

[54] **METHOD AND APPARATUS FOR CONTROLLING AN OFFSHORE WELL**

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[52] U.S. Cl.166/.5, 30/97, 166/55

[51] Int. Cl.E21b 29/00, E21b 33/06

[58] Field of Search.....166/55, 55.6, .5, .6, 315, 166/93; 30/94-97; 251/1

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Primary Examiner—David H. Brown

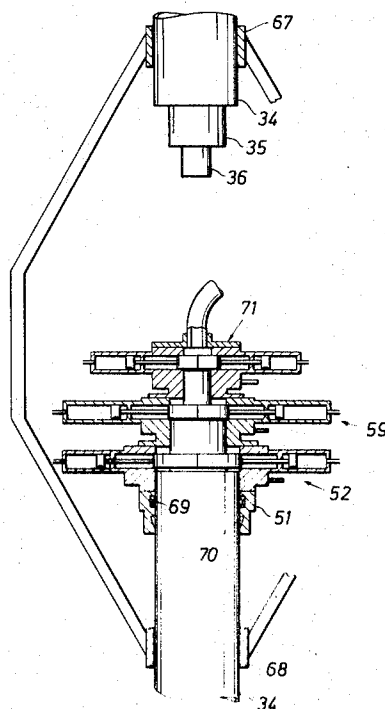
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[57] **ABSTRACT**

An improved system and method for bringing uncontrolled offshore wells under control is disclosed and includes subsurface bifurcated equipment for attachment to the pipe strings. The equipment includes a supporting frame which isolates a section of pipe from upper and lower sections. The isolated section of pipe and interior pipes are successively sealed off, cut away and sealed off to prevent any loss of fluid. Control fluids are injected into the closed off pipe strings to bring the well under control.

38 Claims, 30 Drawing Figures



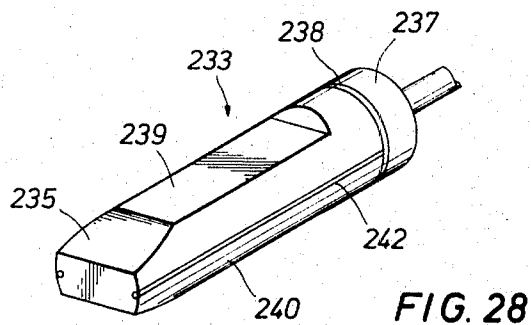
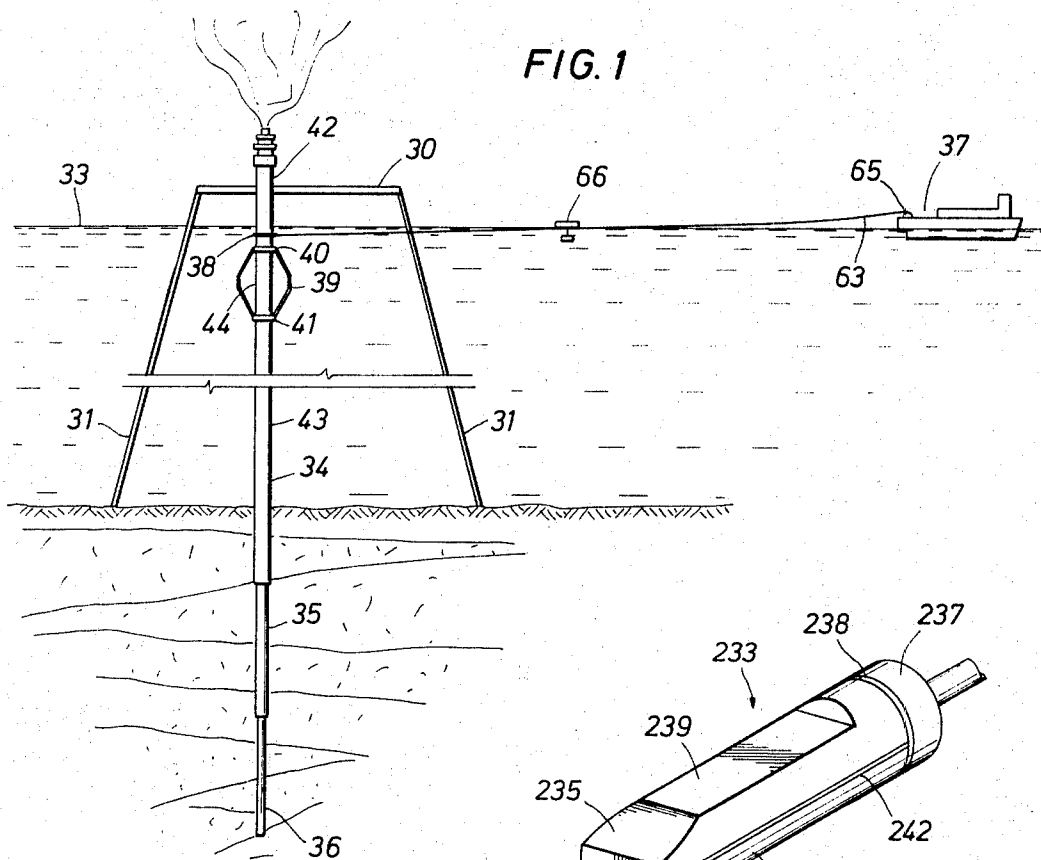


FIG. 29

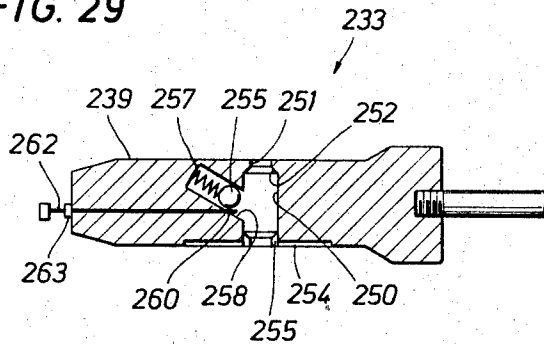
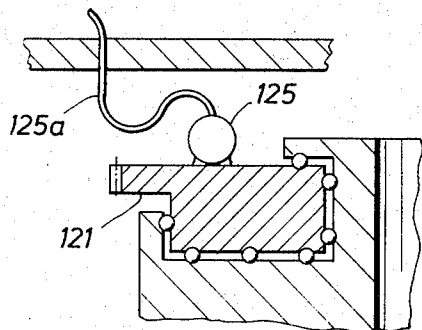
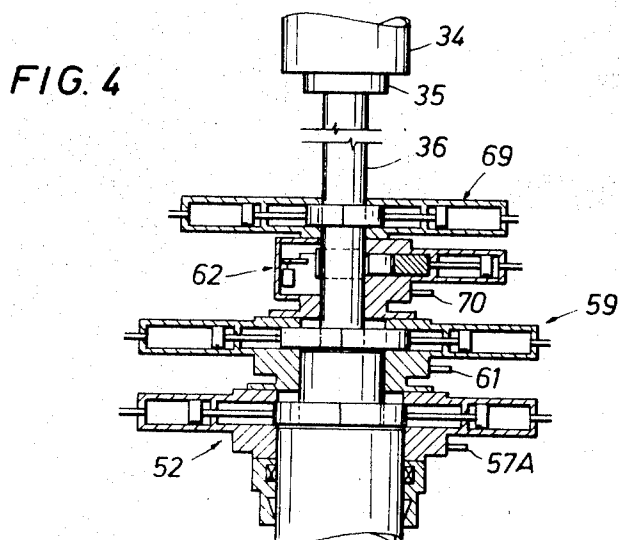
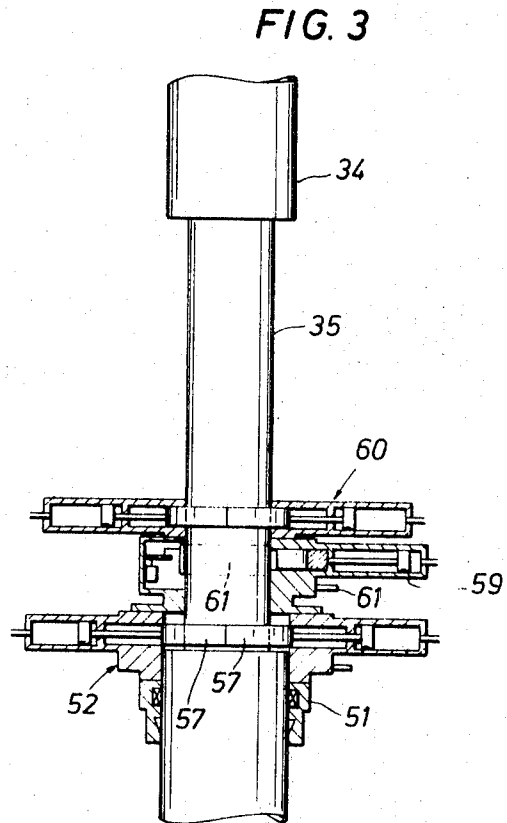
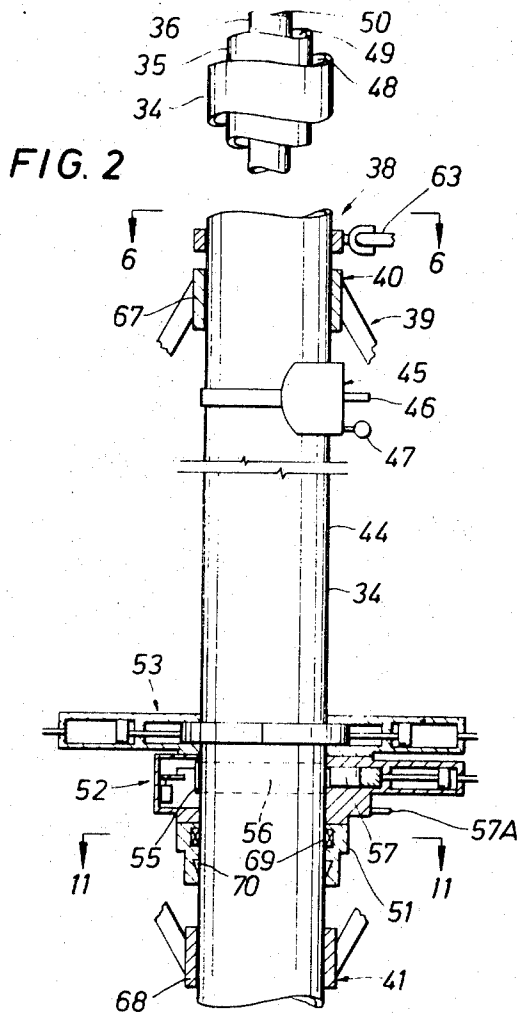


FIG. 30



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FIG. 5

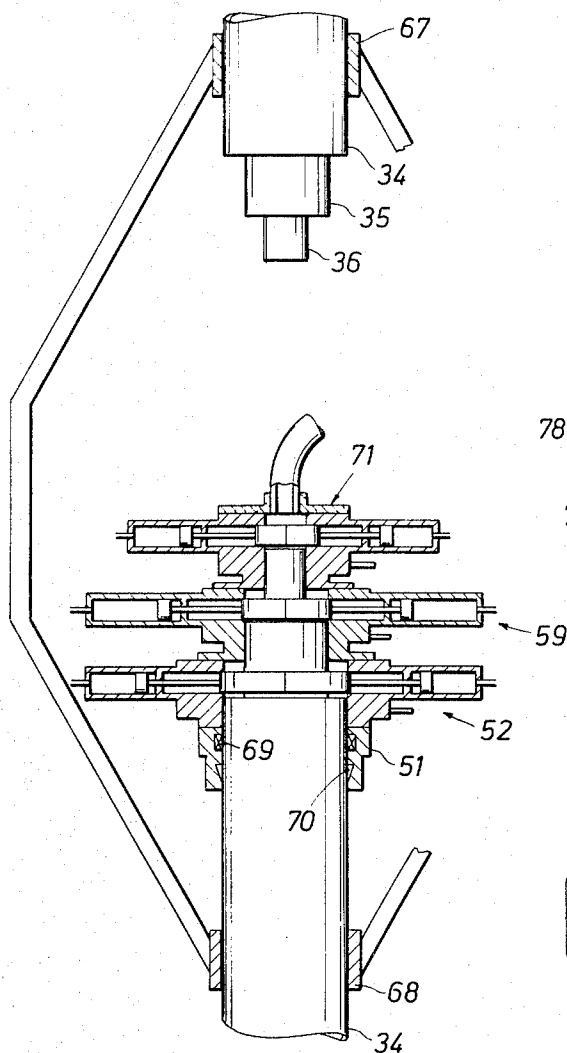


FIG. 6

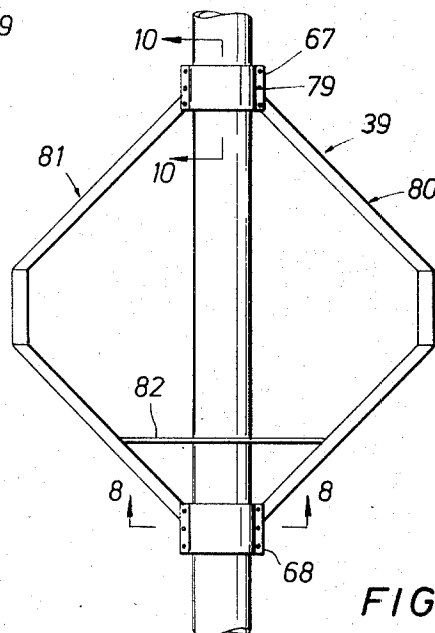
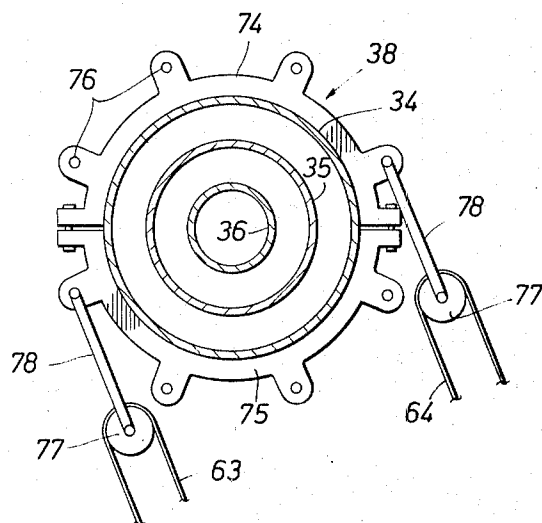


FIG. 7

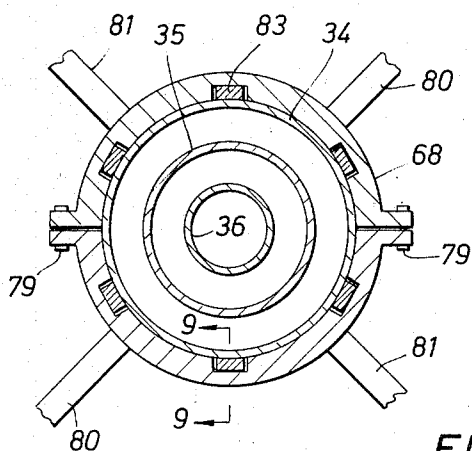
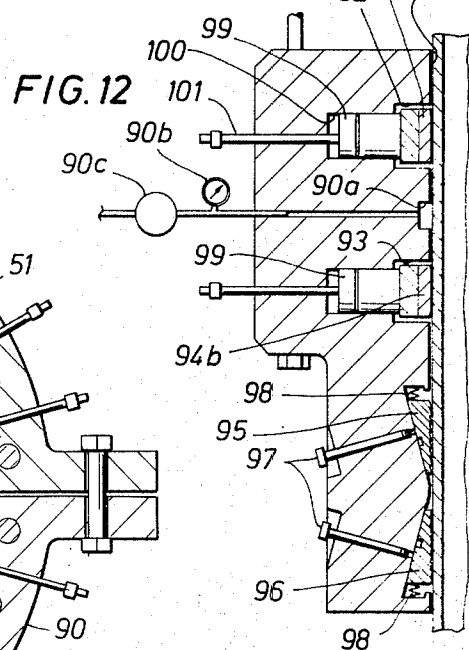
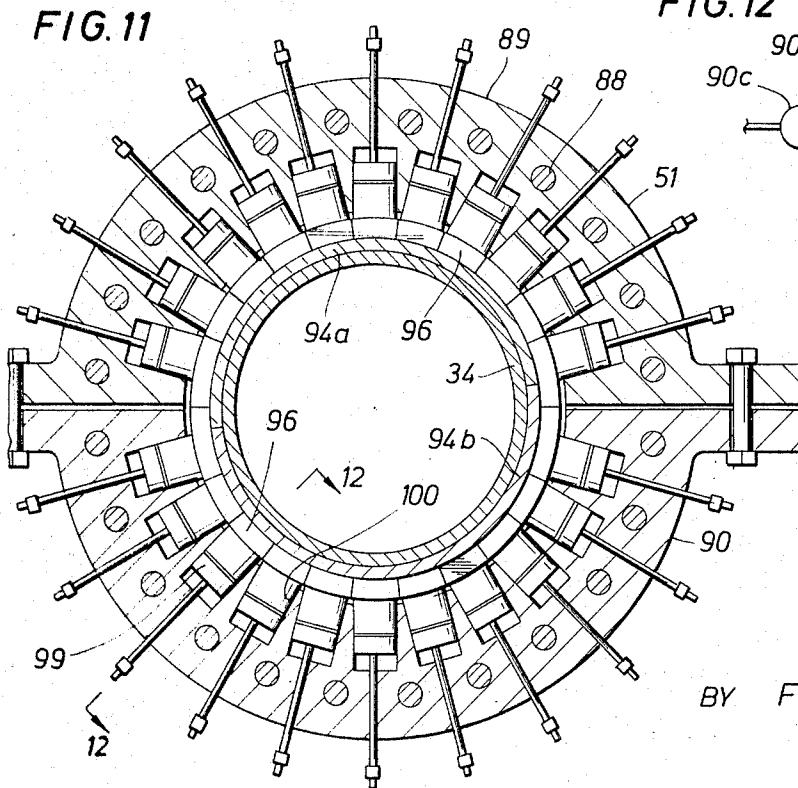
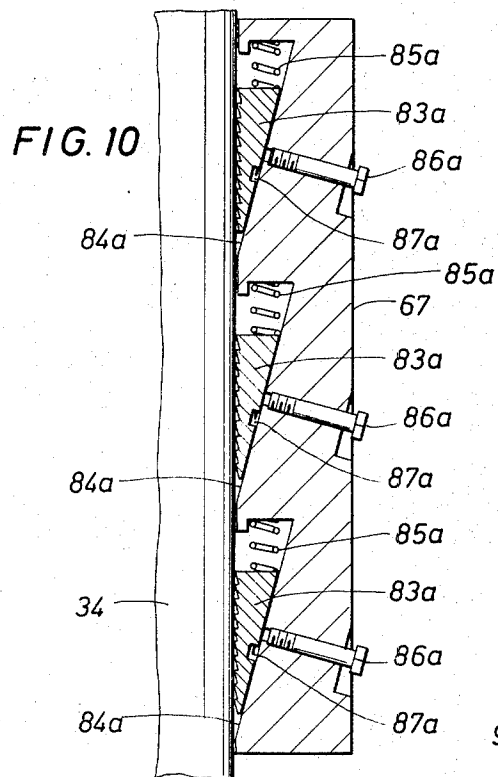
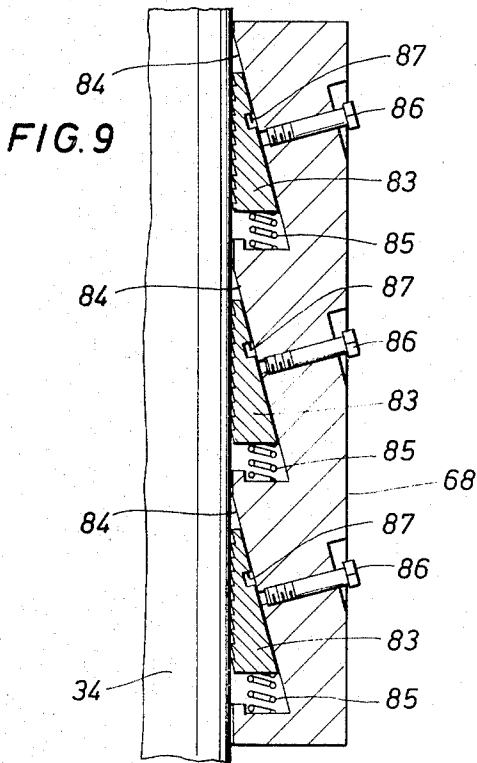


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FIG. 13

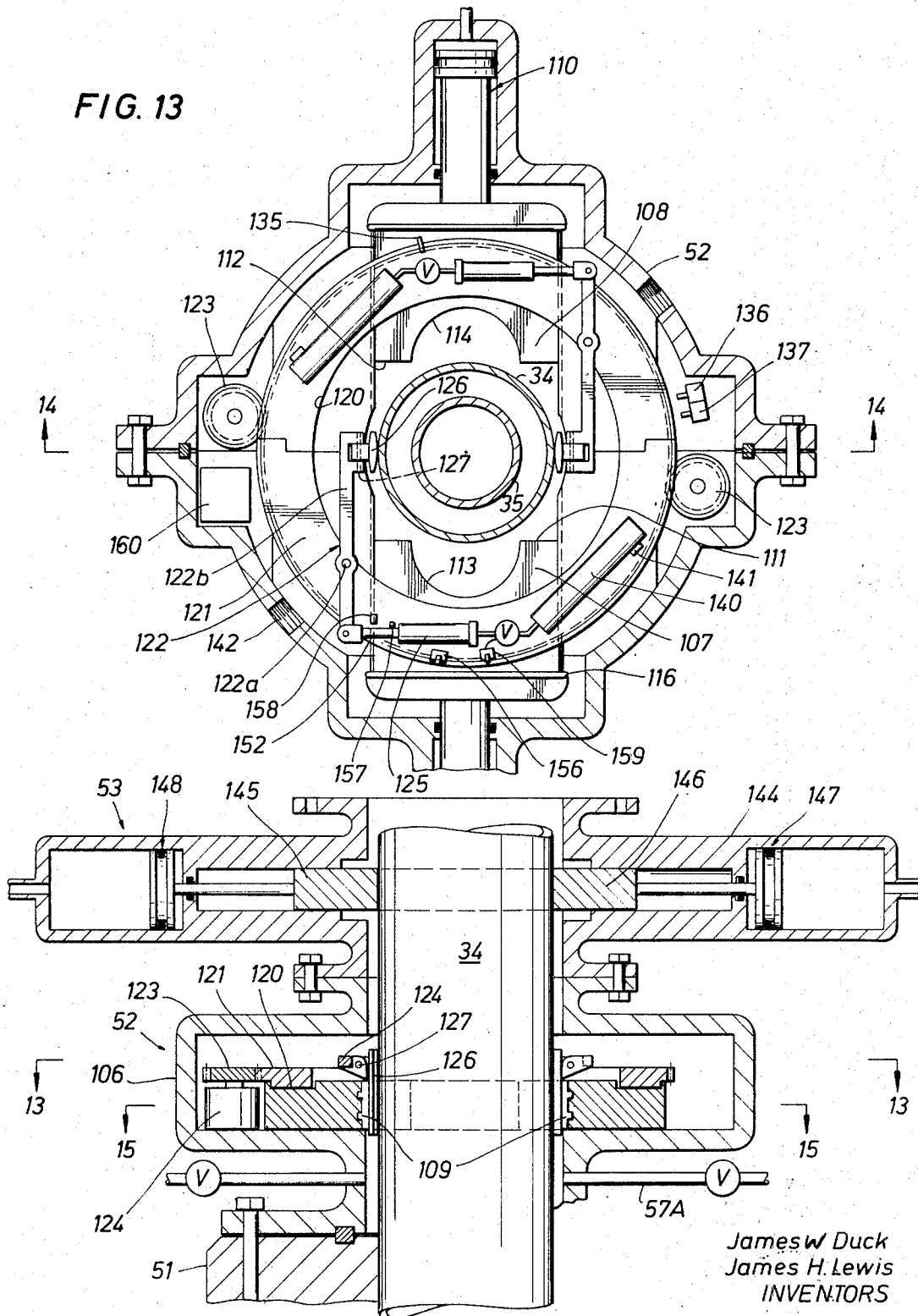


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FIG. 15

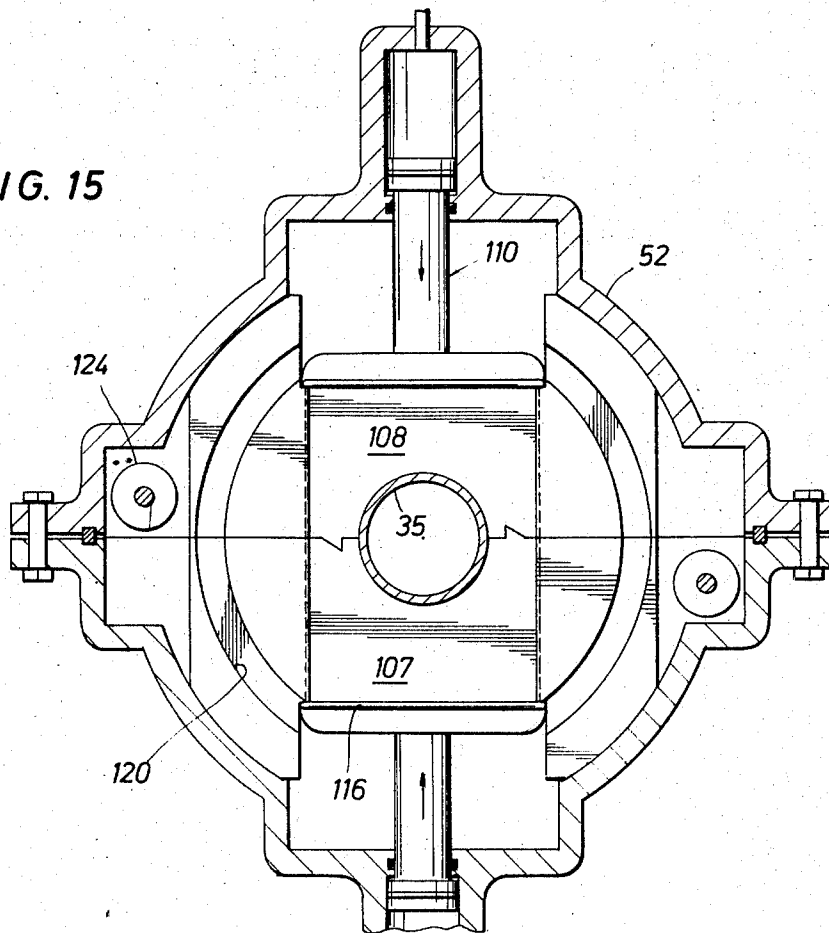


FIG. 16

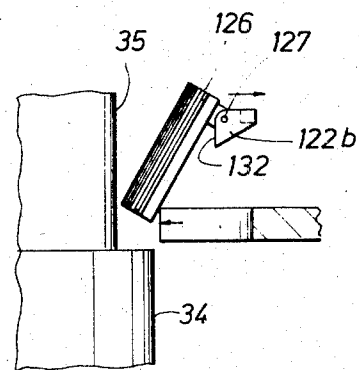
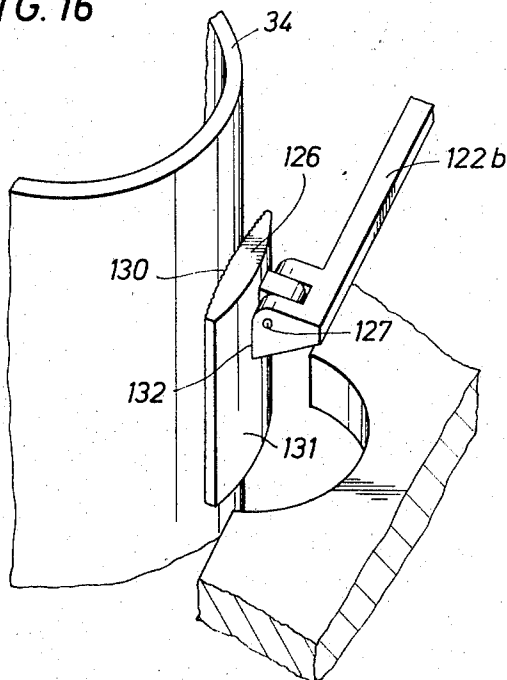


FIG. 17

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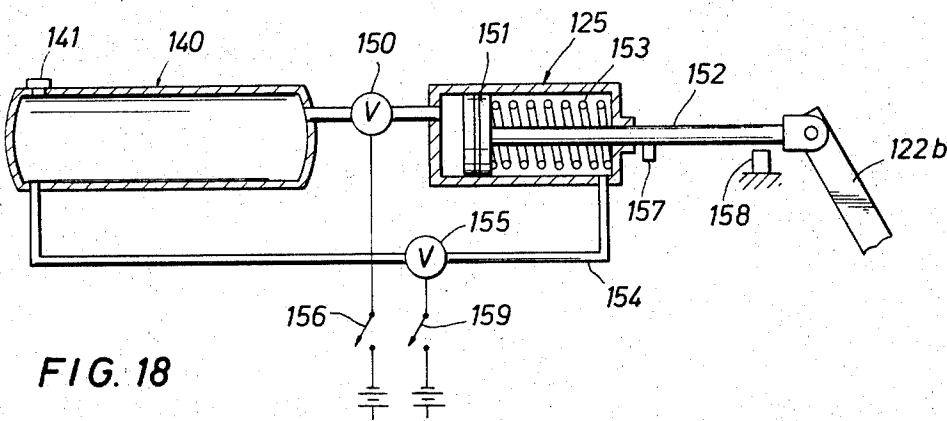


FIG. 18

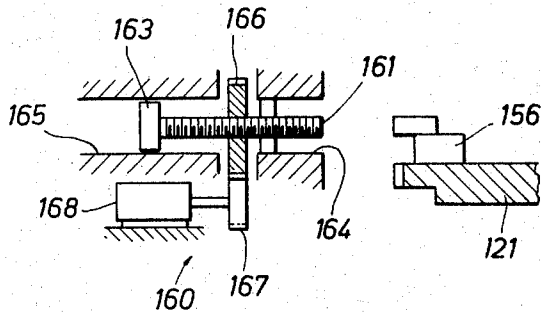


FIG. 19

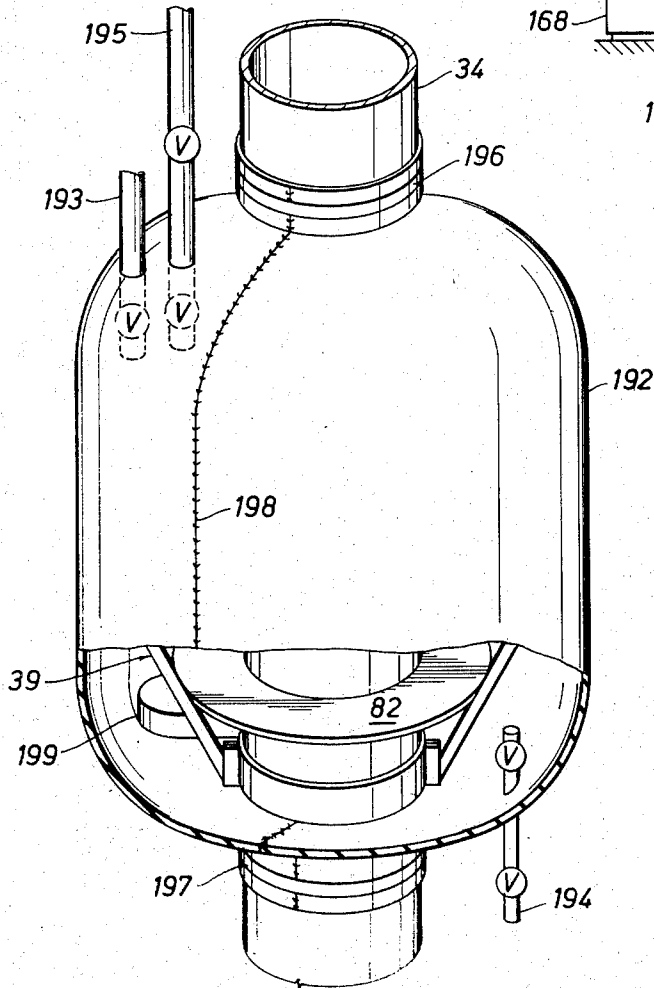


FIG. 24

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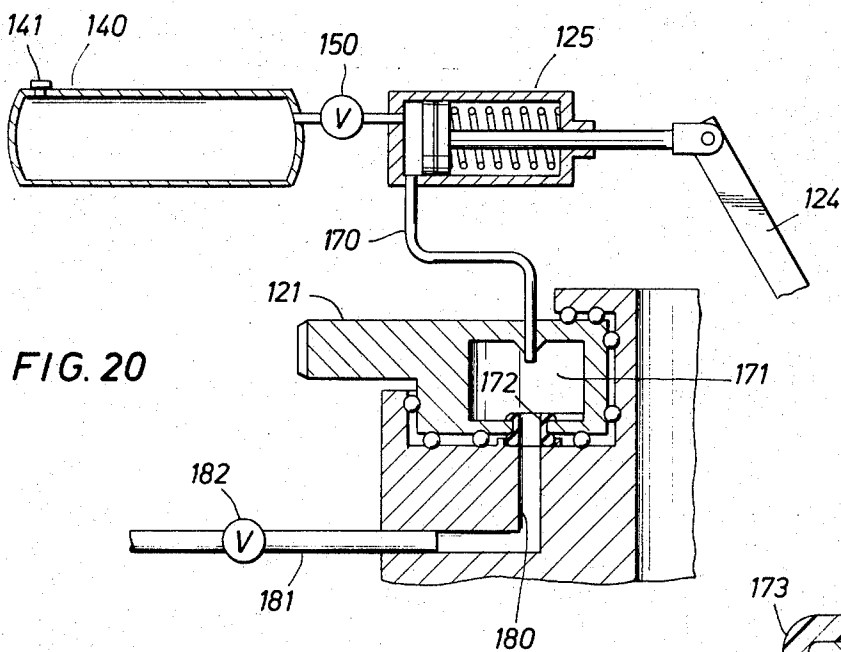


FIG. 20

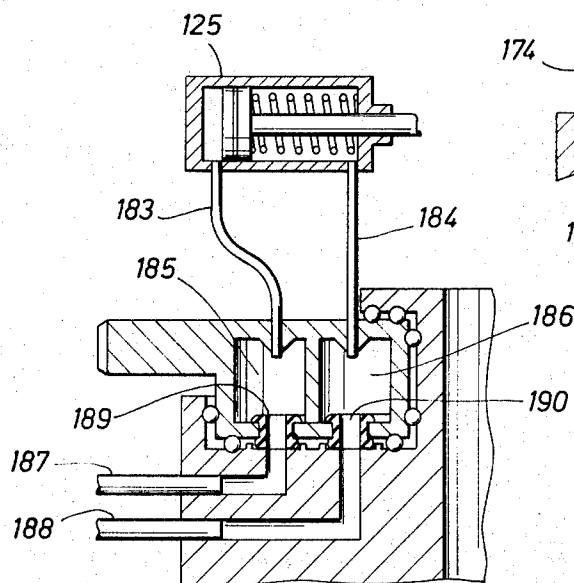


FIG. 22

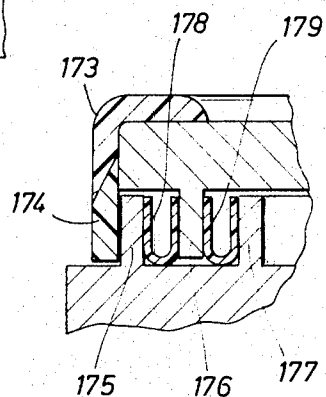
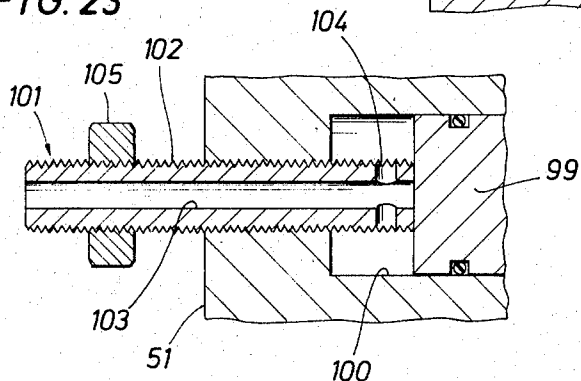


FIG. 21

FIG. 23



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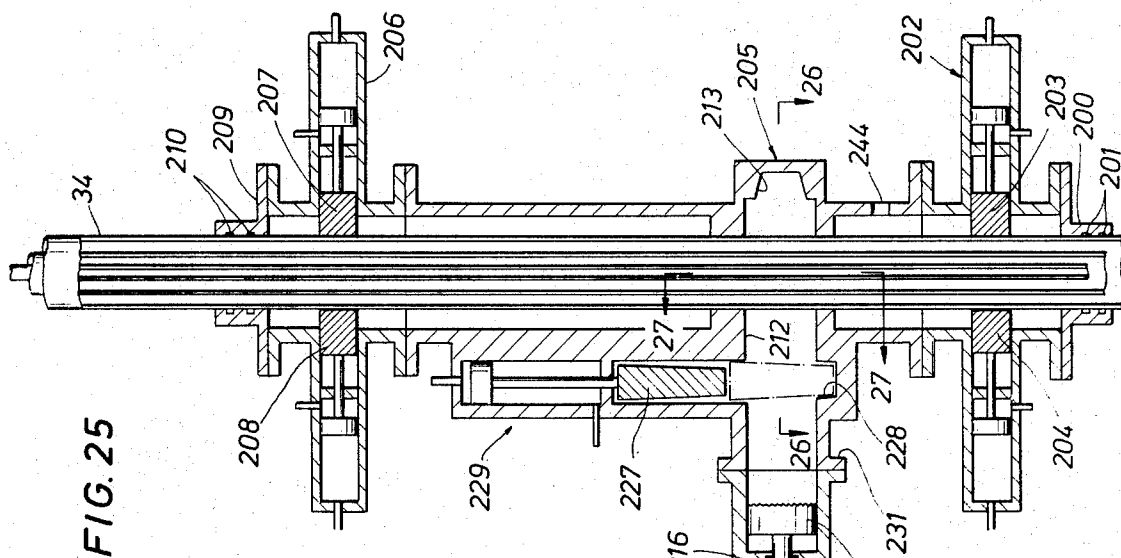


FIG. 25

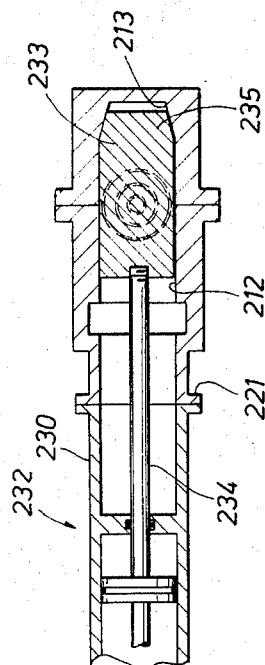


FIG. 26

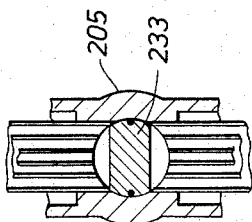
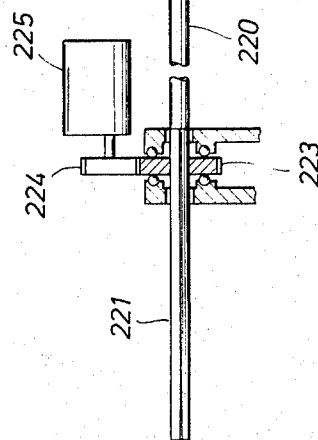


FIG. 27



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METHOD AND APPARATUS FOR CONTROLLING AN OFFSHORE WELL

BACKGROUND OF THE INVENTION

This invention relates to methods and apparatus for obtaining control over an offshore well which is blowing out. More particularly, the present invention is directed to systems for operating under water to close off one or more pipe strings and for permitting the application of a control fluid, such as mud or cement, to kill an uncontrolled, pressurized well.

An uncontrolled offshore well involves an incredibly complex surface operation to bring it under control and is usually attendant with contamination of the water by the produced petroleum products. This is because it is typically a situation wherein the well is ignited or blazes with an intense fire which must be first extinguished by fire fighters before remedial control operations can be attempted to cap and control the well. Once the fire is extinguished, there is the time interval between capping of the well during which large amounts of oil and gas are produced to contaminate the surrounding water areas. Alternative methods of leaving the fire going and attempting to drill an offset well for control purposes are time consuming, difficult to accomplish and many times fail completely to obtain the objective. It is, of course, in the interest of conservation of natural resources to provide a way of controlling a well without permitting the contaminating petroleum fluids to enter into the body of water surrounding the well. Not only contamination is a problem, but time is a factor as the cost of trying to control the well, the lost time of production, the lost production and the great hazards involved are monumental in scope and nature.

Accordingly, it is an object of the present invention to provide new and improved systems for obtaining control over an uncontrolled well without the attendant loss of petroleum fluids and for obtaining control in a relatively short period of time and with reduced hazards.

SUMMARY

The present invention involves a system using bifurcated apparatus which is installed on pipe strings below a water level. A supporting frame is attached to an outer pipe string and supports the upper section of a pipe relative to a lower section of the pipe while isolating a section of pipe free of weight or tension. On the isolated section of pipe a base member is installed with a sealing means to seal off the periphery of the pipe; a cutting and sealing unit and an upper sealing unit are next installed. In one form of the invention, the pipe section is cut completely in two and sealed off, whereupon a control fluid can be applied to kill the well. In another form of the invention, the pipe sections are individually cut away, sealed off and killed in a sequential manner. In still another form, the operations can be conducted in an air chamber.

The apparatus of the invention includes bifurcated assemblies for sealing and cutting off the pipes. In the sealing assemblies, provision is made for controlling the fluid under pressure. In the cutting and sealing unit, the cutter is operative to remove a section or sections of pipe in front of a sealing unit and is retractable to permit operation of the sealing unit.

These and other features of the invention will be apparent from the detailed description hereinafter provided, wherein reference is made to the accompanying drawings.

DRAWINGS

In the drawings:

FIG. 1 is a pictorial representation of an offshore well and illustrates broadly components of the present invention;

FIG. 2 is a view of the isolated section of pipe and apparatus for cutting and sealing off the outer pipe with respect to a first inner pipe;

FIG. 3 is a view of the isolated section of pipe and apparatus for cutting and sealing off the first inner pipe with respect to a second inner pipe;

FIG. 4 is a view of the isolated section of pipe and apparatus for cutting and sealing off the second inner pipe with respect to a third inner pipe;

FIG. 5 is a view similar to FIG. 4 and further illustrating a flow control unit;

FIG. 6 is a view in cross-section taken along line 6—6 of FIG. 2;

FIG. 7 is a view of the work support frame attached to a pipe string;

FIG. 8 is a view in cross-section taken along line 8—8 of FIG. 7;

FIG. 9 is a view in cross-section taken along line 9—9 of FIG. 8;

FIG. 10 is a view in cross-section taken along line 10—10 of FIG. 7;

FIG. 11 is a view in cross-section taken along line 11—11 of FIG. 2;

FIG. 12 is a view in cross-section taken along line 12—12 of FIG. 11;

FIG. 13 is a view in cross-section taken along line 13—13 of FIG. 14;

FIG. 14 is a view in cross-section taken along line 14—14 of FIG. 13;

FIG. 15 is a view in cross-section taken along line 15—15 of FIG. 14;

FIGS. 16 and 17 are perspective views illustrating the operation of the cutting means;

FIG. 18 is a schematic illustration of a hydraulic system illustrated in FIG. 13;

FIG. 19 is a schematic illustration of a selectively operable mechanism for actuating the hydraulic mechanism of FIG. 18;

FIG. 20 is a schematic illustration of an alternative form of hydraulic mechanism;

FIG. 21 is a view in cross-section illustrating a sealing means;

FIG. 22 is a schematic illustration of still another alternate form of hydraulic mechanism;

FIG. 23 is a view in cross-section taken along line 12—12 of FIG. 11 and enlarged in cross-section;

FIG. 24 is a schematic illustration of an air chamber means;

FIG. 25 is a view in cross-section of an alternative cutting and sealing system;

FIG. 26 is a view in cross-section taken along line 26—26 of FIG. 25;

FIG. 27 is a view in cross-section taken along line 27—27 of FIG. 25;

FIG. 28 is a perspective view of a sealing ram for the unit shown in FIG. 25;

FIG. 29 is a view in cross-section of an alternative construction for a sealing ram; and

FIG. 30 is a schematic illustration of an alternative form of the hydraulic system.

In a typical offshore well operation for which the present systems are designed, an offshore platform 30, as shown in FIG. 1, is supported by struts 31 on the sub-surface 32 below the water level 33. One or more telescoped pipe strings 34-36 extend from the surface of the platform 30 through the water, then through the underlying substrata to earth formations below the body of the water. As is typical in this sort of operation, a so-called "surface casing" 34 extends from a platform into the earth formations for an interval of length and is commonly used to prevent the hole from caving in. Successively smaller diameter pipes 35 and 36 are telescoped through the surface casing and extend to successively increased depths into the earth formation and are commonly cemented into place. Thus a typical well string from an offshore well platform can include a number of telescopically arranged pipe strings, each extending to a deeper depth within the formation, and one or more of the interior pipe strings traverse an earth formation through which petroleum products are produced.

With a given offshore production system as described above, if a blowout occurs where the petroleum products are produced in an uncontrolled fashion through the pipes to the surface platform, it is almost inevitable that ignition of the products will occur and a fire will be produced which is continuously fed by the pressurized products produced from the formations. The system of the present invention contemplates an underwater operation which can be performed in, say, the upper thirty feet of water where a subsurface swimmer can operate for prolonged periods of time without incurring the usual diving hazards. The system broadly contemplates the location of a work boat 37 to the windward side of the platform 30, and, through the use of flotation equipment, a swimmer attaches a towing guide ring 38 to the outer pipe string 34. The boat 37 is suitably anchored in place to maintain a given position. Cables are attached between the boat 37 and the towing ring 38 to transport equipment to and from the pipe string 34. A subsurface frame 39, which is bifurcated, is first towed into place under water and is attached at spaced locations 40, 41 along the outer pipe to provide a rigid support between the upper part 42 of the pipe and a lower part 43 of the pipe 34, so that the pipe section 44 intermediate of the upper and lower support locations 40, 41 can be completely removed with the support frame 39 providing a means for maintaining the upper part 42 of the pipe and any assemblages which may be attached thereto from moving downward. From the boat, air, hydraulic and electrical lines for the units are cabled to the frame 39 for operation of the various units.

After the working support frame 39 is attached to the pipe 34, a hot tap machine 45 is towed into place and fixed near the upper end of the pipe section below the upper support location 40, as shown in FIG. 2. The hot tap machine 45, which is conventional, is strapped to the pipe 34; a tap 46 is drilled through the first pipe wall; and the pressure within the pipe is sampled by a gauge 47. If there is no pressure, it may be reasonably assumed that the annular area 48 between the outer

pipe and the first inner pipe 35 is not the cause of the blowout, and the tapping machine is operated to pierce the second pipe wall. This tapping operation is continued until the annulus between pipes, where the pressure or the fluids produced in the well are coming from, is discovered.

In the most complex situation which can be encountered, there can be pressure in each of the annuluses 48 and 49 of the pipes as well as the central conduit 50.

Assuming an extreme case, in the practice of the systems of the present invention the outer pipe 34 is sealed off around its outer periphery at a location just above the lower support location 41 with a base member unit 51 (FIG. 2). Unit 51 is bifurcated so that it can be bolted in place to the outer pipe 34. The lower base member unit 51 is also a sealing device, and, after the base member unit 51 has been tested to ensure that a seal is maintained between it and the outer surface of the pipe 34, a bifurcated cutting and shutoff unit 52 is towed into place and sealingly attached to the base member unit 51 in position for operation. At the upper end of the cutting and shutoff assembly 52, a blowout preventer unit 53 is sealingly attached so that the assembly includes an upper blowout preventer unit 53, an intermediate shutoff and cutting unit 52, and the lower base unit 51. With the pipe thus sealed at spaced locations by the sealed assembly, the cutting and shutoff unit 52 is actuated so that a cutter 55 cuts away a section 56 of the outer pipe (shown in dashed line), and, following the cutting operation, sealing means 57 in the shutoff and cutting unit are actuated to seal off the annulus between the outer pipe and the next inner pipe. For convenience of illustration, cutter 55 and sealing means 57 are shown in the plane of the drawing of FIG. 2 and are only schematically illustrated. The actual construction will hereinafter be more fully explained.

At this point, if so desired, control mud or liquid such as cement may be pumped into this annulus via a port 57A to control the pressure in the annulus 48 between the pipes 34 and 35.

To control the pressure within the next inner annulus 49 (as shown in FIG. 2), the upper blowout preventer 53 is removed, and the outer pipe section 44 between the support locations of the working frame is removed. The pipe section 44 is removed by conventional cutting. Another cutting and shutoff unit 59 is then sealingly attached to unit 52, and unit 59, in turn, is sealingly capped at its upper end with a blowout preventer unit 60 so that there is effectively a seal between the upper blowout preventer 60 on the first inner pipe 35 and the sealing means 57 of the first cutting and shutoff unit 52 on the outer pipe 34. The operation is then repeated where an annular section 61 of the pipe 35 is cut out, and the shutoff unit 59 is operated to seal off the second inner annulus 49. Following this, control mud or other liquids may be pumped into the second annulus via a port 61. The section of the first inner pipe may be cut away then between the support locations of the working frame, and still another cutting and shutoff unit can be used on the next annulus between the pipes. This operation is repeated until the final interior pipe 36 is cut away, as shown in FIG. 4, and the cross-section of the pipe is closed, which completely caps off the well. The control fluids which may be injected, of course, into the various

annuluses, as desired, have controlled the well. Once the well has been controlled, the apparatus can be removed and conventional remedial operations performed on the well. During this entire operation, it will be appreciated that the fire is permitted to continue so that there is no pollution of the water and that, as the shutoffs of each pressured annulus of pipe are obtained, there is no escape of contaminating fluids to the water. In addition, the operation is relatively quick, and at all times the well is under control.

Referring again to FIGS. 1, 2 and 6, the bifurcated towing ring 38 is first attached by a swimmer near the upper end of the pipe just below the water level, and tow cables 63, 64 are coupled between winches 65 on the boat 37 and the towing ring so that equipment may be floated into place. The ends of the towing cables 63, 64 are respectively attached to separate winches on the boat so that positive to-and-fro movement of equipment can be accomplished. The equipment is transported by use of a float 66 and a cable connector (not shown) for the cable and transporting the equipment under water to the well string.

After the towing ring 38 is installed, the supporting work frame 39 in bifurcated sections is towed into place and attached to the pipe so that it provides upper and lower supporting members 67, 68 respectively attached to the pipe 34. The upper supporting member 67 has gripping means which hold the upper section of the pipe from moving downward, and the lower ring of the supporting work frame 39 has gripping means which prevent the work frame from moving downward relative to the pipe 34. Thus, a section 44 of pipe 34 is isolated between the upper and lower support rings 67, 68 and is effectively isolated from the pipe string 34 so that it can be removed. After the working station 39 is installed, the hot tap apparatus 45 is floated into position. A diver attaches the hot tap device to the upper end of the pipe by strapping it to the outer section of the pipe, and the tap is operated to drill through the successive pipe walls — the pressure being sampled as the tap progresses. The purpose of this test is, of course, to determine in which annulus the pressure exists.

A base sealing unit 51 which is bifurcated is next floated into position and attached to the outer pipe near the lower ring 68. The base unit 51 includes a sealing member 69 for sealing the annulus of the pipe and slip members 70 which firmly fix the base member to the pipe so that it cannot move. After the base unit 51 is located in position, the bifurcated cutting and sealing unit 52 is floated into place and attached to the lower base unit 51 and to the pipe 34, and the bifurcated upper sealing unit 53 is attached to the cutting and sealing unit 52. In the example shown, it is assumed there is pressure between the annulus of the outer and first inner section of pipe, so that the units 51 and 53 positioned on the outside of the pipe 34 provide upper and lower seals on the pipe. The cutting unit 52 is operated to cut away an annular section 56 of the pipe 34 and, after the annular section of pipe is cut away, the sealing member 57 is actuated to seal off the outer section of the first inner pipe 35, which effectively seals the annulus 48 from a point below the sealing unit 57 and the seal 51 on outer pipe 34. By means of a port 57A below the sealing unit 52, control fluids such as mud or ce-

ment may be pumped in the annulus to kill the pressure in this section of the well. The upper bifurcated sealing unit 53 is then removed since the cutoff sealing devices 57 provides a seal, and the outer section of the casing 34 is cut away by means of an underwater torch or the like and removed. If desired, the first inner pipe can be tied to the outer pipe by welding or an attaching device (not shown).

Next, another bifurcated cutting and sealing unit 59 is attached to the first cutting and sealing unit 52, and an upper sealing unit 60 is attached to it. The next section of pipe 35 is cut away, and the sealing unit 59 is operated to close off the annulus between the pipe 35 and the pipe 36. If there is pressure in the annulus, control fluid such as mud or cement can be injected through port 61 in the unit to kill the well.

To control the last section of pipe, the upper sealing unit 60 is removed, and a cutting and sealing unit 62 is substituted after the intermediate section of pipe 35 has been cut away. A sealing unit 69 can be installed, and the inner pipe 36 is cut as described before. The sealing unit 62 operates to close off the cross-sectional area 50 of pipe 36. The well may be killed through injection of a control fluid through the port 70 in the sealing unit 62. Alternatively, the sealing unit 69 can be removed and an exterior port device 71 can be attached to the upper end and operated to kill the well by injecting fluids after the sealing unit 62 is opened. When this final operation is conducted, it will therefore be appreciated that each section of the pipe is controlled and that there is no possibility of contamination of the water by the petroleum products since they are controlled in place.

Referring now to FIG. 6, the tow ring 38 is shown which is comprised of bifurcated half-sections 74, 75 which can be bolted together about the periphery of the pipe 34. Around the outside perimeter of the tow ring 38 are a number of eyelets 76 and sheaves 77 attached by swivels 78 or the like to receive the tow line from the boat. The tow cables 63, 64 can be inserted, for example, by a swimmer taking a nylon rope from the boat and passing it through the sheaves and returning it to the boat where a cable can be attached to one end of the rope and drawn through the sheave and attached to a winch. It is preferable that a winch be attached to each end of the cable through a suitable cathead or the like, whereby the cable can be positively pulled in either direction for moving equipment to and from the well site.

The work platform as shown in FIGS. 7 and 8 includes upper and lower ring members 67, 68 which are bifurcated and provided with bolt means 79 for attaching the two halves of a ring to one another. Each half ring has two or more supporting frames 80, 81 disposed at 90° relative to one another to form a symmetrical, somewhat diamond-shaped form with diagonal arms, intermediate parallel support members and lower diagonal arms and a lower working platform 82. It will be obvious that the arm members are required to support the weight of the pipe above the upper ring 67 as well as any other equipment on the pipe and, therefore, should be sufficient and adequate to support the load. In this regard, suitable additional bracing and support members may be employed to provide adequate bracing. It is the function of the support-

ing frame member 39 to support the section of the pipe 34 above the upper support ring 67 and to transmit this load through the supporting frame members to the lower support ring member 68 which is, in turn, attached to the lower section of pipe 34. The attachment of the upper and lower support rings is not only by means of the clamping connection of the bifurcated ring members but also by virtue of slips 83 which are disposed around the periphery of the support rings. As shown in FIG. 9, the slips 83 in the lower support ring 68 are mounted in inclined recesses 84 in the inner wall of the ring, and the sliding surfaces can be dovetailed to one another if so desired. The slips 83 are respectively engaged by springs 85 within the ring 68, so that the springs tend to urge the slips 83 along the inclined plane to move them inwardly into engagement with the wall of the pipe 34. The slips 83 are ordinarily prevented from actuation by means of screw members 86 or the like which are threadedly received in openings 87 in the slips and pass through the housing sections so that the slips, in a retracted position, compress the springs and would normally be out of engagement with the wall of the pipe. After the apparatus has been positioned on the pipe, the screw members 86 are released so that the springs can urge the slips into engagement with the wall of the pipe. As shown in FIG. 10, the slip arrangement within the upper supporting ring is the same as the slip arrangement in the lower supporting ring, except that it is reversed so that the weight of the pipe acting through the slip is transmitted to the supporting ring. That is, slips 83a are urged downwardly by springs, and bolts 86a are used to retain the slips in a retracted position. If desired, oppositely opposing slips can be used in each of the supporting rings.

Referring now to FIGS. 11 and 12, the lower base and sealing unit 51 is illustrated in cross-section. The lower base and sealing unit 51 is comprised of two semi-circular sections 89, 90 which can be bolted together around the periphery of the pipe 34. Vertical holes 88 pass through the assembly for bolting the base assembly to adjacent sealing and cutting units or the like.

Looking at FIG. 12, which is a vertical cross-section, the interior wall 91 of the sealing assembly 51 has upper and lower annular shaped recesses 92, 93 as well as an intermediate annular recess 94. In the lower section of the interior are slips 95, 96 which are arranged on inclined surfaces and may be dovetail-connected to the inclined surfaces for attachment. The slips use screws 97 for maintaining the slips in a normally retracted position and spring members 98 behind the slips for urging the slips into gripping engagement with the casing. As illustrated, the slips are arranged in opposite directions so that the housing will support weight in a downward direction, for reasons which will hereinafter become more apparent. Within the upper and lower annular recesses 92, 93 are semi-circular lead sealing members 94a, 94b, and behind each of the sealing members 94a, 94b are arcuately shaped plates 96. As shown in FIG. 11, the semi-circular sealing members 94a, 94b may be displaced slightly upon location on the pipe so as to avoid a direct opening to the split between the ring members. The arcuately shaped backup members 96 are disposed around the circum-

ference of the lead members 94a, 94b so as to form a more or less continuous backup ring. To each of the arcuate members 96 is attached a piston 99 which is slidably and sealingly received in a cylinder 100. Each cylinder 100 is, in turn, connected via a hollow bolt 101 to a source of hydraulic pressure, not shown. The hollow bolt 101, as shown in FIG. 23, has a threaded member 102 with a passageway 103 therethrough, and within the chamber, side ports 104 are provided for admitting hydraulic pressure into the cylinder. Through an exterior coupling to the hollow bolt, hydraulic pressure can be applied to the cylinder 100, and the piston 99 applies pressure through the arcuate members 96 to the lead ring segments 94a and 94b to urge them into sealing engagement with the pipe. At the same time, the bolt member 101 can be actuated through its threaded arrangement in the housing by means of the lug attachment 105 to mechanically engage the rearward end of a piston and maintain the piston with a mechanical force on the lead ring independent of hydraulic force. Thus a mechanical backup is provided for the sealing member. Between the sealing members, seals (not shown) are provided between the sections 89 and 90. To test the tightness of the seal, the sections 89, 90 have a recess 90a intermediate of seals 94a, 94b. The recess 90a is coupled to a pressure gauge 90b and a valve 90c. Pressure can be applied to the recess 90a to determine if the seals are tight.

Referring now to FIGS. 13 and 14, a cross-section is illustrated of the cutting and sealing unit 52 which is affixed to the top of the base unit 51. The cutting and sealing unit 52 has a large hollow casing or housing 106 in which a pair of rams 107, 108 (FIG. 13) are diametrically opposed to one another and are mounted on parallel guideways 109 (FIG. 14) to be reciprocated backward and forward by means of a hydraulic cylinder arrangement 110. The rams 107, 108 include forward surfaces 111, 112 which engage one another as well as semi-circular recesses 113, 114 which are sized to the outer diameter of the interior casing. Suitable sealing members (not shown) are disposed along the engaging surfaces and elsewhere to provide a fluid-tight sealing arrangement when the rams are closed on the pipe (FIG. 15) so that fluid flow in a vertical direction past the rams is prevented. In the rearward part of each ram, offset shoulders 116 can be provided together with sealing means to seal against surfaces at the rearward location in the housing. Thus, it will be appreciated that if the outer casing 34 is removed, the rams 107, 108 can be closed and sealed with respect to the inner pipe 35 (FIG. 15), and fluid flow in a vertical direction past the rams is prevented. As illustrated, the housing 106 is bifurcated and arranged for coupling about the pipes, and suitable sealing members are provided to seal these halves with respect to one another. The housing 106, when completed, has an annular shaped ring groove 120 (to be explained in detail later) which carries a split gear ring 121. The gear ring is assembled and has outer gear teeth which engage oppositely disposed spur gears 123 which are coupled to hydraulic motors 124. The hydraulic motors 124, when actuated, serve to rotate the gear ring 121. Mounted on and above the gear ring is a linkage mechanism 122 which is pivoted to the gear ring 121 at pin 122a, and a link arm 122b has one end connected to a hydraulic cylinder 125 and

an opposite end connected to a cutter 126. As illustrated, the cutter 126 is pivotally connected at 127 to the linkage arm 122b and extends vertically over a greater distance than the width of the rams. The hydraulic piston 125, when actuated, urges the cutter 126 into engagement with the circumference of the pipe 34 and, by virtue of tungsten carbide tip surfaces, the pipe is cut away across the width of the cutter.

Referring to FIG. 16, a cutter blade is illustrated in contact with a casing pipe 34 and in FIG. 17 in a position where the pipe 34 has been cut away. The cutter blade has a generally curved forward surface 130 and a rearward, downwardly extending surface 131 which is parallel to the front surface 132 of an extension on arm 122b so that the arm ordinarily biases the blade 126 into contact with the casing 34. When the blade is positioned in front of the ram, as shown in FIGS. 16 and 17, a rearward motion of the linkage arm 122b will cause the lower portion of the blade to engage the ram, and it will tilt upwardly as the arm moves away from the pipe, so that the blade may be removed from the location between the ram surfaces, thereby permitting the ram to be closed.

A small projection member 135 is mounted on the gear 121 so that the rotative position of the ring within the housing can be indicated. Thus, each time the ring 121 is rotated, each of the limit switches 136, 137 will be actuated. The location of the projection member 135 relative to the ring 121 is such that when the blades 126 are in line with the rams, the projection 135 will be intermediate of the two switches 136, 137. At this location, a second cylinder 140 with an access opening 141 will be disposed adjacent to an access port 142 in the housing.

The sealing means or blowout preventer 53 includes a bifurcated housing member 144 which has sections carrying sealing rams 145, 146 in suitable guides, and, when assembled, the rams 145, 146 are oppositely disposed relative to one another. Hydraulic means 147, 148 are provided for moving the rams in a conventional manner. In the position illustrated in FIG. 14, the rams 145, 146 seal against the pipe 34 and also provide a seal against travel of fluid in a vertical direction through the ram.

Turning now to the hydraulic system for operating the cutters, it is the purpose of the system to actuate and retract the cutter. A first system is illustrated in FIGS. 18 and 19 where in a pressure tank 140 is coupled via a normally closed solenoid valve 150 to a hydraulic cylinder 125 containing a piston 151 coupled by a piston rod 152 to the linkage arm 124. A spring 153 in the cylinder 125 normally urges the piston toward a retracted position. A return conduit 154 couples the cylinder 125 to the tank 140, and it has a normally closed solenoid valve 155. To operate the system the tank 140 is charged with air under pressure via inlet 141 which includes a one-way check valve normally preventing escape of pressure. When it is desired to apply pressure to the linkage, the valve 150 is opened by closing switch 156 which closes an electrical circuit, and valve 150 is opened and latched in this position. The spring-biased side of cylinder 125 is at atmospheric or a relative low pressure so that the piston 151 is acted upon to apply pressure to the linkage 124 and, hence, the cutter blade. Stops 157, 158 on the piston rod 152

and housing limit the inward travel of the blade so that only one pipe is cut. To reverse the force on the linkage, a solenoid valve 155 is opened by closing switch 159 which closes an electrical circuit, and the valve 155 is latched in an open position. The opening of valve 155 equalizes the pressure across the piston 151, and spring 153 retracts the linkage. Of course, a high pressure external to cylinder 125 greater than the internal pressure can also serve to retract the linkage.

Switches 156 and 159 are selectively operable. As shown in FIG. 13, switches 156 and 159 are mounted on the ring 121, and an actuating mechanism 160 is such that when actuator 135 is disposed intermediate of switches 136 and 137, switches 156 and 159 are on opposite sides of the actuating mechanism 160 and blade 126 is in front of a ram. The actuating mechanism 160, as shown in FIG. 19, is comprised of a threaded member 161 with fixed guide members 162, 163 in guide tracks 164, 165 so that the screw member 161 cannot rotate. A gear 166 is mounted between the guide frame and has a threaded opening received on the threaded member 161. A motor 168 drives a gear 167 which, in turn, rotates the gear 166 causing the threaded member to move either forward or backward, depending upon the rotation of motor 168. Hence, when the switches 156 or 159 are located to either side of the actuating mechanism 160, it is actuated to position the threaded member 161 in position to actuate a switch 156 or 159. The switch 156 or 159 is selectively actuated by turning the gear an appropriate angular amount. After actuation of a switch, the threaded member 161 is retracted and the gear 121 can be rotated. Thus, each switch 156 or 159 can be selectively actuated.

Referring now to FIG. 20, another embodiment of the hydraulic system is illustrated. Tank 140 and cylinder 125 are as described heretofore. To bleed off the pressure from the piston for return of the piston rod, the high pressure side of the cylinder 125 is coupled via a conduit 170 to a closed chamber 171 in each segment of gear 121. Chamber 171 has a lower opening 172 which is lined with a rubber insert 173 attached to a teflon member 174 (FIG. 21). Member 174 is aligned relative to an upstanding flange 175 on the housing to provide a sealing surface. As shown in FIG. 21, gear 121 has a downwardly extending flange 176 intermediate of upwardly extending flanges 175, 177 on the housing. U-shaped sealing members 178, 179 constructed of teflon are disposed between adjacent flanges to provide a pressure seal in both directions. It will be appreciated that since gear 121 is in two pieces, the sealing members are separate parts and closed at each end. The housing has an access passage 180 coupled to a conduit 181 which includes a selectively operable valve 182. Valve 182 may be located exterior to the housing where conduit 182 can be opened to relieve pressure on the cylinder 125. Alternatively, supplemental pressure can be applied via the conduit 181 to the cylinder. Also, as illustrated, gear 121 is contained in the housing by roller bearings which provide a thrust support and permit ease of rotation.

Referring now to FIG. 22, a different embodiment is illustrated wherein the opposing ends of cylinder 125 are coupled via conduits 183, 184 to separate chambers 185, 186 which are, in turn, coupled to conduits

187, 188 via ports 189, 190. Conduits 187, 188 are extended to exterior control systems whereby the pressure in the cylinder 125 can be selectively controlled to apply pressure to the cutting blade as well as retract it.

Referring to FIG. 30, still another variation for controlling the hydraulic system 125 where one or more flexible conduits 125a are passed through the housing is shown. In this arrangement, the gear is oscillated between angular positions rather than rotated so that a direct connection can be made to the hydraulic cylinder 125.

Turning now to FIG. 24, a system is illustrated wherein the working frame 39 and working area is enclosed by a fabricated housing 192 of resilient material such as reinforced rubber. The housing is provided with upper and lower conduits 193, 194, with internal and external control valves and an upper valve controlled inlet conduit 195 through which air pressure can be supplied. The housing 192 is attached to the pipe 34 by upper and lower strap means 196, 197 and has a vertical split 198 which is clamped shut after installation by means of suitable clamping means which are schematically illustrated. A manhole opening and cover 199 are provided in the lower end of the housing for access. By virtue of the housing, water can be removed from the working area by air pressure, and the various units employed can be welded in place.

Another form of the present invention is illustrated in FIGS. 25-29. In this embodiment, the working equipment includes a bifurcated lower base member 200 which has opposing slips 201 and may include means providing an annular seal as described heretofore. Attached to the base member 200 is a blowout preventer device 202 which has rams 203, 204 which are selectively operated in a conventional manner by hydraulic means to seal off the casing 34 and prevent fluid flow in a vertical direction. Attached to the preventer 202 is a cutting and sealing unit 205. Above the cutting and sealing unit 205 is another blowout preventer 206 with sealing rams 207 and 208 to sealingly engage the casing and prevent fluid flow in a vertical direction. Attached to the preventer 206 is an upper base member 209 which includes oppositely disposed slips 210 and which can include additional sealing means. The units as described are bifurcated along the center line and a plane perpendicular to the plane of the drawing. As will be apparent from the organization, the pipe 34 is sealed above and below the cutting and sealing unit 205.

The unit 205 includes a central bore 212 which has a diameter greater than the diameter of the pipe 34. The bore 212 terminates to one side of unit 205 in a tapered wall seating recess 213. The bore 212 is continued in a housing port 215 and terminates at a wall 216 which forms part of a hydraulic system 217. The hydraulic system includes a piston 218 which on one side is coupled by a piston rod 219 to a mill cutter 222 disposed in the bore 212. The other side of the piston 218 is coupled by a piston rod to a square-shaped driving shaft 221. The shaft 221 is slidably received in a socket in a gear 223 which is suitably supported to prevent sidewise motion yet permit rotation. The gear 223, in turn, is driven by a gear 224 coupled to a drive shaft of motor 225. When the motor 225 is operated, the shaft 221 and hence the mill cutter 222 are rotated. The

piston 218 is actuated by hydraulic pressure to move the mill cutter 222 into cutting engagement with the pipe. Thus, it will be readily appreciated that cutter 222 can be driven to cut through all pipes traversing the bore 212 and thereafter retracted to the position illustrated.

After the above operation the pipe 34 is severed or cut in two. To seal off the cross-section of the pipes, the housing 205 has a transversely located shut-off ram 227 which is selectively operated by a hydraulic system 229. From the open position shown, the ram 227 is movable downwardly into a tapered recess 228 to seal off the bore 212, thereby isolating the cutting mill from the pressure in the pipe conduits.

When the cutting mill 222 is isolated from the pipe strings, the housing 215 is removed and a ram housing 230 attached to flange 231. The ram housing 230 includes a hydraulic system 232 and a ram 233 attached to a piston rod 234. After attachment to flange 231, transverse gate 227 is opened and ram 233 passed through bore 212. The ram 233 has a forward tapered nose section 235 which seats in the housing recess 213 as shown in FIG. 26. The shape of ram 233 includes a rearward cylindrical portion 237 provided with an annular seal 238, a central portion having parallel flat surfaces 239 and side cylindrically shaped surfaces 240, and the tapered nose piece 235. Lengthwise extending seals 242 are provided along the sides 240. When the ram 233 is in position, it seals with respect to the body of housing 205 to close off the fluid flow and therefore control the well. Port 244 can be used to inject a control liquid.

To facilitate the closing of ram 233, it may be provided with a bypass. As shown in FIG. 29, a cylindrical passageway 250 extends between surfaces 239 and has an upper restricted opening 251 and an inner tapered seat 252. In the lower surface 239 are access slots 254 communicating with the spaces between the flutes 255 in the bore 250. A sealing ball 256 is located in an angularly disposed passage 258 and compresses spring 257 while being held in place by a pin 260. The pin 260 is located in a longitudinally extending passage in the ram 233 and abuts an actuating rod 262, which has one end extending beyond the end of the ram 233. A shearable connection 263 normally holds rod 262 in a fixed position until the end of the rod 262 engages the housing, thereby slipping pin 260 from the bore and permitting the ball 256 to be released and seated in the seat 252 to shut off fluid flow. With this type of valve, fluids can be pumped through the valve into the well but will not return because of the valve action of the ball.

From the foregoing description, it will be apparent that the concept of the present invention involves a subsurface or underwater operation for control of a well. Fundamentally, it involves bifurcated units which can be attached to a pipe under water and provide a sealed control apparatus which permits cutting and sealing of well conduits while under pressure without loss of fluids. The schematic illustrations depict the technique of strapping and sealing units to the pipes under water. It is contemplated that the operations can be monitored by the use of underwater cameras both inside and outside of the equipment. The various control lines for air, hydraulic and electrical power are supplied from the boat in a conventional manner.

In the operation of the present system, as described heretofore, the boat 37 is located in position. The towing guide ring 38 is attached under water to the pipe conduit 34 and the tow cables 63, 64 attached. The various pieces of equipment are then towed into the working location by use of the cables 63, 64 and flotation equipment such as a buoy 66.

The working frame 39 is attached to the pipe 34 to provide the rigid support for the pipe and the isolation of a pipe interval on which operations can be conducted. Frame 39 when made in bifurcated sections is quickly and easily installed although, if desired, a supporting frame can be constructed in place by conventional underwater construction techniques.

The next step is to determine the location of the pressure in the pipe conduits so that the situation can be evaluated. Alternatively, if testing is not performed, the pipe sections can be sequentially isolated. The presence of pressure is determined by use of a conventional hot tap machine which can selectively sample each pipe under pressure control and determine the presence or absence of pressure. Use of the control cutting and sealing units is not necessary for outer sections of pipe which are not under pressure. In this case, such unpressurized pipe conduits can be safely stripped away first.

To control the pressurized conduit, a cutting and sealing unit is positioned on the pipe and sealing means provided above and below the unit. This assembly is a sealed chamber about the pipe so that the pressurized pipe can be cut and then sealed off. After sealing off the pressurized conduit, well control fluid is pumped to the pressurized pipe to control the well.

As illustrated in FIGS. 13-15, the bifurcated cutting and sealing unit 52 includes mirror sections which join to form an assembly which along one axis includes sealing rams. A rotatable cutter assembly is provided which has an actuator 135 on a gear 121 to indicate position. The gear 121 is driven by a hydraulic motor 124 which can be reversed, and actuator 135 cooperates with switches 136, 137 on the housing to indicate position. When the actuator 135 is intermediate of switches 136, 137, the cutters 126 are disposed in front of the rams and an inlet port 141 in a tank 140 is positioned opposite to an access port 142 in the housing. Thus, tank 140 can be charged with air under pressure through the access port 142 by attaching an air hose to port 141. Another actuator 160 is operated, and switch 156 can be actuated by a partial rotation of gear 121. Switch 156 actuates a valve 150 so that pressure is applied to the cutter 126 via a linkage 122. Actuator 160 is retracted and gear 121 rotated so that cutter 126 wears away a section of the pipe. As illustrated, cutter 126 cuts a section of pipe greater in width than the width of the rams. A stop 157 on the piston rod engages a stop 158 on the gear housing 121 to limit the inward travel of the cutter 126. After the pipe has been cut through, the actuator 135 is again positioned between switches 136, 137 so that actuator 160 can be operated. By partial rotation of gear 121, switch 159 is actuated so that the pressure in the hydraulic cylinder 125 is equalized and the cutters are retracted by the linkage. As the cutters are in front of the rams, the cutters are tilted out of the way of the forward sealing surfaces of the rams. The rams are then actuated to seal off the inner casing with respect to the outer casing.

The upper preventer unit 53 shown in FIG. 14 is actually rotated 90° so that the sealing rams 145, 146 are respectively disposed in one-half of the unit assembly for attachment with the pipe.

To control the hydraulic power for the cutters, an external conduit control may be provided by providing a passageway through gear 121. Gear 121 is, of course, mounted on roller bearings in a cage on the housing. The passageway is provided by half-moon openings with depending lip seals which traverse a port in the housing. There will, of course, be some discontinuity when the lip seals are displaced from the opening in the housing at the separation plane between the gear sections, but this does not present any undue difficulty. More than one external control conduit can be used as illustrated in FIG. 22.

It is also feasible to enclose the entire operation in a flexible air chamber to permit operations to be performed in other than a water environment as shown in FIG. 24.

Rather than operate on pipe strings individually and in sequence, in FIGS. 25-29, this embodiment contemplates but a single operation. In this operation, the cutting and sealing unit 205 intermediate of upper and lower sealing assemblies is arranged so that in a first operation the pipe conduits are severed by a milling cutter 222. The cutter is retracted and the unit closed off by a gate ram 227 which permits replacement of the cutter with a sealing unit. The sealing unit has a ram which traverses and closes off the unit so that control fluid can be applied to the pressurized conduit. It is apparent that while the sealing unit is illustrated as detachable, it can be incorporated in the unit diametrically to the cutter so that, upon retraction of the cutter, the sealing unit can be used to close off the bore.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A method for controlling pressure in a well string extending from a surface strata to a point above a water level and which includes at least one telescoping interior string of pipe comprising the steps of
 - sampling the pressure in the annulus between the interior string of pipe and the well string,
 - isolating a section of well string under water so that portions of the well string above and below the isolated section are supported relative to one another independently of the isolated section of well string,
 - sealing off the isolated section of well string at spaced apart locations to provide a sealed closed chamber about said section of well string between said locations,
 - cutting away a portion of said sealed off isolated section of well string within said chamber with a cutting means,
 - removing the cutting means from the well string, and
 - sealing off the cross-section of the cut-away portion of the isolated section of well string within said chamber.

2. The method of claim 1 wherein said well string includes at least two or more interior strings of pipe within the string of pipe, and the first step is to sample the pressure in each string of pipe.

3. The method of claim 2 wherein the steps of claim 1 are performed for each string of pipe.

4. A method for controlling pressure in a well string having multiple conduits and extending from a surface strata to a point above a water level, comprising the steps of

attaching a support frame under water for supporting portions of a well string above and below an isolated section relative to one another and independent from said isolated section,

tapping the well string to determine which conduit is under pressure,

stripping away any conduits not under pressure, attaching a bifurcated sealing unit to a conduit under pressure to seal against the outer wall of said conduit,

attaching a bifurcated cutting and sealing unit to said sealing unit,

attaching a bifurcated sealing unit to said cutting and sealing unit to seal against the outer wall of said conduit,

cutting away a peripheral section of said conduit with a cutting means, and

removing the cutting means and sealing off said conduit.

5. The method of claim 4 and further including the steps of pumping a control fluid into said conduit.

6. A method for controlling pressure in a well string extending from a surface strata to a point above a water level comprising the steps of

isolating a section of well string under water so that portions of the well string above and below the isolated section are supported relative to one another independently of the isolated section of well string, sealing off the isolated section of well string in an under water air chamber,

sealing off the isolated section of well string at spaced apart locations to provide a sealed closed chamber about said section of well string between said locations,

cutting away a portion of said sealed off isolated section of well string within said chamber with a cutting means,

removing the cutting means from the well string, and sealing off the cross-section of the cut-away portion of the isolated section of well string within said chamber.

7. Apparatus for obtaining control over an offshore well which includes one or more coextensively extending conduits comprising

means for coupling to a pipe conduit at spaced locations for supporting portions of said conduit above and below an isolated section relative to one another and independent from said isolated section,

means for sealing a pipe conduit at spaced apart locations and including means intermediate of said sealing means for cutting a pipe conduit and means independent from said cutting means for sealing off a cut pipe conduit, and

means for coupling to a pipe conduit and to a boat for transporting equipment to and from said pipe conduit.

8. Apparatus for obtaining control over an offshore well which includes one or more coextensively extending conduits comprising

means for coupling to a pipe conduit at spaced locations for supporting portions of said conduit above and below an isolated section relative to one another and independent from said isolated section,

means for sealing a pipe conduit at spaced apart locations and including slip means for gripping a conduit and preventing movement relative to said pipe conduit, upper and lower segmented sealing rings, pressure plate means disposed adjacent to said sealing rings and hydraulic means for applying pressure to said rings,

means intermediate of said sealing rings for cutting a pipe conduit, and

means independent from said cutting means for sealing off a cut pipe conduit.

9. The apparatus of claim 8 and further including means forming a pressure channel intermediate of said sealing rings, and means for coupling said pressure channel to a pressure device for determining the efficiency of the sealing rings.

10. The apparatus of claim 8 and further including mechanical means for maintaining a force on said rings.

11. The apparatus of claim 10 wherein said mechanical means includes a threaded jam member having a hydraulic passageway therethrough.

12. Apparatus for obtaining control over an offshore well which includes one or more coextensively extending conduits comprising

means for coupling to a pipe conduit at spaced locations for supporting portions of said conduit above and below an isolated section relative to one another and independent from said isolated section,

means for sealing a pipe conduit at spaced apart locations and including slip means for gripping a conduit and for preventing movement relative to said pipe conduit, means for normally retaining said slip means in a retracted position, means for actuating said slip means upon release of said retaining means,

means intermediate of said sealing means for cutting a pipe conduit, and

means independent from said cutting means for sealing off a cut pipe conduit.

13. Apparatus for obtaining control over an offshore well which includes one or more coextensively extending conduits comprising

means for coupling to a pipe conduit at spaced locations for supporting portions of said conduit above and below an isolated section relative to one another and independent from said isolated section,

means for sealing a pipe conduit at spaced apart locations and including means intermediate of said sealing means for cutting a pipe conduit, said intermediate means including a segmented annular ring member, means for rotating said ring member, cutting means attached to said ring member and

selectively movable between a position in contact with a pipe conduit and a retracted position, and sealing means independent from said cutting means movable transversely for sealing off a cut pipe conduit.

14. The apparatus of claim 13 and further including hydraulic means for operating said cutting means.

15. The apparatus of claim 14 wherein said hydraulic means includes at least one passageway extending through said ring member.

16. The apparatus of claim 14 wherein said hydraulic means includes at least two passageways extending through said ring member.

17. The apparatus of claim 14 wherein said cutting means are pivotally coupled to linkage means on said ring member and tiltable relative to the surface of a pipe conduit.

18. The apparatus of claim 17 and further including means for selectively operating said hydraulic means.

19. The apparatus of claim 17 wherein said hydraulic means includes a first piston and cylinder coupled to said linkage means, a power cylinder, and selectively operable valve means coupling said cylinders to one another.

20. The apparatus of claim 19 and further including means for selectively operating said valve means for moving said cutter means into and out of engagement with a pipe conduit.

21. Apparatus for obtaining control over an offshore well which includes one or more coextensively extending conduits comprising

means for coupling to a pipe conduit at spaced locations for supporting portions of said conduit above and below an isolated section relative to one another and independent from said isolated section,

means for sealing a pipe conduit at spaced apart locations and including means intermediate of said sealing means for cutting a pipe conduit and means independent from said cutting means for sealing off a cut pipe conduit, and resilient wall means forming an air chamber about said coupling and sealing means.

22. Apparatus for obtaining control over an offshore well which includes one or more coextensively extending conduits comprising

means for coupling to a pipe conduit at spaced locations for supporting portions of said conduit above and below an isolated section relative to one another and independent from said isolated section,

means for sealing a pipe conduit at spaced apart locations and including means intermediate of said sealing means, said intermediate means including a transverse bore for receiving a cutter,

means for cutting a pipe conduit disposed in said bore and movable for transversely severing said pipe strings, and

sealing means sized for reception in said bore for sealing off a cut pipe conduit.

23. The apparatus of claim 22 and further including gate means for sealing off said bore intermediate of said pipe strings and cutter means.

24. The apparatus of claim 22 wherein said sealing means includes selectively operable bypass means.

25. Apparatus for sealing off a pipe string comprising

sealing means engageable with the periphery of a pipe string,

means disposed in facing relationship to said sealing means for engaging said sealing means substantially around its periphery, said engaging means being segmented,

hydraulic means operative for forcing said engaging means against said sealing means for sealing the periphery of a pipe string, said hydraulic means including a piston and cylinder, and

mechanical means for additionally acting on said engaging means, said mechanical means including a rod member engaging said piston and having a hydraulic passageway therethrough.

26. The apparatus of claim 25 wherein said apparatus is in at least two segments, and means for coupling said segments to one another.

27. The apparatus of claim 26 wherein said apparatus includes upper and lower sealing and hydraulic means and an intermediate testing passage.

28. The apparatus of claim 27 and further including means on said apparatus for locking said apparatus to a pipe string to prevent longitudinal motion in at least one direction.

29. The apparatus of claim 28 wherein said locking means includes oppositely arranged slip means.

30. The apparatus of claim 29 including means for normally retaining said slip means in a retractable position and being releasable to permit said slip means to engage a pipe string.

31. Apparatus for cutting a string of pipe including a bifurcated housing member defining separate housing segments, each of said segments including a ring segment mounted on the housing for rotation about an axis means for driving said ring segment, cutter means on said segment including a linkage and actuate means, and

means for coupling said housing segments to one another, said ring segments having interconnections to form an annular ring member, and

said cutter means having an operative surface pivotally coupled to said linkage so that said surface is normal to said ring, said linkage being operable to move said surface relative to said ring member whereby said surface may be tilted relative to said member and transversely movable sealing members disposed below said ring member for sealing at a location above a string of pipe severed by said cutter means.

32. The apparatus of claim 31 wherein said housing member has an inlet port below said sealing members for injecting control fluids.

33. The apparatus of claim 31 wherein said actuating means includes a piston and cylinder coupled between said linkage and ring member for actuating said cutter means.

34. The apparatus of claim 33 and further including passage means extending through said ring member and coupled to said piston and cylinder.

35. The apparatus of claim 33 wherein said actuating means further includes tank means coupled to said piston and cylinder, and selectively operable valve means for controlling the pressure in said piston and cylinder.

36. The apparatus of claim 35, and further including passage means extending through said ring member.

37. The apparatus of claim 35, and further including selectively operable actuator means for operating said valve means.

38. The apparatus of claim 37, and further including means for indicating the position of said ring member. 5

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