United States Patent

[11] 3,581,819

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[54] **PRESSURE EQUALIZING APPARATUS**
29 Claims, 9 Drawing Figs.

[52] **U.S. Cl.** **166/224,** 251/319
[51] **Int. Cl.** **E21b 33/00**
[50] **Field of Search** 166/224; 251/319

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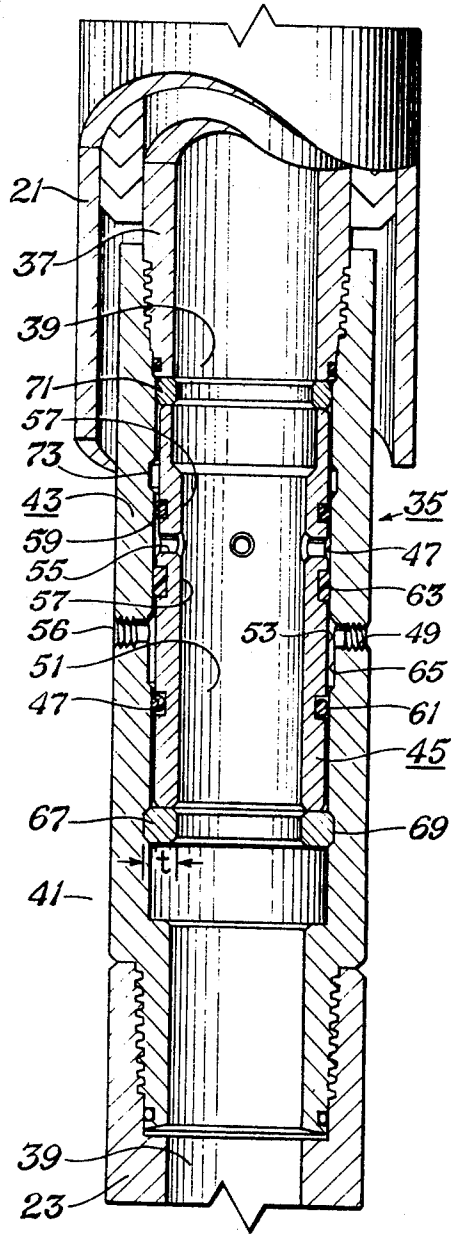
ABSTRACT: Pressure equalizing apparatus characterized by a pressure equalizing device for being left in the well and removable and insertable shifting prong assembly for operating the pressure equalizing device without removing it from the well; the apparatus being adapted to allow any damage done by high differential pressures to be done to seals on the removable shifting prong assembly and prevent any damage to seals on the pressure equalizing device. Specific individual structures are also disclosed.



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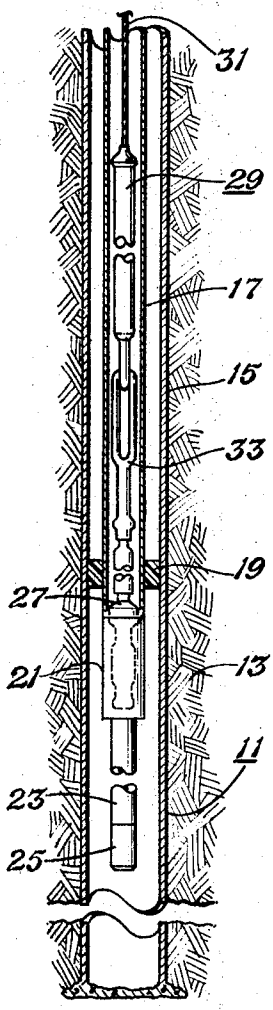

Fig 1

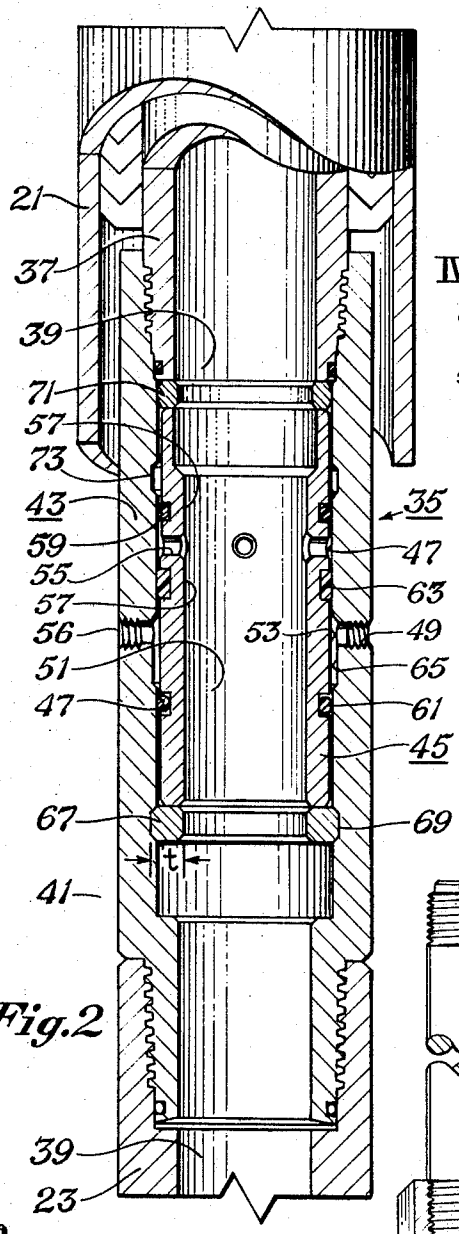

Fig.2

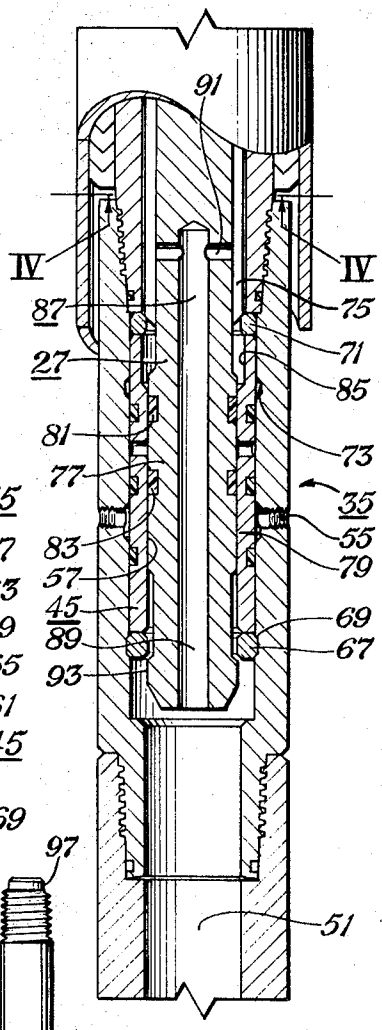

Fig.3

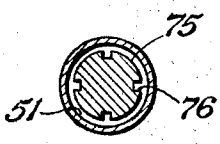

Fig.4

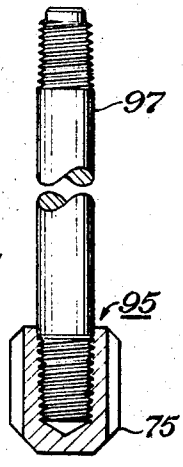

Fig.7

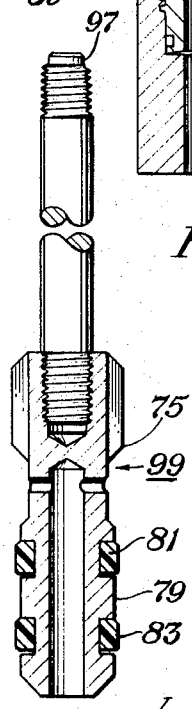

Fig.8

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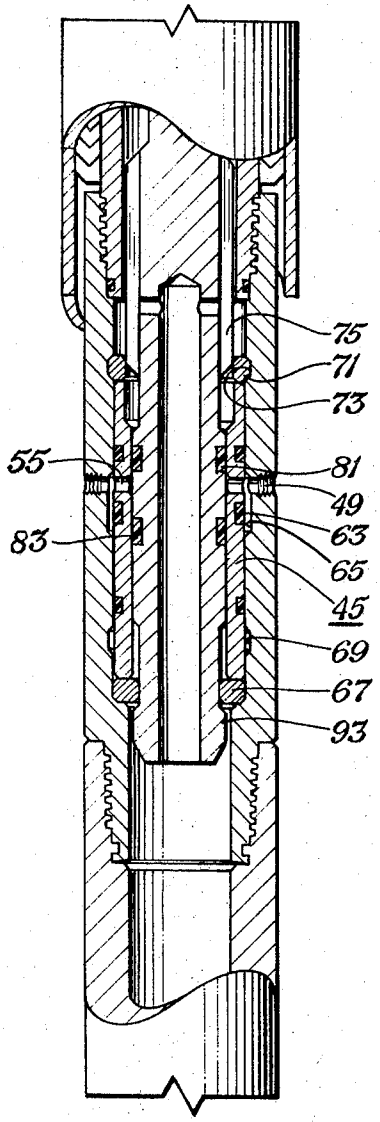

Fig.5

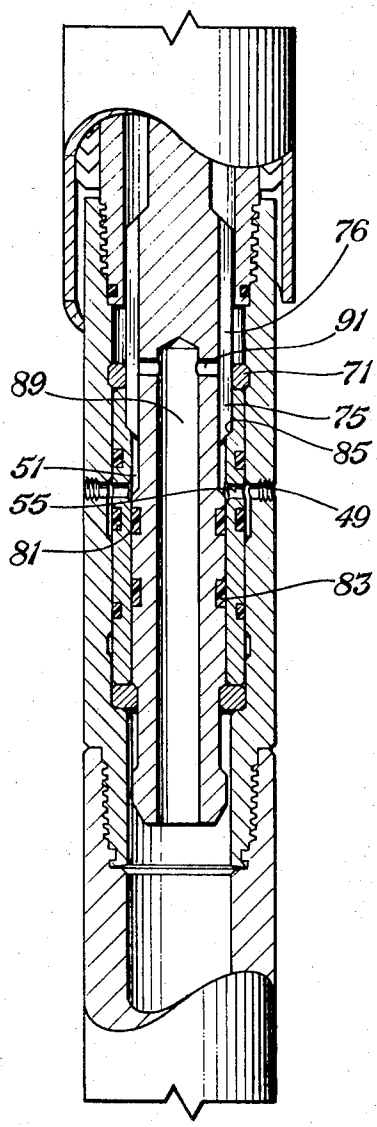

Fig.6

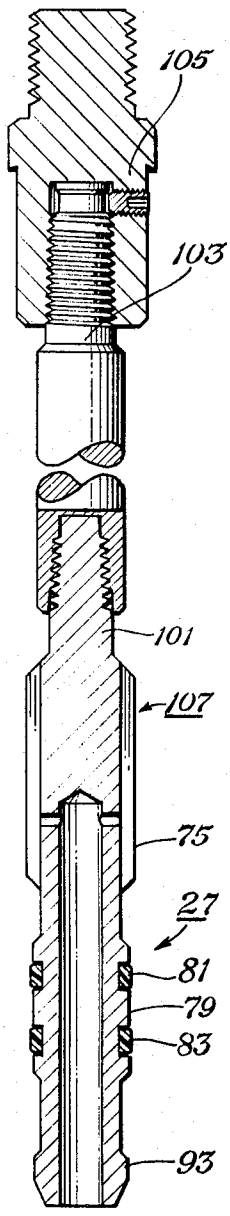

Fig.9

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PRESSURE EQUALIZING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates broadly to well tools; and, more particularly, to a pressure equalizing device connectable in a flow conduit for providing fluid communication between the exterior and interior of the flow conduit, and to a shifting prong assembly for operating the pressure equalizing device.

2. Description of the Prior Art

Many kinds of downhole equipment have been introduced into the oil field for controlling the flow of fluids in completion, production, and workover operations. The flow control devices range from simple plugs such as "bull plugs" to prevent flow to relatively complex shutoff controls for closing and terminating flow from, or "shutting in," a well upon the occurrence of some contingency such as a break in a delivery line and for automatically reopening when downstream pressure is restored. The downhole flow control devices have been employed in conjunction with packers and downhole locking mandrels for retaining the flow control device at the desired depth.

An equalizing device should be run between the locking mandrel and the flow control device for several reasons, including the following: (1) to provide a fluid passage when running the tools into the well and especially with closed flow controls when setting in or passing through landing nipples as there may not be another fluid flow passage therearound; (2) to provide fluid flow passage when pulling the tools from the well; this is particularly useful when passing through landing nipples higher in the well where the flow control has been closed or plugged and it would otherwise be necessary to lift the entire column of fluid above the landing nipple; (3) to equalize the pressure across shutoff controls so as not to be blown up the hole by the pressure differential from below when unlocking and pulling the locking mandrel; and (4) to equalize pressure across and thereby reopen shutoff flow controls; such as, storm chokes or tubing safety valves; when it would be difficult and expensive to inject pressure down the tubing string to equalize the pressure or to pull the flow control.

It is particularly desirable to have a pressure equalizing device that can be run in, operated, or pulled with a wireline instead of the more expensive pulling rigs employing tubing and the like.

In particular, the prior art devices have not provided the following long sought features: (1) a pressure equalizing combination that allows a pressure equalizing device to be installed at any depth in the well and repeatedly operated without having to move a flow control device associated therewith and without having to retrieve the pressure equalizing device and inspect it for damaged seals, (2) a pressure equalizing device whose ports can be completely opened or completely closed by a mandrel in a shifting prong assembly prior to permitting flow across its ports, having the disruptive effects of high velocity fluid flow during the opening pressure differential taken by retrievable seals on the shifting prong assembly without adversely affecting the pressure equalizing device, and (3) a pressure equalizing device having a flow area for equalizing flow of fluid that is variable at the option of the field user for adaptation to a given reservoir or well condition.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial side elevational view, partly in section, illustrating the pressure equalizing apparatus combination in situ in a well penetrating subterranean formations, in accordance with one embodiment of this invention.

FIG. 2 is a partial side elevational view, partly in section, illustrating a pressure equalizing device in the closed position in accordance with one embodiment of this invention.

FIG. 3 is a partial side elevational view, partly in section, illustrating the combination of a shifting prong assembly and the pressure equalizing device in a closed position in accordance with another embodiment of this invention.

FIG. 4 is a partial cross-sectional view along the lines IV–IV of FIG. 3.

FIG. 5 is a partial cross-sectional view illustrating the combination of FIG. 3 after the valve has been opened and before fluid flow is permitted therethrough.

FIG. 6 is a partial cross-sectional view of the embodiment of FIG. 5 after fluid flow is permitted by downward movement of the shifting prong assembly.

FIG. 7 is a partial side elevational view, partly in section, illustrating a simple shifting prong assembly in accordance with one embodiment of this invention.

FIG. 8 is a partial side elevational view, partly in section, illustrating a shifting prong assembly having seals thereon in accordance with another embodiment of this invention.

FIG. 9 is a partial side elevational view, partly in section, of a shifting prong assembly having, in addition to the seals, a bottom shoulder for closing the pressure equalizing device upon withdrawal, in accordance with another embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is a primary object of this invention to provide a combination apparatus and a pressure equalizing device having the desirable features of the prior art devices and also the long sought features delineated hereinbefore and unattainable before this invention. Other specific objects are implicit in structural features delineated hereinafter.

The following descriptive matter describes the preferred embodiment of this invention; namely, a combination pressure equalizing device and shifting prong assembly for use downhole in a well penetrating subterranean formations. Accordingly, the terms "upward" and "downward" are employed in their relative context for that environment. This invention may be useful in other environments in a position other than the vertical position. In such eventuality the terms conveying the same relative direction with respect to the position of the combination would be substituted for upward and downward.

Referring to FIG. 1, well **11** will have been completed in a bore hole penetrating subterranean formation **13**. For example, casing **15** may have been cemented in place in the bore hold by conventional cement circulation techniques, leaving a cement sheath (not shown) around the casing. Inside casing **15** is suspended tubing **17**. The annulus between tubing **17** and casing **15** may be separated into a plurality of zones by one or more packers **19** sealingly emplaced therebetween. Tubing **17** may have a landing nipple **21**, or as referred to more specifically hereinafter an equalizing sub **21**, having a pressure equalizing device held therewithin by a locking mandrel (not shown). The pressure equalizing device may have a lower conduit **23** having a flow control device **25** thereon. The tubing containing the equalizing sub having the pressure equalizing device held in place by locking mandrel therewithin and the desired conduit and flow control device attached thereto may be made up with the string of tubing and run in with the tubing, and the packer **19** set. In another mode of installation, the equalizing sub may be run in with the tubing **17** and the locking mandrel, pressure equalizing device, conduit, and flow control device later run in and set with a running tool on a wireline. In still another mode of installation, the pressure equalizing device may be placed at any depth in the tubing with a locking mandrel that has its own slips and does require a landing nipple, or equalizing sub. These modes of installation are known to the art and do not require detailed description herein.

As illustrated in FIG. 1, a shifting prong assembly **27** is being run into the previously set pressure equalizing device on a conventional wireline tool string **29** suspended and operated from the surface via wireline **31**. Included in wireline tool string **29** are jars **33** for jarring upwardly or downwardly for effecting the requisite force to move the valve within the pressure equalizing device, as described more clearly hereinafter.

Referring to FIG. 2, pressure equalizing device 35 is sealingly secured within equalizing sub 21 by locking mandrel 37. When pressure equalizing device 35 is closed, as illustrated in FIG. 2, there is no fluid communication between the interior 39, and the exterior 41 of the pressure equalizing device 35 and associated conduits such as conduit 23, except by way of flow control device 25.

As long as the well produces normally, there is no need for fluid communication other than through the flow control device 25. As indicated, however, in the event of a broken delivery line, or other event to effect closure of flow control device 25, there is a need to equalize the pressure across the flow control device to prevent having to pull the flow control device to open it when production is ready to be resumed. Rarely will there be adequate pressure at the surface to enable building up a pressure equal to that beneath the flow control device; that is, the pressure at the bottom of the well. Accordingly, it is advantageous if a pressure equalizing device has been installed such that it can be operated into the open position to bypass fluid by means of an economical wireline apparatus. In equalizing the pressure, the well head is shut in, as by closing appropriate valves to the delivery line and the use of a conventional lubricator atop the valve Christmas tree at the well head. As is well known, a conventional lubricator has a seal means through which the wireline may be passed downwardly into the well and a conventional sheave over which the wireline is passed for applying the requisite force by the surface equipment to obtain reciprocal movement of the wireline. FIG. 2 illustrates such a pressure equalizing device 35 that is operable by suitable wireline apparatus.

Specifically, pressure equalizing device 35 comprises a tubular body 43, a tubular valve 45 and suitable holding means and seal means. Tubular body 43 has a first internal longitudinally extending seal surface 47 and a first aperture 49 from the exterior to the interior of the tubular body 43 and intermediate the ends of the seal surface 47.

Tubular valve 45 has a central bore 51 and has an exterior surface 53 conformably positioned adjacent seal surface 47 of the tubular body 43. Valve 45 is movable longitudinally of the tubular body between an open position and a closed position. It has a second aperture 55 from its exterior to its interior. Second aperture 55 is out of communication with first aperture 49 when valve 45 is in the closed position but is movable downwardly with the valve to be brought into fluid communication with first aperture 49 when valve 45 is in the open position. Any number of first and second apertures 49 and 55 may be employed. Ordinarily, there are at least four in a downhole pressure equalizing device. There may be as many as 13 or more around the periphery of the respective tubular body 43 or valve 45. Desirably, the first apertures 49 are located in substantially the same transverse plane and the second apertures 55 are also coplanar. It has been found particularly advantageous in one embodiment of this invention to employ more apertures than needed in high pressure wells; for example, wells having a pressure in excess of 3,000—5,000 pounds per square inch gauge; and to employ plugs 56 to seal off one or more of the first apertures 49 in the tubular body 43 when used in high pressure wells and restrict the high flow rates under the high differential pressures. To prevent inadvertently plugging all of the first apertures 49, one or more will have a structure; such as, smooth, or unthreaded, walls that are not adapted to receive the sealing plugs. This option is referred to as the "field option," enabling the user to equalize pressure rapidly in any particular field and adjust the pressure equalizing device to a particular field and a particular reservoir in which it is being employed.

Valve 45 also has a second internal seal surface 57 defining a portion of the central bore 51 and extending along the longitudinal axis of the bore on both sides of second aperture 55. The seal surface is adapted for receiving a pair of respective seal means on a mandrel inserted in the bore for sealing off the second aperture until the valve is fully opened or fully closed, as described in detail hereinafter.

First seal means comprising seals 59 and 61 are peripherally disposed on the exterior of valve 45, on both sides of first aperture 49, and intermediate tubular body 43 and valve 45. The first seal means thus isolates the first aperture 49, and prevents fluid communication longitudinally between valve 45 and tubular body 43.

Second seal means 63 is disposed peripherally about valve 45 so as to be intermediate the first and second apertures 49 and 55 and intermediate the tubular body 43 and valve 45 for preventing fluid communication between the first and second apertures 49 and 55 when the valve 45 is in the closed position. A passageway 65 is provided in tubular body 43 adjacent first aperture 49 for nonsealingly receiving the second seal means when the first and second apertures are moved into fluid communication, as in the open position of the valve. Passageway 65 and its nonsealing relationship with second seal means 63 allows any fluids trapped below first aperture 49 to be vented therefrom and facilitates longitudinal movement of valve 45 with respect to tubular body 43. Otherwise, the valve 45 may be difficult to move in high pressure installations.

A first holding means comprising snap ring 67 and annular recess 69 releasably holds valve 45 in the closed position. The first holding means is movable with the valve 45 to and from the closed position and is operable to impose an obstruction in the central bore 51 when moved from the closed position. Specifically, snap ring 67 has a first thickness t and predetermined internal and external diameters when it is conformingly received in conforming recess 69 in tubular body 43 in the closed position. When moved from the closed position, as by being moved out of recess 69 and downwardly within central bore 51, snap ring 67 retains its thickness but has a smaller internal and external diameter because the ends are compressed toward each other when it is moved from the recess. Thus, the smaller internal diameter imposes a restriction within central bore 51. Snap ring 67 is movable longitudinally of tubular body 43 when sufficient force is applied thereto parallel with the longitudinal axis of the body. It is advantageous if the valve and snap ring are so positioned that the force is applied by valve 45 to move snap ring 67 downwardly from recess 69.

A second holding means comprising second snap ring 71 and second annular recess 73 releasably hold valve 45 in the open position. The second holding means is movable with valve 45 to and from the open position and is operable to impose an obstruction in central bore 51 when moved from the open position. Specifically, second snap ring 71 has a predetermined internal and external diameter when conformingly received in conforming annular recess 73 and has a smaller internal and external diameter when displaced from annular recess 73, as illustrated in FIG. 2. Second snap ring 71 has a thickness less than the thickness t for reasons which will be explained hereinafter in connection with the passage of a shifting prong assembly within the pressure equalizing device. Second snap ring 71 is movable from annular recess 73 and longitudinally of tubular body 43 when sufficient force is applied thereto parallel with the longitudinal axis of tubular body 43. Advantageously the valve 45 and second snap ring 71 are so positioned that the force to move second snap ring 71 from recess 73 is applied via valve 45.

The following descriptive matter with respect to FIGS. 3—6 show a combination including the embodiment of FIGS. 1 and 2 in stages of operation via a shifting prong assembly inserted within pressure equalizing device 35. Referring to FIG. 3, the pressure equalizing device 35 is composed of the same structural elements described hereinbefore with respect to FIG. 2; namely, the tubular body 43, the tubular valve 45, and the respective seal means and holding means. In addition, a shifting prong assembly 27 is inserted therewithin. Shifting prong assembly 27 has a shoulder portion 75 adapted to operationally engage the second holding means, or, more specifically, the second snap ring 71, to move it into the open position in which the second snap ring 71 is conformingly received in annular recess 73. As can be seen in FIG. 4, shoulder por-

tion 75 defines a fluid passageway 76 intermediate mandrel 77 and the wall of the central bore 51.

In instances where the pressure equalizing device is to be pulled from the well, a simple shifting prong assembly employing only shoulder 75 to open pressure equalizing device 35 may be all that is required. As illustrated, however, the pressure equalizing device will not be pulled from the well but will be shifted to equalize the pressure and allow the shut in flow control 25, FIG. 1, to reopen for normal production operations. Accordingly, the shifting prong assembly 27 also has a mandrel 77 that supports shoulder portion 75 and that has a seal portion 79 that conforms to, and is movable longitudinally of central bore 51 adjacent, the internal seal surface 57 of valve 45. The shifting prong assembly 27 has a seal means such as a pair of seal means 81 and 83 disposed peripherally about the seal portion 79 and spaced from the shoulder portion so as to be disposed on both sides of second aperture 55 when the shoulder portion 75 operationally engages the second holding means, or second snap ring 71. This spacing allows sealing off the apertures before valve 45 is moved into the open position.

The central bore 51 of valve 45 has an annular recess 85 for receiving shoulder portion 75 of mandrel 77. Annular recess 85 is deep enough so as to allow shoulder portion 75 to pass downwardly a distance sufficient to position the pair of seal means 81 and 83 below second aperture 55 when shoulder portion 75 is fully received in recess 85, FIG. 6. As will be apparent, shoulder portion 75 is prohibited from entering into recess 85 by second snap ring 71 as long as valve 45 is not in the open position. Once second snap ring 71 and valve 45 have been moved downwardly into the open position, the ends of second snap ring 71 move apart as it expands to be conformingly received by second annular recess 73. The resulting increased internal diameter allows shoulder portion 75 to pass through second snap ring 71. Thereafter, shoulder portion 75 can be fully received within recess 85 so that its bottom end is contiguous the bottom end of recess 85. Shoulder portion 75 thus must have a diameter larger than the internal diameter of second snap ring 71 when second snap ring 71 is in any position other than the open position in which it is conformingly received by second annular recess 73; and must be small enough to pass within second snap ring 71 when received by second annular recess 73. Similarly, recess 85 must have a diameter large enough to receive the shoulder portion 75.

A fluid flow passageway 87 comprising longitudinal passageway 89 and transverse aperture 91 communicates through the mandrel 77 with the regions above and below the pair of seal means 81 and 83 to prevent trapping pressure in either region.

As illustrated, shifting prong assembly 27 also has a second shoulder portion 93 that is adapted to pass through central bore 51, past the first holding means when the first holding means and the valve are in the closed position and not to be moved past the first holding means when it is in any other position; such as, when snap ring 67 is moved from annular recess 69. Expressed otherwise, second shoulder 93 has an external diameter less than the internal diameter of snap ring 67 when snap ring 67 is expanded into annular recess 69 but larger than the internal diameter of snap ring 67 when it is moved from annular recess 69 into the smaller internal diameter of tubular body 43 below annular recess 69. Second shoulder 93 has an external diameter that will pass downwardly past second snap ring 71 in any position. Even with the same diameter recesses, second snap ring 71 has a larger internal diameter than snap ring 67, since second snap ring 71 has a thickness less than the thickness t of snap ring 67. Thus, second shoulder portion 93 may pass downwardly through both holding means and through internal bore 51 within valve 45 so as to be positioned on the side of the first holding means opposite the second holding means when the shoulder portion 75 operationally engages the second holding means, in the form of second snap ring 71. Once the first holding means has been displaced into any other position, as by valve 45 being opened, second shoulder 93; and, consequently, shifting prong assembly 27; may not be withdrawn from the pressure equalizing device without moving snap ring 67 upwardly into the closed position, correspondingly moving valve 45 into the closed position. This is a desirable feature in normal operations since it insures that the pressure equalizing device is always closed when a shifting prong assembly is withdrawn and forms a particularly preferred embodiment of this invention.

In this particularly preferred embodiment, the second shoulder portion 93 and the pair of seal means 81 and 83 are relatively spaced on mandrel 77 such that the pair of seal means are disposed along both sides of second aperture 55 when the second shoulder portion 93 operationally engages the first holding means in the form of snap ring 67 for moving the valve to the closed position. This spacing allows sealing off the aperture before valve 45 is moved into the closed position.

Means is provided for operating the shifting prong assembly. The means may comprise the wireline tool string 29 incorporating jars 33 for upward or downward application of force to operate the valve by "jarring." Other means such as electrically driven jars on wireline or even a "spaghetti string" of tubing or rod may be employed, if desired.

In operation shifting prong assembly 27 is lowered into the well and into central bore 51 of pressure equalizing device 35 as described in connection with FIG. 1. It is lowered until shoulder portion 75 engages second snap ring 71. At this point further downward movement is impeded by first holding means comprising snap ring 67 in annular recess 69. Accordingly, it is necessary to apply a force downwardly via shoulder 75, second snap ring 71, and valve 45 to move snap ring 67 from annular recess 69. Accordingly, jars 33 are operated to apply the requisite downward jarring force. Upon the application of sufficient force via valve 45, snap ring 67 is displaced downwardly from annular recess 69 into the open position, as illustrated in FIG. 5. Second snap ring 71 is moved into second annular recess 73 and valve 45 is in the open position with second aperture 55 adjacent and in fluid communication with first aperture 49. The pair of seals 81 and 83 still prevent fluid flow therethrough, however. In the open position, second snap ring 71 increases its internal diameter when it expands into second annular recess 73, allowing shoulder portion 75 to pass downwardly therethrough. It is noteworthy that in this open position, second seal means 63 is passed into nonsealing passageway 65, which allows fluid flow therearound and prevents trapping of pressure therebelow. Damage to the seals in the pressure equalizing device during opening is prevented, since no flow is permitted as yet.

The shifting prong assembly 27 is moved further downwardly, as shown in FIG. 6, to allow fluid to flow through first and second apertures 49 and 55, and between the interior and the exterior of the pressure equalizing device and its related conduits and flow control. Specifically, shoulder portion 75 passes downwardly through second snap ring 71 until it is fully received in annular recess 85. The pair of seal means 81 and 83 are moved on the same side of second aperture 55, which is in the fluid communication with first aperture 49. Fluid can flow upward longitudinally along central bore 51 between the shifting prong assembly and the wall of central bore 51, via fluid flow passageway 76 to the region above the pair of seal means 81 and 83. Fluid may flow by transverse aperture 91 and longitudinal aperture 89 to the region below the pair of seal means 81 and 83. Consequently, the pressure is equalized on both sides of the flow control device 25, FIG. 1, allowing the flow control device 25 to reset itself to the open position for normal production operations. Thus, it can be seen that any damage done by the high velocity flow of the fluid under the high initial differential pressure will be taken by the seal means such as seal means 81 on the shifting prong assembly 27. The shifting prong assembly will be removed from the well and the seal means may be readily inspected and replaced if necessary. No damage is sustained by seals on valve 45 since it is fully open before any fluid flow is allowed.

Should trouble develop during equalization of the pressure, the shifting prong assembly may be moved upwardly to position the pair of seal means **81** and **83** on both sides of second aperture **55** to stop the inward flow of fluid until the trouble can be corrected. Then the shifting prong can be moved downwardly to finish equalizing the pressure.

Once the pressure has been equalized it is desirable to remove the shifting prong assembly and to close the pressure equalizing device for normal production operations. Accordingly, the shifting prong assembly is moved upwardly until second shoulder portion **93**, FIG. **5**, operationally engages snap ring **67** of the first holding means. At this point, the pair of seal means **81** and **83** are disposed on both sides of second aperture **55** and prevent further fluid flow therethrough. Also, further upward movement is impeded by second holding means comprising second snap ring **71** conformingly received in second annular recess **73**. Accordingly, it is necessary to apply an upward jarring force by jars **33** to displace second snap ring **71** from second annular recess **73**. The upward force is applied via second shoulder means **93**, snap ring **67**, and valve **45**. Specifically, second shoulder **93** applies the force directly to snap ring **67** to move it toward the closed position, just as shoulder portion **75** applied the force directly to second snap ring **71** to move it toward the open position.

When sufficient force has been applied to displace second snap ring **71** from second annular recess **73**, snap ring **67** is moved upwardly and into annular recess **69**, closing valve **45** in pressure equalizing device **35**, as illustrated in FIG. **3**, and allowing second shoulder portion **93** to be passed upwardly through central bore **51**. Thus, it can be seen that with this embodiment, the shifting prong assembly cannot be moved from within the pressure equalizing device without closing the pressure equalizing device. Thereafter, the shifting prong assembly and the wireline running tool are removed from the pressure equalizing device, as illustrated in FIG. **2**.

While the preferred embodiment and its operation has been described in detail hereinbefore, other embodiments may be employed. In this regard it is believed instructive to look at various embodiments of the shifting prong assembly which may be employed to effect opening of the pressure equalizing device.

A simple embodiment of the shifting prong assembly comprises pulling prong assembly **95**, illustrated in FIG. **7**. Pulling prong assembly **95** has a shoulder portion **75** for engaging second snap ring **71** to move valve **45** downwardly into the open position. Pulling prong assembly **95** provides no valve seal protection and is ordinarily employed only when the pressure equalizing device **35** is to be pulled from the well. Pulling prong assembly **95** has an upper shaft **97** which is adapted to be connected to the bottom of a conventional pulling tool, connected to the bottom of a conventional wireline tool string (not shown).

A similar pulling prong assembly **99** is illustrated in FIG. **8**. Pulling prong assembly **99** has shoulder portion **75** and also has seal portion **79** with the pair of seal means **81** and **83** thereon. Pulling prong assembly **99** is also employed when the pressure equalizing device is to be left open as when it is being pulled from the well. The provision of the seal surface and the pair of seal means enable protecting the seals on the valve **45** of the pressure equalizing device **35** during the equalizing of the pressure. Shifting prong assembly **99** also has a shaft **97** adapted for being similarly connected with a pulling tool (not shown).

Shifting prong assembly **27**, described hereinbefore is illustrated in FIG. **9**. FIG. **9** illustrates the shoulder **75**, seal portion **79**, pair of seal means **81** and **83** and second shoulder portion **93** without the pressure equalizing device therearound. The specific relationships between the parts has been described hereinbefore and need not be repeated. Shifting prong assembly **27** has shafts **101** and **103** for positioning it at a desired length with respect to an adapter **105** that is connected, as by threaded connection, to the bottom of a conventional wireline tool string **29**, FIG. **1**. Shifting prong assembly **27** is ordinarily employed to operate the pressure equalizing device **35** into an open position for equalizing of pressure temporarily and then closing pressure equalizing device **35** as the shifting prong assembly **27** is withdrawn from the well. The lower portion **107** from shaft **101** downwardly may be employed as a running prong assembly. Portion **107** employed as a running prong assembly is usually attached to the bottom of a suitable conventional running tool, such as a wireline running tool, being used to run the locking mandrel with the pressure equalizing device attached, into and securing it within equalizing sub **21**, FIG. **1**. As indicated hereinbefore, it is desirable to run the combination of locking mandrel, pressure equalizing device, associated conduit and flow control device into the well with the pressure equalizing device in the open position. Thus, portion **107** may be employed in either the shifting prong assembly or the running prong assembly, since they will have the same length and relationship in each case. When attached to the bottom of the running tool running the locking mandrel within the equalizing sub, the valve **45** is maintained in the open position until the running tool is sheared off the locking mandrel. When the running tool is sheared off the locking mandrel, the pulling prong assembly is withdrawn from the pressure equalizing device, positively closing valve **45**, as described hereinbefore with respect to shifting prong assembly **27**.

Various embodiments of the respective holding means may be employed, also. For example, one may employ as the holding means pivotal members that will impose an obstruction within central bore **51** when the respective shoulder portions of the shifting prong assembly, in either of its embodiments, is moved therepast.

Any of the conventional and satisfactory seals may be employed for the respective seals or seal means. For example, O-rings, cylindrical seals, and the varieties of packing such as vee packing may be employed in a conventional manner. Ordinarily, the better and more permanent seals are employed on valve **45** since it will remain in position in the well for prolonged intervals; whereas, more economical seals may be employed on the shifting prong assembly. The materials employed in the seals should resist the fluids in the well bore. For example, most wells produce hydrocarbon fluids, and the materials of which the seals are made should be hydrocarbon resistant material such as synthetic rubber like Neoprene or Hycar, or plastic.

From the foregoing descriptive matter it will be seen that this invention enables, for the first time, users of wireline production equipment to employ a pressure equalizing device that will satisfy the objects and provide all of the features delineated hereinbefore. Specifically, this invention has the following features and advantages:

1. a valve that can be shifted into the open or closed position in the pressure equalizing device by a suitable shifting prong assembly before any flow is permitted through its apertures; in this way, the opening pressure differential is taken by retrievable seals on the shifting prong assembly and not by the seals on the pressure equalizing device itself. This enables the user to employ a simple, fast, inexpensive wireline operation to reopen shut-in devices such as storm chokes; provides improved safety, and ensures fewer leaking flow controls;
2. a larger number of apertures than may be necessary with plugs for plugging some of them enables the user to have a variable flow area through the ports by using plugs in one or more of the apertures in the tubular body of the pressure equalizing device; thereby adjusting the flow area to individual well conditions to allow faster equalizing in some wells and lower volume rate of flow in certain high pressure wells; providing faster wireline jobs with less waiting time for wells to equalize; and enabling viscous fluids to flow into and equalize the pressure between the various regions;
3. a sleeve valve that can be forcibly shifted in either direction, having positive opening and closing, and enabling repeated use with the assurance that the valve

can always be opened or closed; since there are no buttons to erode away, since positive opening or closing action is effected before fluid flow is obtained, and since the valve is positively closed when the shifting prong assembly is withdrawn; and

4. the pressure equalizing device is corrosion resistant and can be run is sweet or sour wells, wells containing hydrogen sulfide.

The pressure equalizing devices of this invention may also be employed in other ways; for example, a similar tool could be made in tubing dimensions and run as a part of the tubing string and the valve could be opened or closed with a shifting prong assembly providing a downhole circulating device with the same degree of seal protection and other advantages as described for the pressure equalizing device.

Although the invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention.

What I claim is:

1. A combination of a pressure equalizing device and shifting prong assembly comprising:

a. a tubular body having a first internal longitudinally extending seal surface and a first aperture from the exterior to the interior of said tubular body intermediate the ends of said seal surface;

b. a tubular valve having a central bore and having an exterior surface conformably positioned adjacent said seal surface; said valve being movable longitudinally of sad tubular body between an open position and a closed position, and having a second aperture located so as to be in fluid communication with said first aperture when said valve is in the open position and out of fluid communication with said first aperture when said valve is in the closed position; said valve further having a second internal seal surface defining a portion of said central bore and extending along the longitudinal axis of said bore on both sides of said second aperture for receiving a seal means on a mandrel inserted in said bore for sealing off said second aperture until said valve is fully opened;

c. first seal means disposed on both sides of said first aperture and intermediate said tubular body and said valve for isolating said first aperture from regions above and below said first seal means;

d. second seal means disposed intermediate said first and second aperture and intermediate said tubular body and said valve for preventing fluid communication between said first and second apertures when said valve is in the closed position;

e. first holding means releasably holding said valve in the closed position, movable with said valve to and from the closed position, and operable to impose an obstruction in said bore when moved from the closed position;

f. second holding means releasably holding said valve in the open position, movable with said valve to and from the open position, and operable to impose an obstruction in said bore when moved from the open position;

g. a shifting prong assembly comprising a mandrel having a shoulder portion adapted to move said second holding means to the open position; and

h. means for operating said shifting prong assembly.

2. The combination of claim 1 wherein said means for operating said shifting prong assembly includes a wireline operable tool and wireline connected with said shifting prong assembly and with surface equipment and adapted to effect operation of said shifting prong assembly.

3. The combination of claim 1 wherein said tubular body has a passageway adjacent said first aperture for nonsealingly receiving said second seal means when said first and second apertures are moved into fluid communication.

4. The combination of claim 1 wherein said first and second holding means comprise respective snap rings adjacent the ends of said valve and respective annular recesses in said tubular body positioned and formed to conformingly receive respective said snap rings when said valve is in the respective closed and open positions, said snap rings being movable from respective said annular recesses and longitudinally of said tubular body when sufficient force is applied thereto parallel with the longitudinal axis of said tubular body.

5. The combination of claim 4 wherein said force to move respective said snap rings from respective said annular recesses is applied via said valve.

6. The combination of claim 5 wherein the force serving to move said snap ring toward and into said respective annular recess is applied via said shoulder portion of said shifting prong assembly.

7. The combination of claim 1 wherein said second holding means comprises a snap ring adjacent the upper end of said valve and an annular recess in said tubular body positioned and formed to conformingly receive said snap ring when said valve is in the open position, said snap ring being movable longitudinally of said tubular body and to and from said annular recess when sufficient force is applied thereto parallel with the longitudinal axis of said tubular body and said shoulder portion of said shifting prong assembly is adapted to engage and move said snap ring and hence said valve downwardly into said open position.

8. The combination of claim 1 wherein said shifting prong assembly also has on said mandrel a seal portion conforming to and movable longitudinally of said bore adjacent said internal seal surface of said valve, and has a seal means disposed about said seal portion and spaced from said shoulder portion so as to be disposed on both sides of said second aperture when said shoulder portion operationally engages said second holding means, and a fluid flow passageway through said mandrel communicating above and below said seal means.

9. The combination of claim 8 wherein said valve bore has an annular recess for receiving said shoulder portion of said mandrel; said annular recess being deep enough to position said seal means below said second aperture when said shoulder portion of said mandrel is fully received in said annular recess.

10. The combination of claim 8 wherein said shifting prong assembly also has on said mandrel a second shoulder portion that is adapted to pass through said bore and past said first holding means when said first holding means and said valve are in closed position and not to be moved past said first holding means when said first holding means is in any other position, said second shoulder portion being spaced on said mandrel so as to be on the side of said first holding means opposite said second holding means when said shoulder portion operationally engages said second holding means.

11. The combination of claim 10 wherein fluid flow through said second aperture is blocked by said seal means and said first and second holding means are disposed intermediate said shoulder and said second shoulder in any position other than the closed or open position; and said holding means impose respective obstructions in said bore, thereby requiring movement of said valve with said mandrel into either the closed or open position.

12. The combination of claim 10 wherein said first holding means comprises a first snap ring of a first thickness adjacent the lower end of said valve and an annular recess in said tubular body positioned and formed to conformingly receive said first snap ring when said valve is in the closed position and said second holding means comprises a second snap ring of a second thickness thinner than said first thickness adjacent the upper end of said valve and an annular recess in said tubular body positioned and formed to conformingly receive said second snap ring when said valve is in the open position, said snap rings being movable longitudinally of said tubular body and to and from respective said annular recesses when sufficient force is applied thereto parallel with the longitudinal axis

of said tubular body; and said second shoulder portion is adapted to pass through said bore and past said second holding means in any position; said bore has an annular recess for receiving said shoulder portion of said mandrel; said annular recess, said shoulder portion, and said seal means being relatively spaced such that said seal means are below said second aperture when said valve is in the open position and said shoulder portion is fully received in said annular recess.

13. The combination of claim 10 wherein said seal means on said seal portion and said second shoulder portion are spaced on said mandrel with respect to each other such that said seal means are disposed on both sides of said second aperture when said second shoulder portion operationally engages said first holding means for moving said valve to the closed position.

14. A pressure equalizing device comprising:

a. a tubular body having a first internal longitudinally extending seal surface and a first aperture from the exterior to the interior of said tubular body intermediate the ends of said seal surface;

b. a tubular valve having a central bore and having an exterior surface conformably positioned adjacent said seal surface; said valve being movable longitudinally of said tubular body between an open position and a closed position, and having a second aperture located so as to be in fluid communication with said first aperture when said valve is in the open position and out of fluid communication with said first aperture when said valve is in the closed position; said valve further having a second internal seal surface defining a portion of said central bore and extending along the longitudinal axis of said bore on both sides of said second aperture for receiving a seal means on a mandrel inserted in said bore for sealing off said second aperture until said valve is fully opened;

c. first seal means disposed on both sides of said first aperture and intermediate said tubular body and said valve for isolating said first aperture from regions above and below said first seal means;

d. second seal means disposed intermediate said first and second aperture and intermediate said tubular body and said valve for preventing fluid communication between said first and second apertures when said valve is in the closed position;

e. first holding means releasably holding said valve in the closed position, movable with said valve to and from the closed position, and operable to impose an obstruction in said bore when moved from the closed position; and

f. second holding means releasably holding said valve in the open position, movable with said valve to and from the open position, and operable to impose an obstruction in said bore when moved from the open position.

15. The pressure equalizing device of claim 14 wherein said tubular body has a passageway adjacent said first aperture for nonsealingly receiving said second seal means when said first and second apertures are moved into fluid communication.

16. The pressure equalizing device of claim 14 wherein said first and second holding means comprise respective snap rings adjacent the ends of said valve and respective annular recesses in said tubular body positioned and formed to conformingly receive respective said snap rings when said valve in is the respective closed and open positions, said snap rings being movable from respective said annular recesses and longitudinally of said tubular body when sufficient force is applied thereto parallel with the longitudinal axis of said tubular body.

17. The pressure equalizing device of claim 16 wherein said force to move respective said snap rings from respective said annular recesses is applied via said valve.

18. The pressure equalizing device of claim 14 wherein said bore has an annular recess for receiving a shoulder portion of a mandrel being inserted in said valve; said annular recess being deep enough to position any seal means on the mandrel below said second aperture when the shoulder portion of the mandrel is fully received therein.

19. The pressure equalizing device of claim 14 wherein said tubular body has a plurality of first apertures therein and wherein sealing plugs are provided to fit said first apertures whereby the number of first apertures may be decreased in high pressure wells at the option of the field user.

20. The pressure equalizing device of claim 19 wherein at least one of said plurality of first apertures has a structure that is not adapted to receive said sealing plugs thereby preventing inadvertently plugging all of said first apertures.

21. The pressure equalizing device of claim 14 wherein said first holding means comprises a snap ring adjacent the lower end of said valve and an annular recess in said tubular body portion and formed to conformingly receive said snap ring being movable longitudinally of said tubular body and to and from said annular recess when sufficient force is applied thereto parallel with the longitudinal axis of said tubular body.

22. The pressure equalizing device of claim 14 wherein said second holding means comprises a snap ring adjacent the upper end of said valve and an annular recess in said tubular body portion and formed to conformingly receive said snap ring when said valve is in the open position, said snap ring being movable longitudinally of said tubular body and to and from said annular recess when sufficient force is applied thereto parallel with the longitudinal axis of said tubular body.

23. A combination of a pressure equalizing device and shifting prong assembly comprising:

a. a tubular body having a first internal longitudinally extending seal surface and a first aperture from the exterior to the interior of said tubular body intermediate the ends of said seal surface;

b. a tubular valve having a central bore and having an exterior surface conformably positioned adjacent said seal surface; said valve being movable longitudinally of said tubular body between an open position and a closed position, and having a second aperture located so as to be in fluid communication with said first aperture when said valve is in the open position and out of fluid communication with said first aperture when said valve is in the closed position; said valve further having a second internal seal surface defining a portion of said central bore and extending along the longitudinal axis of said bore on both sides of said second aperture for receiving a seal means on a mandrel inserted in said bore for sealing off said second aperture until said valve is fully opened;

c. a shifting prong assembly including a mandrel having a means of engagement for moving said valve longitudinally of said tubular body between a closed position and an open position; said mandrel having a seal means adapted to sealingly engage said second internal seal surface and positionable to effect a seal on both sides of said second aperture in said valve and prevent flow through said second aperture; said shifting prong assembly, after engagement with said valve in said pressure equalizing device, being adapted to travel a greater longitudinal distance in said tubular body than the longitudinal distance traveled by said valve for moving said seal means so as to permit flow through said second aperture after said tubular valve is in the open position.

24. The combination of claim 23 wherein said pressure equalizing device includes:

a. first seal means disposed on both sides of said first aperture and intermediate said tubular body and said valve for isolating said first aperture from regions above and below said first seal means; and

b. second seal means disposed intermediate said first and second aperture and intermediate said tubular body and said valve for preventing fluid communication between said first and second apertures when said valve is in the closed position.

25. The combination of claim 24 wherein said pressure equalizing device also includes first holding means releasably holding said valve in the closed position, movable to and from the closed position, and operable to impose an obstruction in said bore when moved from the closed position.

26. The combination of claim 25 wherein a second holding means is provided for releasably holding said valve in the open position, movable to and from the open position, and having an internal diameter small enough to engage said shifting prong assembly so as to effect downward movement of said valve with downward movement of said shifting prong assembly for travel longitudinally within said tubular body and operable to increase its internal diameter to allow said shifting prong assembly to pass downwardly therethrough when moved into the open position.

27. The combination of claim 24 wherein said tubular body has a passageway adjacent said first aperture for nonsealingly receiving said second seal means when said first and second apertures are moved into fluid communication.

28. The combination of claim 23 wherein said tubular body has a plurality of first apertures therein and wherein sealing plugs are provided to fit said first apertures whereby the number of first apertures may be decreased in high pressure wells at the option of the field user.

29. The combination of claim 28 wherein at least one of said plurality of first apertures has structure that is not adapted to receive said sealing plugs thereby preventing inadvertently plugging all of said first apertures.