 91 and an extension 44' of the adapter flange 44 cooperatively provided to seal the upper portion of the ball with respect to an upper conduit 93. The adapter flange 44 is coupled to the housing head 32 by means of studs 92 threadedly secured within the housing head 32 by means of threads 193. A gasket 94 is provided in a

conventional fashion. Nuts 95 secure the adapter flange 44 to the studs 92.

The adapter flange extension 44' bears against the lower coupling member 91 of the upper coupling assembly 90. Spring 96 provides a resilient downward force from the adapter flange extension 44' against the lower coupling member 91 and against the ball 20. A downwardly facing arcuately shaped surface 97 of the lower coupling member 91 engages the ball. A cylindrical conduit 98 of the lower coupling member 91 is provided to communicate with opening 98 which may be in alignment with passages 37,38 or passage 36 of the ball 20. Seal 99 in surface 97 is provided to cooperate with the ball for sealing about any opening of the ball 20 with the opening 98 of the conduit of the upper coupling member 90.

Inserts 100 and 101 in the opening of the passage 36 of the inner portion of the ball are provided with hardened material such as tungsten carbide. Likewise, the lower portion 91 of the upper coupling assembly 90 and the upper coupling member 72 of the lower coupling assembly 70 are provided of a hardened material so that if a wireline were to extend through the upper conduit 98 through the passage 36 and through the lower conduit 80, turning of the ball 20 may cut such wireline between the hardened material 100 or 101 and the coupling members 91 or 72 acting as an anvil.

Other apparatus may be attached to the top of the adapter flange 44. As illustrated in Figures 1 and 2, a valve flange 105 may be secured to the adapter flange 44 by means of threaded studs 107 and nuts 108. Studs 107 may be secured to the adapter flange 44 by means of threads 109. A head sleeve 110 may be provided to couple the conduit 93 with a similar conduit 111 in the valve flange which may communicate with a vertically extending Christmas tree or the like. Gasket 106 is provided to seal valve flange 105 from the adapter flange 44.

The invention which has been described to this point includes a ball disposed in a chamber of a valve housing in which an inner portion of the ball may be inserted with an outer portion of the ball. The inner portion may be
5 removably secured through the upper passage of the housing. The insert cavity of the ball is of substantially the same diameter as the upper passage of the housing thereby permitting insertion of tubing and other apparatus through the insert cavity of the ball into
10 the lower passage of the housing. The inner portion of the ball is provided with at least one passage therethrough which can communicate with conduits disposed in the lower passage of the ball and the upper passage of the ball. Thus, in its broadest aspects, the safety valve of the present
15 invention includes a rotatable ball and a housing and having an insert in the ball for preventing communication with cooperating upper and lower conduits in upper and lower vertical passages of the housing. Thus, passage 36 in the inner portion of the ball 22 may communicate with an upper
20 conduit 98 or a lower conduit 80 installed in the valve apparatus. When the ball is turned ninety (90) degrees from that illustrated in Figure 1, the communication from the lower portion of the ball is prevented from the upper conduit 98. Thus, there is provided a ball valve with a
25 removable insert which prevents or allows fluid communication between upper and lower conduits in the upper and lower passages of the housing. The removable feature of the ball allows, in an oilfield environment, installation or replacement of tubular components in or
30 below the lower passage of the ball through a blowout preventer attached to the upper part of the housing without removing the valve housing from attachment to a wellhead or the like below the valve housing. Complete control over the well of course is provided by the valve
35 during removal of the blowout preventer and replacement thereof with a Christmas tree, or vice versa.

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In the preferred embodiment of the invention illustrated in Figure 1, the outer portion of the ball has a perpendicular passage 38 and the inner portion of the ball has "T" shaped intersecting passages 36 and 37. The head of the "T" passage is provided substantially along the central axis 20A of the ball, whereas the intersecting passage of the inner part of the ball 37 is provided perpendicularly to the passage 36. For ease of description, the passage provided along the central axis of the ball as illustrated in Figure 1 is termed "the head of the "T" passage" whereas the perpendicular passage in the inner portion of the ball 22 is termed "the base of the "T" passage".

As illustrated in Figure 1, after the inner part of the ball 22 is inserted within the insert cavity 42 of the outer part of the ball 21, the base of the "T" passage 37 is aligned with the perpendicular passage 38 in the outer part of the ball 21. After the insert 22 is aligned and fixed within the outer portion of the ball by means of the alignment key 34 and the axially aligning and securing snap rings 39, 39', the parts of the ball act as a single unit, that is, a "T" passage comprising the head of the "T" passage 36 and the base of "T" passage 37 and the perpendicular passage 38 of the outer portion of the ball 21 move as a unit. Means to be described below allow the ball 20 to move three hundred-sixty (360) degrees within the chamber 40 of the valve 10.

The preferred embodiment of the valve according to the invention, includes at least one lateral outlet in the housing 11, preferably two. A first lateral outlet 25 and a second lateral outlet 26 are illustrated in Figures 1 and 2 and Figures 6 through 12 illustrating the operation of the valve according to the invention. Lateral ball seats 120 and 121 are provided for cooperating with the ball and are inserted within the lateral outlets 25 and 26, respectively, and for sealing with the housing 11. Seal sleeves 122 and 123 are provided and act with springs

124 and 125 to urge the seal sleeves 122 and 123 against the lateral ball seats 120 and 121 against the ball 20. The springs 124 and 125 are disposed in annular shoulders of lateral flanges 128 and 129 which are coupled to the housing by means of threaded studs 132 and 133 into the housing 11. Nuts 136 and 137 secure the lateral flanges 128 and 129 to the studs 132 and 133. Arcuately shaped surfaces on the end openings of the lateral ball seats 120 and 121 cooperate with the exterior of the ball 20 and the seals 140 and 141 act in cooperation with the springs 124 and 125 to sealingly engage the lateral ball seats 120 and 121 about the exterior of the ball and to seal an opening which may exist between the passage in the ball and the passage within the ball seat and seal sleeve which cooperate with the lateral conduits in flanges 128 and 129. Gaskets 180 and 181 are provided between the lateral flanges 128 and the housing 11 and the lateral conduit 129 and the housing 11.

Figure 2 is a cross-section through the valve of the invention along section lines 2-2 of Figure 1. Figure 2 illustrates the valve stem 70 extending through a hole in the housing wall and shows coupling means 71 attached to the end of the valve stem 70 within cooperating receiving means 72 in the outer wall of the outer part of the ball 21. The valve stem 70 and the coupling means 71 and 72 are illustrated in the exploded views of Figures 3A and 3B. Fastened to the wall 11 is a housing 173 of a motive means for rotating the ball 20 within the housing 11. The motive means includes a hydraulic actuator as well as a mechanical actuator.

The hydraulic actuator is illustrated in schematic form in Figure 4. A pinion gear 170 is provided about the valve stem 70 and is held thereto by means of a key 171. Gear 170 is carried within the housing 173 which may be bolted to the valve body 11 so as to be removable therefrom and with the ball 20.

Disposed within the housing 173 are upper and lower racks 175 and 176 meshing with the pinion gear 170 and integral with pistons 177 and 178. The pistons are reciprocal horizontally within the cylinders 179 and 180
5 formed within and by the housing structure as illustrated, there being end caps 181 and 182 closing the cylinders at their heads. As fluid pressure is admitted via port 190 to drive piston 177 to the left, as illustrated in Figure 4, the pinion gear 170 and valve stem 70 is rotated by
10 rack 175 and drives rack 176 and piston 178 to the right thereby exhausting fluid from the space between piston 178 and end cap 182 via port 191. The hydraulic motive means illustrated in Figure 4 is adapted primarily for emergency purposes; that is, when it is desired to quickly and
15 remotely shut off fluid from the lower passage 80 of the conduit disposed in the lower passage 23 of the valve, it is desired to be able to turn the ball ninety (90) degrees so that a portion of the ball having no port extending therethrough may seal about the upper coupling member 72
20 provided in communication with any tubing disposed below in the wellhead.

Therefore, the hydraulic actuator depicted in Figure 4 is constructed such that caps 181 and 182 limit turning of the ball to an angular rotation of ninety (90) degrees
25 so that the valve may be quickly and remotely turned to a full off or safety position. On the other hand, it is desired that the ball may be turned fully about three hundred-sixty (360) degrees such that various orientations may be achieved with the ball within the housing 11.
30 Therefore, the portion of the cylinders to the left of the pinion gear are constructed with end caps 181a and 182a allowing rotation two hundred-seventy (270) degrees from that depicted in Figure 1. The hydraulic actuator being primarily for emergency safety operation of the valve,
35 mechanical hand wheel 190 is also provided about the valve

stem 70 for mechanically turning the valve to various positions as will be discussed in more detail below.

It is believed that the operation of the valve would primarily by the mechanical hand wheel 88 with the hydraulic actuator being reserved for emergency purposes, but, of course, the valve could be operated entirely hydraulically where desired. A position indicator 89 is provided about the valve stem 70 with a pointer means (not illustrated) whereby a person mechanically operating the valve may be informed, by the pointer on the indicator, of the position of the ball 20 within the housing 11.

Figure 5 illustrates a means for inserting the inner part of the ball 22 within the insert cavity 42 of the outer part of the ball 21. Insertion is performed where the adapter flange 44 is not attached to the housing head 32 of the housing 11, but would be used where the lower coupling 71 has been installed in communication with tubing landed in a tubing hanger below the lower passage of housing 11. As illustrated in Figure 5, the insert running tool 200 includes a body 203 threadably secured with a rod 202 by means of threads 201. The illustration of Figure 5 is from a point one hundred-eighty (180) degrees from that illustrated in Figure 1 where the base passage 37 of the inner part of the ball 22 is facing to the left rather than facing to the right as illustrated in Figure 1.

In the position indicated of the running tool of Figure 5, an arm member 204 engaged by the end of rod 202 extends within the opening of the passage 37. After the inner part of the ball 22 has been inserted within the outer part of the ball 21 (See Figure 1) and the upper snap rings 39 and lower snap rings 39' have been cooperatively engaged with the grooves in the outer portion of the ball, the rod 202 is turned until it moves upwardly by means of the threads 201. After the rod 202 moves upwardly sufficiently to clear the end of arm 204, the spring 205 forces the arm member 204 to the right out

of the passage 37. The running tool 200 then comes out of engagement within passage 37 and may be removed upwardly through the upper passage 24 with the inner part of the ball 22 remaining within the outer part of the ball 21.

5 The inner part of the ball 22 may be retrieved in a similar fashion where the spring 205 may be oriented to keep arm 204 within the head passage of the "T" of the inner bore. By turning the rod 202 in the opposite direction, the arm 204 is forced into the passage 37
10 whereby an upward movement of rod 202 causes the inner part of the ball 22 to be removed from the outer part 21.

Figures 6 through 12 illustrate preferred environments in which the valve may be used. Turning first to Figures 6 through 10, an environment is
15 illustrated where the valve apparatus according to the invention is used to maintain complete control over a well during the time that production tubing is being installed in the well and until and after a Christmas (production) tree is installed for production of the well.

20 Figure 6 illustrates the apparatus assembled where the valve housing 11 according to the invention is attached between a tubing head 5 and a blowout preventer stack 300. The outer part of the ball 21 is installed in the housing 11 but the inner part of the ball which may be
25 inserted in the insert cavity 42 has not yet been installed. The blowout preventer stack 300 is attached to the valve housing by means of a flange 105 as described previously. A tubing hanger 4 has been landed in the tubing head and a coupling member 70 for coupling with the
30 tubing 301. The tubing 301 has been installed through the vertical flow path of the blowout preventer stack and down through the upper passage 24, the insert cavity 42 and through the lower passage 23. The wing or diverter valves 310 and 312 are provided in communication with the lateral
35 outlets of the valve 10. Thus, it is seen from Figure 6 that complete control over the well is established by means of the blowout preventer stack 300 while the valve



10 housing and the outer portion of the ball 21 is in place atop the tubing head 5. Any emergency conditions in the well could at this point be controlled by means of the blowout preventer stack 300.

5 Figure 7 illustrates the condition of the apparatus after the inner part or insert of the ball 22 is installed in the insert cavity 42 of the valve 10. The insert 22 is illustrated where the head of the "T" shaped passage 36 is vertically aligned and the base of the intersecting "T" shaped passage is aligned with the perpendicular passage 38 of the outer part of the ball. In this orientation, the perpendicular passage 38 is aligned with the lateral outlet 26. Of course, the outer portion of the ball and the insert could be aligned with the lateral outlet 25.
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15 In this condition of the valve, vertical communication is established between the coupling member 70 and the head of the "T" passage 36.

 Figure 8 illustrates the condition of the valve apparatus after the ball 20 has been rotated ninety (90) degrees from that illustrated in Figure 7. In Figure 8, the ball has been rotated to a point where the head of the "T" shaped passage 36 is in line with the lateral passages 26 and 25 and the base of the "T" shaped passage in the ball comprising passages 37 and 38 are in communication with the tubing via coupling member 70. In this condition of the valve, control over the well may be established by means of the diverter valves 312 and 310. For example, if there should be a kick or bubble in the production tubing, such condition may be controlled by diverting pressurized fluid flow from tubing 301 via either or both of the wing valves 310, 312 communicating with conduits away from the well. For example, if the installation is on an offshore platform, conduits extending to either side of the platform could be used to divert dangerous pressurized fluid from the well.
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30
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 Figure 9 shows an alternative condition of placement of the ball 20 for complete control over the well. In

5 this illustration, the ball has been rotated one hundred-eighty (180) degrees from that illustrated in Figure 8. A portion of the ball not having an exterior port through it has been rotated where it blocks fluid communication from coupling 70 and hence tubing 301. This is the condition which might be automatically provided by the hydraulic actuating means described in Figure 4 which could be remotely operated and completely prevent pressurized fluid from flowing upwardly from the wellhead

10 5.

Figure 10 illustrates one environment in which the valve apparatus according to the invention may be used. In the configuration illustrated, the valve 10 is used as a master valve in a "short" tree. In normal use, the ball 15 20 serves as the master valve of the apparatus and the well is produced via the wing valves 312 or 310. A cap (not illustrated) over the upper passage of the housing may be installed to complete the short tree embodiment.

Alternatively as illustrated in Figure 10, a swab 20 valve assembly 400 may be attached to the top of the apparatus housing by means of an adapter flange 44. Thus, the well may have swabbing work done on it when the ball 20 is rotated ninety (90) degrees from that illustrated in Figure 10. An adapter 19 may be placed atop the swab 25 valve 400 for connecting a lubricator in the normal way. Because of the low profile of the wellhead and safety valve 10 illustrated in Figure 10, the lubricator may be spaced such that wireline tools do not straddle a normally installed vertical Christmas tree and the safety valve at 30 the same time.

Figures 11 and 12 illustrate the valve 10 in which a normal vertical Christmas tree 500 is attached to the top of the housing 11 by means of an adapter flange 44. The usual master valve 501 is part of the vertical Christmas 35 tree. Figure 12 illustrates the attachment of a swab valve 400 to the top of the Christmas tree 500 and additionally illustrates adapter 600 attached to the top

of the swab valve in which a lubricator for wireline work may be established. In the assemblies illustrated in Figures 11 and 12, well control could be obtained by using the wing valves and lateral conduits as "kill" passages where the ball is rotated to the position illustrated in Figure 10. Control fluid could then be pumped into the well to bring the well under control. Procedures such as circulation, bullheading, pressure relieving, in addition to killing, could also be performed via the lateral passages and control valves, prior to vertical re-entry of the well as described previously.

Description of Gate Control Element Embodiment of the Invention

Figure 13 illustrates generally at 710 the valve according to the gate control element embodiment of the invention. The valve has a housing 701 defining a vertical housing passage 704 and a lateral housing passage 706. Disposed in the lateral housing passage 706 is a gate 708 which may be laterally moved in the lateral housing 706 by a gate lateral moving means 720.

The moving means 720, which may be as illustrated a hydraulically driven piston, cooperates with rods 722 and 724 which are coupled to gate 708 by means of couplings 726 and 728.

The gate 708, shown in cross-section of Figure 13, is illustrated in a perspective view in Figure 15 and shows a first gate vertical passage 716 in a first lateral portion of the gate 708. Although the first gate vertical passage is illustrated in Figure 13 to be of the same diameter as the entire vertical housing passage 704, the first gate vertical passage 716 must be at least as large as that portion of the vertical housing passage 704 extending below the lateral housing passage 706. The upper part of the vertical housing passage above the lateral housing passage 706 may have the identical diameter or



substantially the identical diameter of the first gate vertical passage or may be somewhat larger.

The relative dimensions discussed above are necessary such that apparatus to be landed in the lower part of the vertical housing passage 704 may have access through the upper part of the vertical housing passage 704 and the first gate vertical passage 716.

In a second lateral portion 712 of the gate 708, no vertical passage is provided as shown in Figures 13 and 15. In a third lateral portion 714 of the gate, a second gate vertical passage 718 is provided.

The housing 701 is shown schematically attached to a wellhead 730 by means of bolts 715. Tubing 736, attached by means of threaded surfaces 738 to a tubing hanger 734, is landed in the lower portion of the housing 701 by means of cooperating landing shoulders 717. Of course, the tubing hanger 734 could be landed within the wellhead 730, or in the housing 701 of the safety valve 710 as illustrated. The housing 701 of the valve could be fabricated with the housing of the wellhead 730 forming an integral housing.

A lower coupling member 740 is provided in cooperation with an upper portion of the tubing hanger 734. A spring 742 cooperating between upwardly and downwardly facing shoulders of the lower coupling member 740 and tubing hanger 734 is provided to urge the coupling member upwardly against gate 708 when a portion of the gate is moved into the vertical housing passage 704. In a similar way, an upper coupling member 746 is provided in cooperation with an adapter flange 744 and is urged downwardly by means of spring 750 cooperating with upwardly and downwardly facing shoulders of the adapter flange 744 and the upper coupling member 746. An upper conduit 748 is provided within the adapter flange 744. The adapter flange 744 may be connected to the housing 701 by means of threaded bolts 745.

Thus, the upper coupling member 746 and the lower coupling member 740 provide a fluid communication path from the tubing 736 extending into the wellhead 730 and the upper conduit 748 which may be provided in communication with a blowout preventer or a Christmas tree or the like to be described below.

In the configuration illustrated in Figure 13, the adapter flange 744 is shown attached to the valve housing 701. Of course, before the adapter flange 744 is attached to the housing 701, the tubing hanger 734 has full-bore access through the vertical housing passage of the housing 701 of the valve 710 to the lower portion of the vertical housing passage below the lateral housing passage 706, via vertical passage 716 of gate 708.

It should be observed at this point that when the portion of the gate having no vertical passage in it is moved laterally to cover the lower coupling member 740, the upward fluid flow path from the tubing 736 is prevented. Thus, a blowout preventer may be attached to the housing 701 with the gate 708 and that portion 712 of the gate having no vertical passage in it providing complete shut-off for the valve and the resulting complete control over the well.

After the blowout preventer is attached to the housing 701, full-bore access through the bore of the blowout preventer is available for removing the tubing hanger 734 and tubing 736 and replacing it as in workover operations or during initial installation work on the well, the tubing hanger 734 and 736 may be initially placed in the well to the position as that illustrated in Figure 13.

Figure 13 illustrates the adapter flange 744 attached the valve housing 701, where the work has been done of landing the tubing hanger 734 and tubing 736 in the well and the well has been provided with the upper conduit 748 for vertical production of the well as will be discussed in more detail below. It should be further observed that

the gate 708 in the position as illustrated in Figure 13 has the second gate vertical passage 718 aligned with the tubing 736 in the vertical flow path provided by the lower coupling member 740, upper coupling member 746 and the upper conduit 748. In that condition, the safety valve provides vertical communication from the tubing 736 to equipment attached to the top of the well.

It should be also observed that the well can be completely closed off by further moving the gate 708 laterally to the left until the portion 712 of the gate having no vertical passage completely closes off the vertical flow path from the tubing 736. By the same token, the gate 708 may be moved laterally to the right removing the condition of complete shut-off with no damage done to any of the parts of the valve. Such a feature of the invention advantageously enables oilfield workers to feel free to close off a well under the slightest hint of danger caused by a kick or excess pressure coming from the well.

Figure 14 illustrates the valve of Figure 13 in a cross-section through lines 14-14 of Figure 13 and shows the condition of the valve where the second gate vertical passage 718 is in line with the vertical housing passage 704 in the housing 701. Further illustrated in Figure 14 are lateral outlets 752 and 754 which are in communication with the inner section of the vertical housing passage 704 and the lateral housing passage 706. As will be illustrated with respect to later figures and discussion, the lateral outlets 752 and 754 cooperate with other passages which may be provided in the gate 708 for providing lateral diverting paths in the valve.

Also illustrated in Figure 14 is an alternative lateral moving means 720' for moving the various lateral portions of the gate 708 into the intersection of the vertical housing passage 704 and the lateral housing passage 706. A shaft 7122 is connected to a gear 7120 for laterally moving gate 708 of Figure 13. A handwheel 7124

is attached to the shaft 7122 to provide manual means for rotating the shaft and the gear to laterally move the gate 708 to the various operative positions. Hydraulic lateral moving means may also be provided, and an illustrative
5 embodiment of such is presented below.

Figure 15 previously discussed in connection with Figure 13, shows one construction of the gate of the first embodiment of the invention with the large first gate vertical passage 716 having a diameter at least as large
10 as the vertical housing passage 704 beneath the lateral housing passage 706. The second lateral portion 712 having no vertical passages is illustrated as well as the third lateral portion 714 having the second gate vertical passage 718. The diameter of the second gate vertical
15 passage 718 is sized to cooperate with the lower coupling member 740 and the upper coupling member 746 illustrated in Figure 13.

Figure 16 illustrates the valve 710, according to the first embodiment of the invention, connected between a
20 wellhead 730 and a blowout preventer 760. A second construction of the gate 708 is illustrated having a fourth lateral portion 762 with an "L" or "T" shaped passage 763 provided to communicate with the first and/or second lateral outlets 752 and 754. As illustrated in
25 Figure 16, the gate 708 is in a lateral position such that the first gate vertical passage 716 is aligned with the vertical housing passage 704 of the housing 701. Thus, as mentioned above, the tubing hanger 734 with its tubing 736 may be inserted through the vertical flow path of the
30 blowout preventer stack 760 and through the vertical housing passage 704 into landed engagement below the lateral housing passage 706. In addition to providing complete shut-off of the vertical fluid flow path from the tubing 736 by moving the gate 708 laterally to the left
35 where the second lateral portion having no vertical passage 712 covers the tubing hanger 734, the gate 708 may be moved to the right whereby the "L" or "T" shaped

(64)

passage 763 may provide a diverting path from the tubing 736 to either or both the first lateral outlet 752 and the second lateral outlet 754.

Figure 17 illustrates the valve 710 in the condition after the tubing hanger 734 has been landed in the lower part of the vertical housing passage 704 and an adapter flange 744 with an upper conduit 748 has been provided and a Christmas tree 764 with a master valve 766 attached. The valve 710 is connected to a wellhead 730 as above and a swab valve 7400 and an adapter 7600 for connection of a lubricator is provided for establishing wireline work through the swab valve, Christmas tree, upper conduit 748 and into the tubing 736. As illustrated however, the portion of the gate 712 having no vertical outlet is shown preventing communication from the tubing 736. Thus, the gate 708 must be moved to allow vertical communication for wireline work.

Shown also in the illustration of Figure 17 are wing or diverter valves 7130 and 7131 which may be connected to outlets 752 and 754, respectively so that when a "T" shaped passage 763 as that of the illustration of Figure 16 is brought laterally in communication with the lateral valves 752 and 754, the fluid from the tubing 736 may be diverted from the well. Well control could be obtained by using the wing valves 7130 and 7131 and lateral conduits 752 and 754 as "kill" passages if the "L" or "T" shaped passage 763, illustrated in Figure 16, were to be brought into communication with the tubing 736 and lateral passages 752 and 754 by laterally moving the gate 708 to the right from that illustrated in Figure 16. Control fluid could then be pumped into the well to bring the well under control. Procedures such as circulation, bullheading, pressure relieving, in addition to killing could also be performed via the lateral passages and control valves prior to vertical reentry of the well.

Figure 18 illustrates the valve 710 in use as a master valve of a horizontal production tree 710'. In the

illustration of Figure 18, the portion 762 of the gate having a "T" shaped passage provides fluid communication between the tubing 736 and the lateral outlets 752 and 754. Thus, with the cap 744' connected to the housing 701
5 production of the well may be provided via the wing valves 7130 and 7131 serving as production control valves.

In another illustration of the valve 710 shown in Figure 19, the second gate vertical passage 718 is shown in alignment with the production tubing 736 and the upper
10 conduit 748 providing vertical communication to the Christmas tree 764, swab valve 7400 and adapter 7600.

Figure 20 illustrates still another possible configuration of the gate 708 where two "L" shaped passages 788 and 789 are in communication with two
15 production tubings 736' and 736'' landed by means of a tubing hanger in the lower portion of the vertical housing passage.

Figures 21 through 26 illustrate an alternative embodiment of the gate control element of the invention.
20 Figure 21 shows the alternative embodiment which is substantially the same as that illustrated in Figure 13 with the exception that a gate 780 is provided within the lateral housing passage 706 of valve 7100 which has as illustrated, for example, in Figures 23, 24 and 25, a
25 vertical cavity 7160 and a removable insert 7150 having a vertical bore 7140 through it.

Figures 23, 24 and 25 illustrate that various embodiments of the gate may be provided within the lateral housing passage 706 of the valve 7100 illustrated in
30 Figure 21. The gate 780 illustrated in Figure 21 is of the kind illustrated in Figures 24 and 25 where a first portion of the gate has the vertical cavity 7160 and a second portion 7120 of the gate has no bore or vertical passage through it. A third portion of the gate 7130 has
35 either a "T" shaped passage through it as illustrated in Figure 25 or a single or a double "L" passage through it as illustrated in Figure 24.

In the illustration of Figure 21, the passage 7620 may be either a "T" or an "L" or a double shaped passage within the portion of the gate 780 designated generally as 7130. The valve 7100 has a housing 7101 with a lower
5 vertical housing passage 7402 and an upper vertical housing passage 7400 coaxial with one another and forming an upwardly facing shoulder 7501.

The upper vertical housing passage 7400 has a larger diameter than that of the lower vertical housing passage
10 7402 such that the insert 7150 may be inserted via the upward vertical housing passage 7400 into landed engagement on shoulder 7501. The insert 7150 has a downwardly facing shoulder 7502 which cooperates with the upwardly facing shoulder 7501 between the lower vertical
15 housing passage 7402 and the upper vertical passage 7400. The lower part of the insert 7150 has substantially the same diameter as the lower vertical housing passage and the upper part of the insert 7150 has substantially the same diameter as the upper of the cavity 7160. Of course,
20 the vertical housing passage in the upper part of the housing 7101 may be larger than the upper diameter of the cavity 7160. The lower part of the cavity 7160 may be larger than the diameter of the lower vertical housing passage below the lateral housing passage 706. Seals 7170
25 are provided in the wall of the insert 7150 to seal about the wall of the vertical cavity 7160.

The illustration of Figure 21 shows the gate 780 in a position where the vertical passage 7140 in the insert
30 7150 is aligned with the tubing 736 and the upper conduit 748 of adapter flange 744 via the lower coupling member 740 and the upper coupling member 746. The insert 7150 may be removed from the gate 780 after the adapter flange 744 is removed from the housing 7101. In a manner similar to that of the first embodiment of the invention discussed
35 above, the gate 780 may be moved laterally to the left within the vertical housing passage 704 until the "T" or "L" shaped passage 7620 is in alignment with the tubing

736 via the lower coupling member 740. Outlets 752, 754 in the housing, illustrated in Figure 22, cooperate with the opening or openings in the side of the gate illustrated Figures 24 and 25 to communicate with such
5 opening or openings.

The gate 780 may be moved still further to the left until that portion 7120 of the gate completely covers the opening from the tubing 736 and lower coupling member 740 thereby completely shutting off the vertical flow path
10 from the tubing 736 in the well.

Figure 22 illustrates a vertical cross-section taken through section lines 22-22 of Figure 21. This illustration of the alternative embodiment of gate control element embodiment of the invention is similar to that of
15 Figure 14 showing the lateral outlets 752 and 754. Additionally illustrated is a hydraulic actuator means 7600 which may be attached to the shaft 7122 in addition to the handwheel 7124. When the valve 7100 is to be used as a safety valve, it may be advantageous to use a
20 hydraulic actuating means 7600 which may be remotely operated to drive the gate 780 to complete shut-off or to the divert mode via a "T" or "L" shaped passage 7620. In normal operation, however, the manual operation of the valve 7124 would serve to position the gate 780 among the
25 various modes of the valve 7100. The illustration of Figure 22 shows the condition of the valve 7100 where the insert 7150 is being either removed or inserted within the cavity 7160 in the housing 7101.

Figures 23, 24 and 25 show the configurations of gate
30 780 which may be used in the lateral housing passage of valve 7100. Figure 23 shows a configuration having a vertical cavity 7160 in which the insert 7150 is landed and held in the gate 780' by means of cooperating shoulders 7501 and 7502.

35 In the illustration of Figure 23 there are but two lateral portions of the gate 780': a first portion 7110 in which the vertical cavity 7160 is provided and a second

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portion 7120 having no vertical passage through it. The configuration of Figure 23 has no means for diverting fluid flow from the lower vertical housing passage via the side of the valve as shown, for example, in Figure 22 with outlets 752 and 754. With the gate 780' of Figure 23 there is a means of completely closing off the vertical flow path between the lower vertical passage 7402 and the upper vertical housing passage 7400. When the first portion 7110 of the gate 780' is aligned with the lower vertical housing passage 7402 and the insert 7150 is inserted within the cavity 7160, vertical flow via the passage 7140 and the insert 7150 is provided by the valve.

Figure 24 shows another configuration of the gate, designated as 780''. It is similar to that of Figure 23 except that the third lateral portion 7130 of the gate 780'' has formed therein two "L" shaped passages 7200 and 7201. Such passages may find application for a dual production tubing completion as illustrated in Figure 20 whereby production via the wing valves may be accomplished.

Figure 25 shows a similar gate to that illustrated in Figure 24 wherein gate 780''' includes a "T" shaped passage 7620 in the third lateral portion 7130 of the gate.

Figure 26 shows the valve 7100 in a configuration where a blowout preventer stack 760 is attached to the top of the valve as was illustrated in Figure 16 for the first gate control element embodiment of the invention. Figure 26 illustrates that the insert 7150 may be conveniently landed within the cavity 7160 of the housing 7101.

Figure 27 illustrates the hydraulic actuator 7600 of Figure 22. A pinion gear 7670 is provided about the gate stem actuator 7122 and is held thereto by means of a key 7671. Gear 7670 is carried within the housing 7673 which may be bolted to the valve body 7101 so as to be removable therefrom and from the gear 7120 illustrated in Figure 22.

Disposed within the housing 7673 are upper and lower racks 7675 and 7676 meshing with the pinion gear 7670 and integral with the pistons 7677 and 7678. The pistons are reciprocal horizontally within the cylinders 7679 and 7680
5 formed within and by the housing structure as illustrated there being end caps 7681 and 7682 closing the cylinders at their heads as fluid pressure is admitted via port 7690 to drive piston 7677 to the left.

As illustrated in Figure 27, the pinion gear 7670 and
10 valve stem 7122 are rotated by rack 7675 and drives rack 7676 and piston 7678 to the right thereby exhausting fluid from the space between piston 7678 and end cap 7682 via port 7691. The hydraulic motive means illustrated in Figure 27 is adapted primarily for emergency purposes;
15 that is, when it is desired to quickly and remotely shut-off fluid from the lower passage 732 of the valve 710 illustrated in Figure 13. For example, it is desired to be able to move the gate until a portion of the gate having no vertical passage therethrough may seal about the
20 upper coupling member 746 provided in communication with any tubing disposed below in the wellhead.

Therefore, the hydraulic actuator depicted in Figure 27 is constructed such that caps 7681 and 7682 limit turning of the stem and movement of the gate to a degree
25 such that the valve may be quickly and remotely turned to a full off or safety position. On the other hand, it is desired that the gate may be moved to other positions allowing for either vertical or horizontal communication with tubing in the wellhead. Therefore, the portion of
30 the cylinders to the left of the pinion gear 7670 are constructed with end caps 7681a and 7682a allowing the gate to be moved in the opposite direction. The hydraulic actuator being primarily for emergency safety operation of the valve, a mechanical handwheel 7124 is also provided as
35 previously described about the valve stem 7122 (See Figure 22) for mechanically turning the valve to various positions.

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Figure 28 illustrates a means for inserting the insert 7150 within the cavity 7160 of gate 780 (or gate 780', 780'' or 780'''). Insertion is performed by means of the tool 7701 which has threads 7702 formed about its external surface. Complementary threads 7703 in the interior of the vertical passage 7140 of the insert 7150 may be used to threadedly secure tool 7701 to the insert 7150. Thus, the tool 7701 may be attached to the insert 7150 by means of the cooperating threads 7702 & 7703 and may be used to land the insert 7150 within the cavity 7160. By turning the tool 7701 to disengage the threads 7702 and 7703, the tool 7701 may be withdrawn leaving the insert 7150 within the cavity 7160. The reverse of the procedure described above may be used to withdraw the insert 7150 from the cavity 7160.

Various modifications and alterations in the described structures will be apparent to those skilled in the art of the foregoing description which does not depart from the spirit of the invention. For this reason, these changes are desired to be included in the appended claims. The appended claims recite the only limitation to the present invention and the descriptive manner which is employed for setting forth the embodiments and is to be interpreted as illustrative and not limitative.

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CLAIMS:

1. A safety valve adapted for placement above a wellhead comprising a housing having a coaxial upper and lower vertical housing passages and at least one laterally disposed outlet, the diameter of the upper and lower passages being sufficiently large to pass a tubing hanger with tubing for landing in the wellhead, and control element means disposed between said upper and lower vertical housing passages for preventing or allowing fluid flow through a passage smaller than the lower vertical housing passage and for providing full diametrical access via the upper housing passage to the lower housing passage.
2. A valve as claimed in claim 1, wherein each of the outlet and upper and lower passages is open to a chamber in the housing, and said control element means comprises a rotatable ball having an outer part with means for seating it within the chamber, said outer part having an insert cavity along a central axis of the outer part, the insert cavity having an inner diameter substantially the same as or less than that of the upper passage, said outer part having a perpendicular passage extending from the insert cavity to the exterior of the outer part, and a removable inner part disposed in said insert cavity and having an outer diameter substantially the same as that of the insert cavity of the outer part and having intersecting passages forming a "T" shape, the head passage of the "T" being along said central axis and the base passage of the "T" being aligned with the perpendicular passage of the outer part.
3. A valve as claimed in claim 2, including means for angularly aligning said inner part within said outer part whereby after said inner part is inserted into said outer part, the base bore of the "T" may be angularly aligned with the perpendicular passage



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of the outer part.

4. A valve as claimed in claim 2, including means for axially aligning said inner part within said outer part, whereby after said inner part is inserted
5 into said outer part, the base bore of the inner part may be axially aligned with the perpendicular passage of the outer part.

5. A valve as claimed in any one of claims 2 to 4, wherein said housing has two lateral outlets
10 open to the chamber in the housing which has two diverter valves each of which is attached to a respective outlet.

6. A valve as claimed in any one of claims 2 to 5, including a closure member for cooperatively acting with
15 said seating means for securing said outer part within the chamber and axially aligning said perpendicular passage of the outer part with said lateral outlet.

7. A valve as claimed in any one of claims 2 to 6, including means for seating and sealing the ball
20 with a lower conduit placed in said lower passage, and means for rotating said ball within the housing to a position where a portion of the external surface of the ball having no passage extending through it covers the lower conduit, thereby blocking the flow path from
25 the lower conduit.

8. A valve as claimed in claim 7, wherein the lateral outlet is one of two lateral outlets, said housing having means for seating the exterior of the ball with the lateral outlets, means for seating the
30 exterior of the ball with an upper conduit placed in said upper passage, and said rotation means is capable of rotating said ball among at least four positions; a first position where the head passage of the "T" completes a fluid flow path from said lower conduit to said
35 upper conduit and said perpendicular passage is in fluid communication with a first of said lateral outlets, a



second position where the head passage of the "T" is in fluid communication with said lateral outlets, said perpendicular passage is in fluid communication with said lower conduit, and a portion of the external surface of the ball having no passage extending through it covers the upper conduit thereby blocking the flow path to the upper conduit, a third position where the external surface of the ball having no passage extending through it covers the lower conduit thereby blocking the flow path from the lower conduit and the head passage of the "T" is aligned with the two lateral outlets and the perpendicular passage is aligned with the upper conduit, and a fourth position where the head passage of the "T" completes a fluid flow path from said lower conduit to said upper conduit and said perpendicular passage is in fluid communication with a second of the lateral outlets.

9. A valve as claimed in any one of claims 2 to 8, including cutting means secured in the head passage of the "T" of the inner part for cutting a wireline cable when said cable extends through said head passage.

10. A valve as claimed in claim 1, wherein said housing has disposed therein lower and upper conduits in said upper and lower passages and at least one laterally disposed outlet and having a chamber between the ends of said conduits and said outlet, said control element means comprising a ball disposed in said chamber, said ball having three output ports with flow paths in the interior of the ball communicating with the three ports and an unported surface, means for rotating said ball among at least three positions: the first position where two of the ports in the ball are aligned respectively with the ends of the upper and lower conduits disposed in the housing and a third port is aligned with said outlet, the second position where one of the ports in the ball is aligned with said outlet and

a second of the ports in the ball is aligned with the end of the lower conduit and the unported surface is aligned with the end of the upper conduit, the third position where the unported surface is aligned with the end of the lower conduit, whereby when the ball is in the first position, a flow path is established between said ends of the lower and upper conduits and said outlet, when the ball is in the second position, a flow path is established between the end of said lower conduit and said outlet and flow is prevented to the end of said upper conduit, and when the ball is in the third position, flow is prevented to said outlet or to said upper conduit from said lower conduit.

11. A valve as claimed in claim 7, 8 of 10 wherein said rotating means includes ball stem means extending through said housing, one end of said ball stem means having coupling means for rotatably coupling said ball stem means to said ball, the other end of said ball stem means extending through the outer wall of said housing, and motive means coupled to the other end of said ball stem for rotating said stem and ball.

12. A valve as claimed in claim 1, wherein each of the upper and lower passages in said housing is open to a chamber in the housing, and said control element means comprises a rotatable ball disposed in said chamber, the ball having an outer part, the outer part having an insert cavity along a central axis of the outer part, the insert cavity having an inner diameter substantially the same as or less than that of the upper passage, and a removable inner part disposed in said insert cavity having an outer diameter substantially the same as that of the insert cavity of the outer part and having a passage through it along said central axis, whereby when said removable inner part is removed from said outer part and said central axis of the outer part is aligned with the upper and lower passages, full diameter access through the insert cavity is provided to the lower passage from the upper passage.



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13. A valve as claimed in claim 1, wherein
said housing has a vertical housing passage and a lateral housing
passage, said vertical and lateral passage intersecting each
other, and said control element means comprises a
5 laterally movable gate disposed in said lateral passage,
said gate having a first lateral portion with a first
gate vertical passage having a diameter substantially
the same as or less than the vertical housing passage,
a second lateral portion having no vertical passage
10 therethrough, and a third lateral portion with a second
gate vertical passage having a diameter smaller than
said first gate vertical passage, whereby, when said
gate is in a lateral position where said first gate
vertical passage is aligned with said vertical housing
15 passage, full diameter access through the vertical
housing passage and the first gate vertical passage is
provided.

14. A valve as claimed in claim 13, including
means for laterally moving said gate in said lateral
20 housing passage between at least two positions: the
first position where said gate is in a lateral position
such that said first gate vertical passage is aligned
with said vertical housing passage and full diameter
access through the vertical housing and the first gate
25 vertical passage is provided, and the second position



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where said gate is in a second lateral position such that said second lateral portion of said gate is aligned with said vertical housing passage and the vertical flow path through the vertical housing passage is closed.

5 15. A valve as claimed in claim 14, including
means for disposing upper and lower conduits in said
vertical housing passage, the upper conduit having
its lower end open to the intersecting lateral passage,
10 the lower conduit having its upper end open to the in-
tersecting lateral passage, and lateral moving
means is adapted to move said gate among said two po-
sitions and a third position: the third position where
said gate is in a lateral position such that said second
gate vertical passage is aligned with the open lower
15 end of the upper conduit and the open upper end of the
lower conduit.

 16. A valve as claimed in claim 15, including
 , at least one lateral outlet in said housing, said
lateral outlet being substantially perpendicular to
20 said vertical housing passage and to said lateral hous-
ing passage and being open to the intersection of the
lateral housing passage and the vertical housing pas-
sage, and the gate further having, a fourth lateral
portion with a gate "L" shaped passage therein, the "L"
25 shaped passage having an opening in the bottom of the
gate and an opening in a side portion of the gate, the
lateral moving means being adapted to move said gate
among said three positions and a fourth position: the
fourth position where said gate is in a lateral position
30 such that said gate "L" shaped passage has its opening
in the bottom of the gate aligned with the upper end of
the lower conduit in the vertical housing passage and
its opening in the side portion of the gate aligned
with the lateral outlet in said housing.

35 17. A valve as claimed in claim 15, including

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two lateral outlets in said housing, said lateral outlets being substantially perpendicular to said vertical housing passage and to said lateral housing passage, each of the outlets being open to the intersection of the lateral housing passage and the vertical housing passage, and the gate further having, a fourth lateral portion with a gate "T" shaped passage therein, the "T" shaped passage having a base passage with an opening in the bottom of the gate and a head passage intersecting the base passage and having opening in the sides of the gate, and the lateral moving means is adapted to move said gate among said three positions and a fourth position: the fourth position where said gate is in a lateral position such that said gate "T" shaped passage has its opening in the bottom of the gate aligned with the upper end of the lower conduit in the vertical housing passage and its openings in the sides of the gate aligned with the respective lateral outlets in the housing.

18. A valve as claimed in claim 1, wherein said housing includes a lateral housing passage, intersecting said upper vertical housing passage and said lower housing passage, and said control element means comprises a laterally movable gate disposed in said lateral passage, said gate having a first lateral portion with a first gate vertical insert cavity, the insert cavity having an inner diameter substantially the same as or less than that of the upper vertical housing passage, and a removable inner part disposed in said insert cavity having an outer diameter substantially the same as that of the insert cavity and having a vertical passage, whereby when said vertical insert cavity of said first lateral portion of said gate is aligned with said upper and lower vertical housing passages, said removable inner part may be removed from or inserted in the insert cavity via the upper vertical housing passage.

19. A valve as claimed in claim 18, including



means for laterally moving said gate in said lateral housing passage between at least two positions: the first position where the vertical passage of the inner part is aligned with the upper and lower vertical housing passages allowing fluid communication between the upper and lower passages of the housing, and the second position where a second lateral portion of the gate having no passage extending through it covers the lower housing passage, thereby closing the flow path from the lower passage to the upper passage of the housing.

20. A valve as claimed in claim 18 or 19, including means for disposing upper and lower conduits, respectively, in said upper and lower vertical housing passages, the upper conduit having its lower end open to the intersecting lateral passage, the lower conduit having its upper end open to the intersecting lateral passage, and whereby in the first position, said inner part is aligned with the upper and lower conduits allowing fluid communication therebetween.

21. A valve as claimed in claim 18, 19 or 20, including at least one lateral outlet in said housing, said lateral outlet being substantially perpendicular to said vertical housing passage and to said lateral housing passage and being open to the intersection of the lateral housing passage and the vertical housing passage, and the gate further having, a third lateral portion with a gate "L" shaped passage therein, the "L" shaped passage having an opening in the bottom of the gate and an opening in a side portion of the gate, the lateral moving means being adapted to move said gate among said first and second positions and a third position: the third position where said gate is in a lateral position such that said "L" shaped passage has its opening in the bottom of the gate aligned with the upper end of the lower conduit in the vertical housing

passage and its opening in the side of the gate aligned with the lateral outlet in said housing.

22. A valve as claimed in claim 18, 19 including two lateral outlets in said housing, said
5 lateral outlets being substantially perpendicular to said vertical housing passage and to said lateral housing passage, each of the outlets being open to the intersection of the lateral housing passage and the vertical housing passage, the gate further having a third lateral
10 portion with a gate "T" shaped passage therein, the "T" shaped passage having a base passage with an opening in the bottom of the gate and a head passage intersecting the base passage and having openings in the sides of the gate, the lateral moving means being
15 adapted to move said gate among said first and second positions and a third position: the third position where said gate is in a lateral position such that said gate "T" shaped passage has its opening in the bottom of the gate aligned with the upper end of the lower
20 conduit in the vertical housing passage and its openings in the sides of the gate aligned with the respective lateral outlets in the housing.

23. A valve as claimed in claim 18, including
25 a second lateral portion with a gate "L" shaped passage therein, the "L" shaped passage having an opening in the bottom of the gate and an opening in a side portion of the gate, and means for laterally moving said gate in said lateral housing passage between at least two positions: the first position where the
30 vertical passage of the inner part is aligned with the upper and lower vertical housing passages allowing fluid communication between the upper and lower passages of the housing, and the second position where said gate is in a lateral position such that said
35 "L" shaped passage has its opening in the bottom of the gate aligned with the upper end of the lower conduit in the vertical housing passage and its opening in the



side of the gate aligned with the lateral outlet in said housing.

24. A valve as claimed in claim 1, wherein
said housing includes a lateral housing passage
5 intersecting said upper vertical housing passage and
said lower housing passage and at least one lateral
outlet in said housing, said lateral outlet being sub-
stantially perpendicular to said vertical housing pas-
sage and to said lateral housing passage and being open
10 to the intersection of the lateral housing passage and
the vertical housing passage, and said control element
means comprises a laterally movable gate disposed in
said lateral passage, said gate having a first lateral
portion with a gate vertical passage having a diameter
15 substantially the same as or less than the upper vertical
housing passage, a second lateral portion with a second
gate vertical passage having a diameter smaller than
said first gate vertical passage, and a third lateral
portion with a gate "L" shaped passage therein, the
20 "L" shaped passage having an opening in the bottom of
the gate and an opening in a side portion of the gate,
whereby, when said gate is in a lateral position where
said first gate vertical passage is aligned with said
vertical housing passage, full diameter access through
25 the vertical housing passage and the first vertical
passage is provided.

25. A valve as claimed in claim 24, including
means for disposing upper and lower conduits in said
vertical housing passage, the upper conduit having its
30 lower end open to the intersecting lateral passage, the
lower conduit having its upper end open to the inter-
secting lateral passage, means for laterally moving said
gate in said lateral housing passage between at least
two positions: the first position where said gate is in





a lateral position such that said first gate vertical passage is aligned with said vertical housing passage and full diameter access through the vertical housing and the first gate vertical passage is provided and the
5 second position where said gate is in a lateral position such that said second gate vertical passage is aligned with the open lower end of the upper conduit and the open upper end of the lower conduit.

26. A valve as claimed in claim 25, wherein
10 the lateral moving means is adapted to move the gate among the two positions and a third position: the third position where said gate is in a lateral position such that said gate "L" shaped passage has its opening in the bottom of the gate aligned with the upper
15 end of the lower conduit in the vertical housing passage and its opening in the side portion of the gate aligned with the lateral outlet in said housing.

27. A valve as claimed in claim 24, 25 or 26 including means for cutting a wireline extending
20 through said upper and lower vertical passages and through said second gate vertical passage upon moving said gate from said second position to said third position.

28. A ball adapted for use in a safety valve, the
25 safety valve having a housing with coaxial lower and upper vertical passages disposed therein and at least one laterally disposed outlet and a chamber disposed between the ends of said outlet and passages, the chamber adapted to accept said ball, wherein the ball comprises
30 an outer part having an insert cavity along a central axis of the outer part with an inner diameter substantially the same as or less than the diameter of

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the upper passage of said housing, said outer part having a perpendicular passage extending from the insert cavity to the exterior of the outer part, and a removable inner part disposed in the insert cavity and having an outer

5 diameter substantially the same as that of the insert cavity of the outer part and having intersecting passages forming a "T" shape, the head passage of the "T" being along said central axis and the base passage of the "T" being aligned with the perpendicular passage of the outer part.

10 29. A production tree for use with an oil and gas well comprising a master valve having a housing having at least one lateral outlet, a vertical upper passage and a vertical lower passage coaxial with said vertical upper passage, each of the outlet and upper and lower passages being open to a chamber in the
15 housing, and a rotatable ball having an outer part with means for seating it within the chamber, said outer part having an insert cavity along a central axis of the outer part, the insert cavity having an inner diameter substantially the same as or less than that of the
20 upper passage, said outer part having a perpendicular passage extending from the insert cavity to the exterior of the outer part, a removable inner part disposed in said insert cavity and having an outer diameter substantially the same as that of the insert cavity of
25 the outer part and having intersecting passages forming a "T" shape, the head passage of the "T" being along said central axis and the base passage of the "T" being aligned with the perpendicular passage of the outer part, the housing of said master valve being
30 connected to the tubing head of the well, means for coupling production tubing landed in the well with the lower passage of said master valve, and control valve means attached to said lateral outlet for controlling fluid flow in the production tubing in the well.



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