United States Patent [19]

Carroll et al.

[11] **3,893,512**

[45] **July 8, 1975**

[54] **METHOD AND APPARATUS FOR CONTROLLING FLOW FROM WELLS**

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[73] Assignee: **Otis Engineering Corporation,** Dallas, Tex.

[22] Filed: **May 1, 1972**

[21] Appl. No.: **249,212**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 143,879, May 17, 1971, abandoned.

[52] **U.S. Cl.** **166/315**; 166/73; 166/127; 166/226

[51] **Int. Cl.** **E21b 23/00**

[58] **Field of Search** 166/72, 73, 127, 191, 209, 166/226, 237, 289, 290, 297, 313, 314, 315; 251/349, 353

[56] **References Cited**

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Assistant Examiner—Jack E. Ebel
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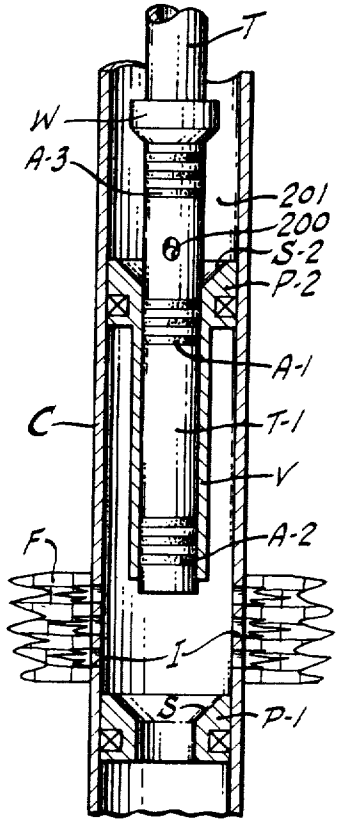
[57] **ABSTRACT**

Method of and apparatus for controlling flow from the producing formation of a well upon the occurrence of a disaster, an accident or a fire, which could result in turning the well loose for flow of well fluids from the well out of control for any reason, contemplating movement of the producing flow conductor or tubing string downwardly through at least one or more packers in the well bore, at least one above the producing zone, and where there are more than one producing zones, one above each producing zone and in most cases one below the lowest producing zone. The flow conductor or tubing string is provided with sealing sections connected therein of sufficient length to seal with the spaced packer or packers above and below the producing formation to close off entrance of well fluids into the conductor when it has moved downwardly to a lower position. Such downward movement may result from destruction of the suspension for the tubing string accidentally or intentionally upon the occurrence of a disaster or hazard. Means is disclosed for absorbing the shock of stopping the downwardly moving conductor and for closing the upper packer in the event the conductor parts and a shorter section passes completely through such upper packer. Means is disclosed for mechanically dropping the flow conductor and for hydraulically supporting and releasing the conductor by fluid control through the tubing or through a separate control line. Means is also disclosed for producing a formation through the annulus above a packer.

6 Claims, 15 Drawing Figures



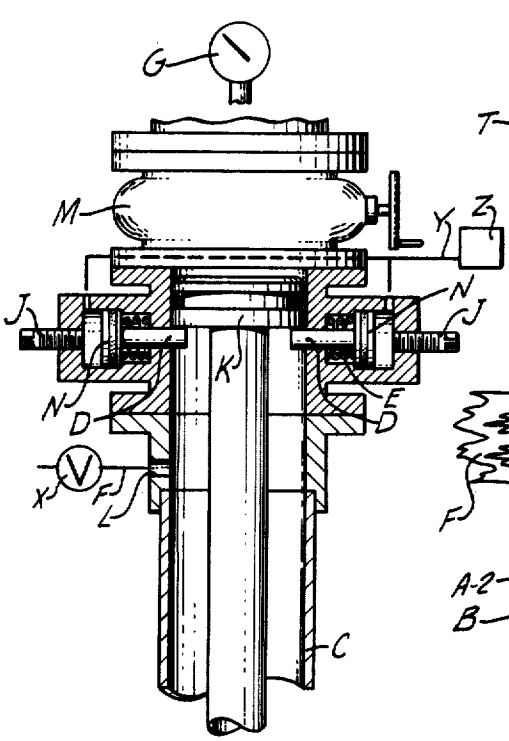


FIG. 1

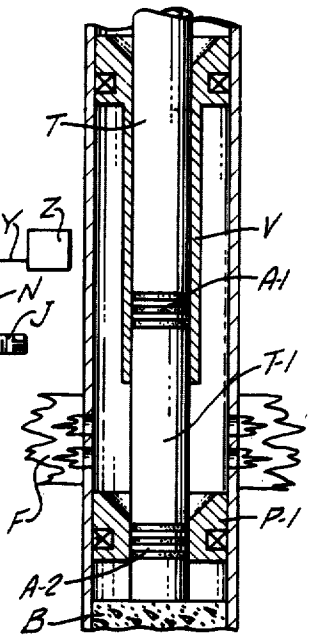
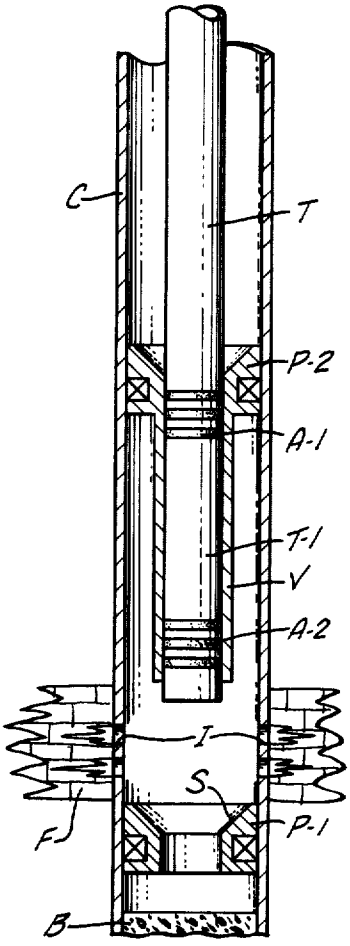


FIG. 2



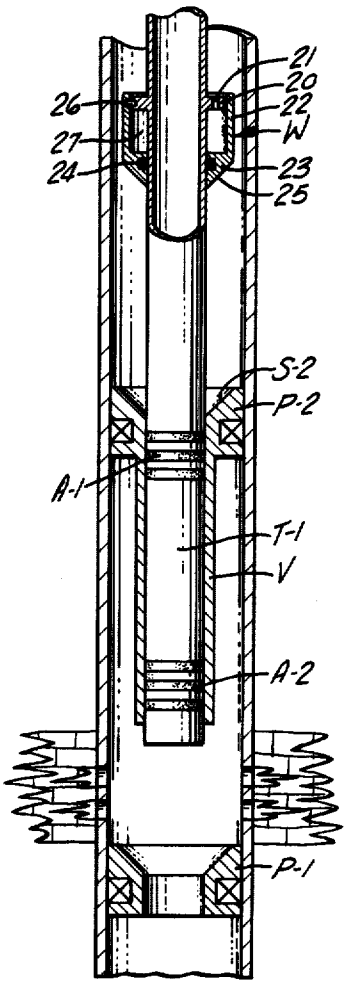
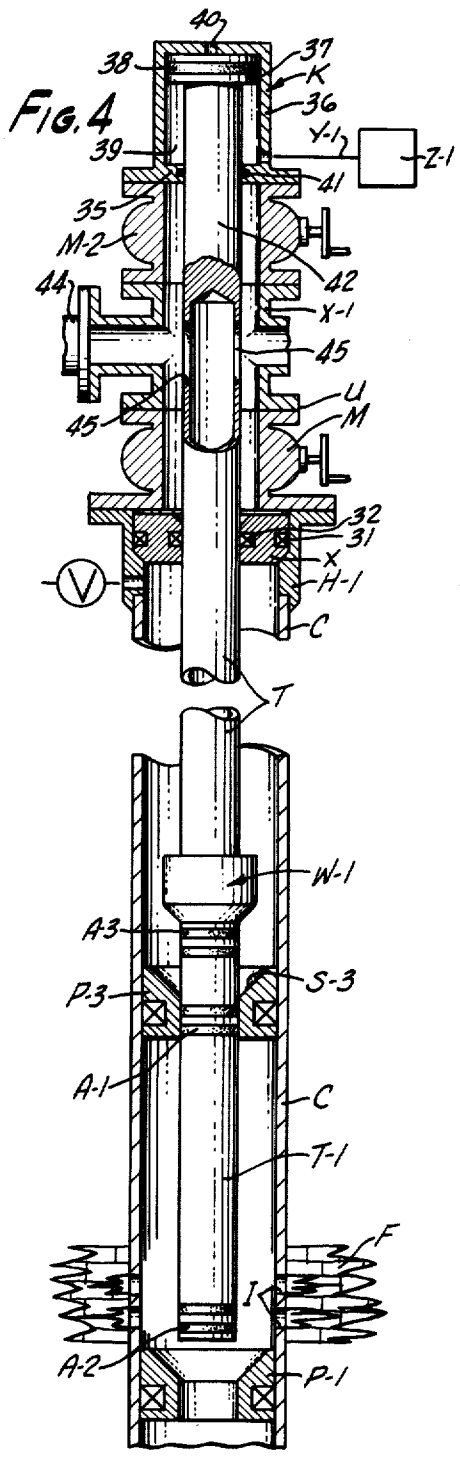


FIG. 3

FIG. 4



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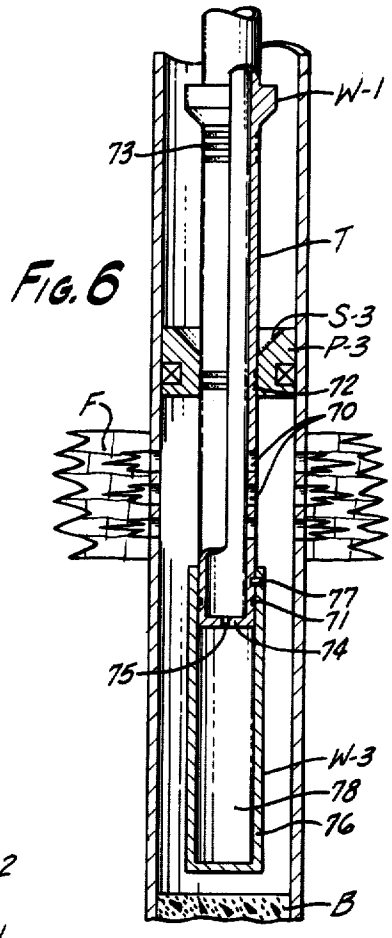
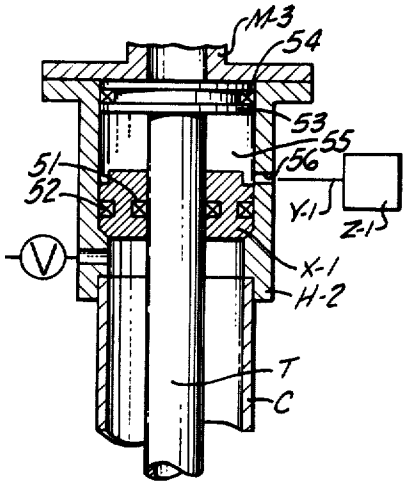


FIG. 6



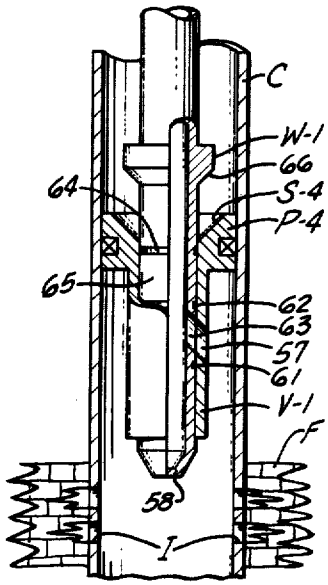


FIG. 5

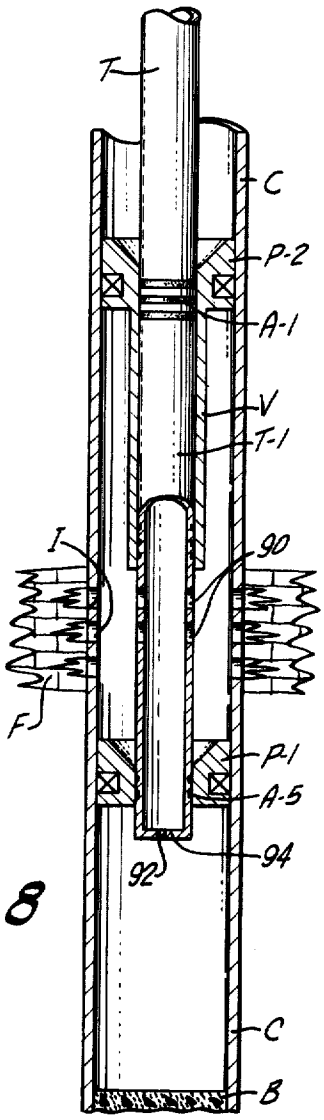


FIG. 8

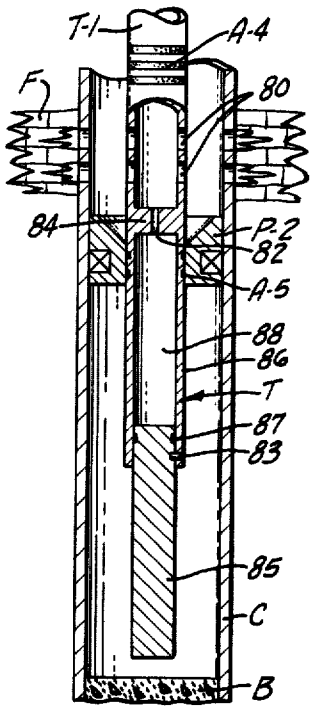


FIG. 7

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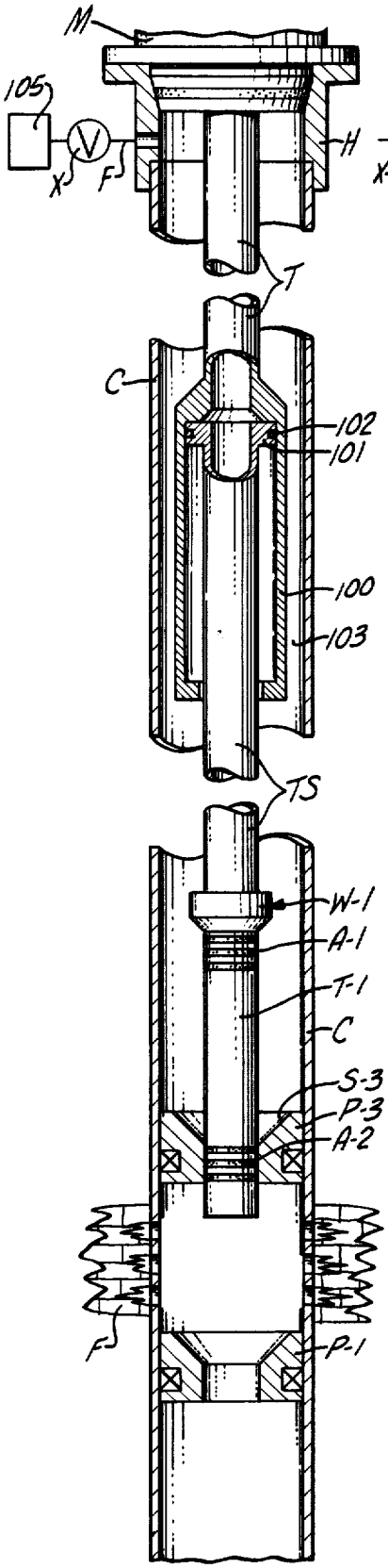

FIG. 9

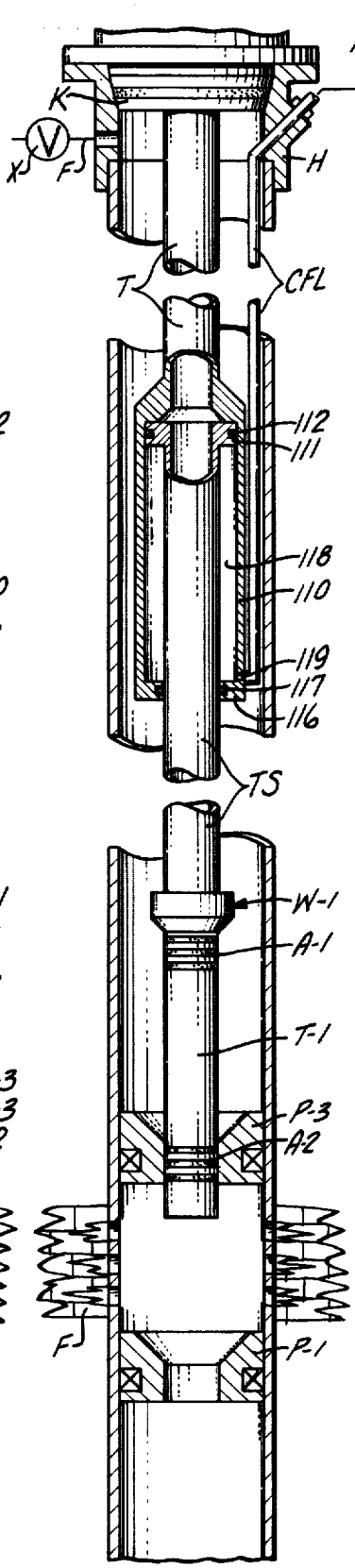

FIG. 10

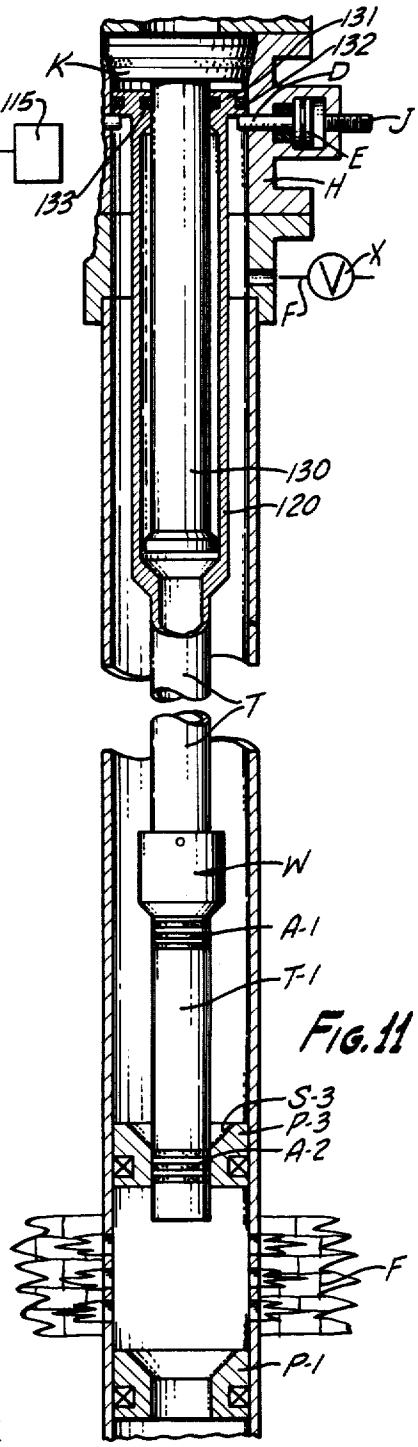

FIG. 11

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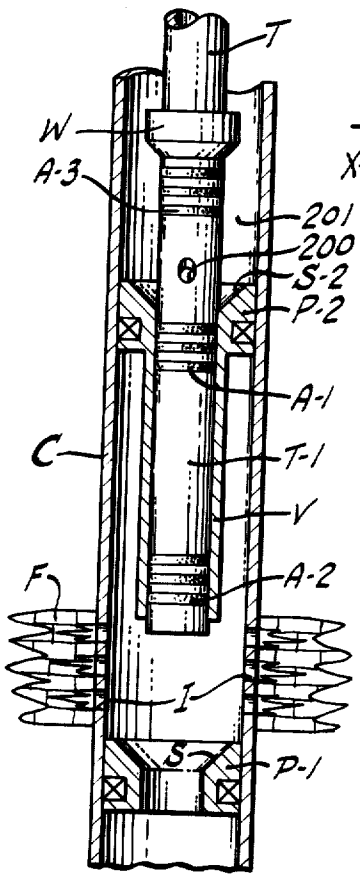
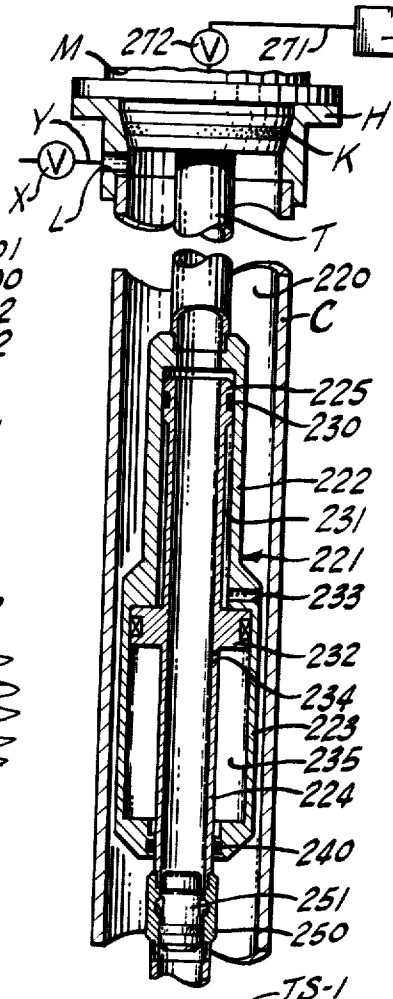
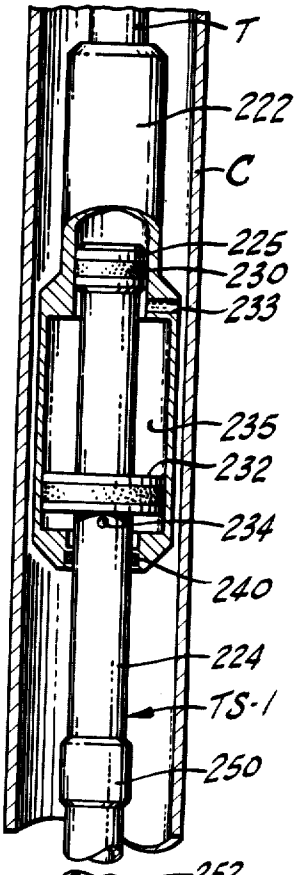


FIG. 12





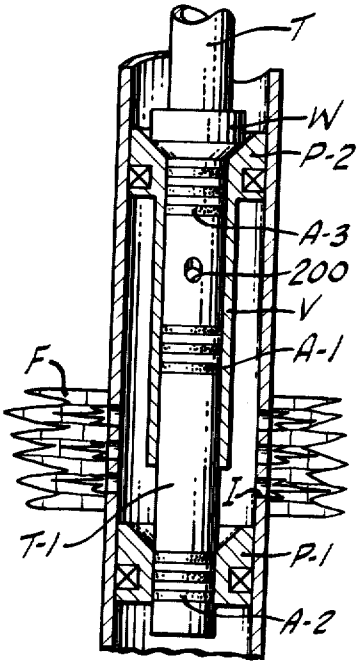


FIG. 13

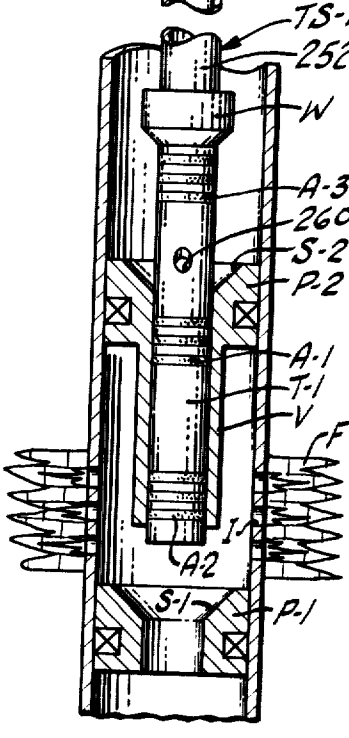


FIG. 14

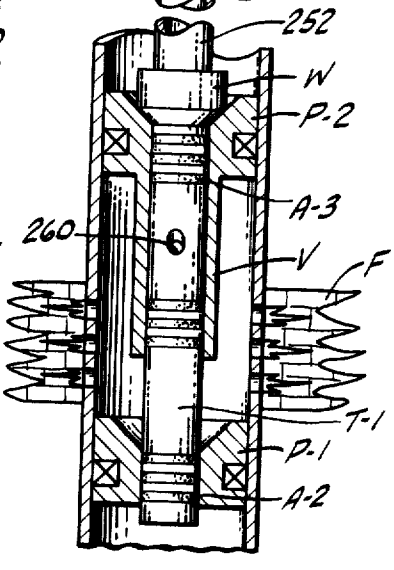


FIG. 15

METHOD AND APPARATUS FOR CONTROLLING FLOW FROM WELLS

This application is a continuation-in-part of our application Ser. No. 143,879 entitled METHOD AND APPARATUS FOR CONTROLLING FLOW FROM WELLS filed May 17, 1971 and now abandoned.

This invention relates to new and useful improvements in methods and means for controlling flow from the producing formation or formations of a well, in the event of the occurrence of a disaster or hazardous condition.

It is one object of the invention to provide a system for controlling the flow of well fluids from the producing formations of a well by lowering the production flow conductor through a packer positioned above the producing formation, or a pair or more of packers positioned one above and one below each producing formation, to provide an imperforate section of conductor exposed to fluids from the producing formation to close off admission of such well fluids into the flow conductor and so close off flow from the producing formation or formations.

A particular object of the invention is to provide a system, method and apparatus for closing off flow of well fluids from the producing formation of the well in the event of the occurrence of a disaster or dangerous condition by means of the flow conductor or tubing string being moved to position an imperforate section of such tubing string in a position exposed to the producing formation and sealing with the packers above or above and below the producing formation to prevent the fluids from the producing formation from entering the flow conductor.

An important object of the invention is to provide a method and apparatus for closing off the producing formation or formations of a well, in the event of the occurrence of a disaster or hazardous condition, to prevent the uncontrolled escape of well fluids from the well bore, and in which the closure is effected automatically by movement of the production flow conductor upon release of the suspension therefor, or destruction of such suspension intentionally produced to deliberately free the tubing for movement downwardly in the well bore.

A further object of the invention is to provide means for absorbing the shock of lowering the flow conductor in the well to position an imperforate section thereof in sealing engagement with a well packer and the imperforate section exposed to the producing formation.

Still another object of the invention is to provide a well installation in which the tubing string or flow conductor is suspended at the surface in a manner in which the string may be lowered when desired to permit movement of an imperforate section of the conductor adjacent the producing formation into a position exposed to the producing formation for closing off flow from the producing formation into the flow conductor.

Still another object of the invention is to provide a means for suspending a section of tubing in a position permitting flow from a well producing formation and wherein means is provided to permit downward movement of each suspended tubing section to position an imperforate section thereof exposed to the producing formation to close off flow of well fluids into the tubing.

A further object is to provide in a well installation of the character set forth means for suspending a movable section of tubing in a position permitting flow from the well producing formation releasable to permit said suspended tubing section to move downward to close the inlet into the tubing to close off flow of well fluids from the producing formation into and up through the tubing to the surface and wherein said suspending means is operable to lift the movable section of tubing to the original position reopening the inlet into the tubing for permitting flow of well fluids from the producing formation through the tubing to the surface.

A further object is to provide a well installation of the character described wherein the suspended tubing section is supported and controlled by fluid pressure communicated through a control line extending from the surface through the annulus into an annular cylinder around the suspended tubing section for applying fluid pressure to an annular piston on the tubing section in the cylinder.

It is another object of the invention to provide a well installation of the character described wherein the fluid pressure to the control cylinder for the suspended tubing section is communicated through the main tubing string in the well.

It is a still further object of the invention to provide well installation of the character described having a part in the tubing section positioned so that the well produced through the annulus above a packer thereby providing substantially greater cross sectional area for flow along a major portion of the well than available through only the tubing employed.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, wherein:

FIG. 1 is a schematic view, partly in elevation and partly in section, of a well installation having a flow controlling system and apparatus therein for practicing the method of the invention;

FIG. 2 is a schematic view of the lower portion of the well installation of FIG. 1 showing the tubing string moved downwardly to close off flow from the producing formation into the tubing string;

FIG. 3 is a view of the lower portion of well flow conductor in a well installation similar to that of FIG. 1 provided with shock absorber means for absorbing the shock of stopping the downward movement of the flow conductor in the well;

FIG. 4 is a schematic view, similar to FIG. 1, of modified form of well installation and suspension for the tubing string and for controlling the movement of the tubing string in the well;

FIG. 5 is a view, similar to FIG. 4, of a modified form of packer and seal arrangement for cutting off admission of well fluid from the producing formation into the flow conductor or tubing string;

FIG. 6 is a view, similar to FIG. 3, of a further modified form of flow conductor installation and shock absorber in inlet seal structure;

FIG. 7 is a view similar to FIG. 6, showing a further modified form of shock absorber and inlet seal structure;

FIG. 8 is a view, similar to FIGS. 6 and 7, showing a further modified form of shock absorber and seal inlet for the flow conductor;

FIG. 9 is a schematic view of a well installation, partly in elevation and partly in section, showing a modified form of suspension for the lower portion of

the tubing string in the wall bore for controlling movement of such portion to close off flow from the well producing formation;

FIG. 10 is a view, similar to FIG. 9, showing a slightly modified version of the suspension for the lower section of the well flow conductor; and,

FIG. 11 is a schematic view, similar to FIG. 4, showing a further modified form of suspension for the flow conductor permitting movement of the conductor to close off flow from the producing formation.

FIG. 12 is a fragmentary schematic view in section showing the lower portion of a well installation similar to that in FIG. 1 including a modified form of lower tubing section for producing the well above the upper packer through both the tubing string and the annulus;

FIG. 13 is a fragmentary schematic view in section of the well installation of FIG. 12 showing the lower tubing section at a bottom position for cutting off admission of well fluids into the flow conductor;

FIG. 14 is a broken fragmentary schematic view in section of another modified form of well installation showing fluid pressure controlled apparatus for suspending a lower section of the tubing string and controlling the position of the section from the surface through the main tubing string and means for producing the well through the annulus above the upper packer; and

FIG. 15 is a broken fragmentary schematic view in section showing the tubing section apparatus of FIG. 14 moved downwardly to shut off admission of well fluids to the flow conductor from the producing formation.

In the drawings, FIG. 1 schematically illustrates a well installation having a string of well casing C extending downwardly into the earth and through a producing formation F. The lower portion of the bore of the casing may be plugged, as by means of a cement plug B in the usual manner. A first production packer P-1, such as the well known Baker Model D production packer, is anchored in the casing below the perforations I in the casing leading to the producing formation F, and has a downwardly tapered guide surface S formed in the upper end of its bore for a purpose to be more fully described hereinafter. A second packer P-2, which may also be a Baker Model D production packer, is anchored in the casing C above the perforations I and has an elongate depending protecting and sealing sleeve V secured to its lower end and depending therefrom.

A string of tubing T has a plurality of seal assemblies or packing subs A-1 and A-2 connected therein and spaced along the length of the string of tubing a sufficient distance to provide an imperforate section T-1 therebetween which is of sufficient length to extend from the uppermost packer P-2 through the lowermost packer P-1 when the tubing string is for any reason moved downwardly in the well casing to the position shown in FIG. 2, to position the imperforate section T-1 between the packers P-1 and P-2 to close off admission of well fluids from the producing formation F into the bore of the tubing string. The upper seal assembly A-1 will seal between the tubing string and the depending sleeve V while the lower seal assembly A-2 will seal between the tubing string and the lower packer P-1, as shown in FIG. 2, with the imperforate section T-1 of tubing disposed therebetween.

The upper end of the tubing string T is supported in a well head H by a hanger K. The hanger seals between the well head and the upper end of the tubing string and directs fluids flowing upwardly through the tubing through the master valve M and the Christmas tree of the well thereabove having the gauge G at the upper end thereof, in the usual manner. A lateral casing flow port or circulation port L is formed in the tubing head and a lateral flow line F is connected thereto and has a casing flow valve X connected therein in the usual manner. The well head H is of the type having laterally movable supporting or suspending locking members or dogs D which engage beneath the hanger K and support the same in the well head. The dogs or suspending locking members D are normally biased outwardly from supporting position by springs E, and are either mechanically moved inwardly to supporting position by threaded lock bolts J or are hydraulically moved in by pistons N which are actuated by control fluid from a source of control fluid pressure Z communicating with the pistons by means of a control fluid line Y leading to the lateral cylinder on the tubing head in which each of the pistons is movable. Thus, it will be seen that the control fluid pressure in the cylinder may be released or reduced to permit the springs to move the dogs D outwardly from below the hanger K to permit the tubing string to drop or move downwardly in the well bore, should a fire or other disaster or dangerous condition occur. When the tubing T moves downwardly, the lower packing sub A-2 will move into sealing engagement with the bore wall of the lower packer P-1 and the upper packing sub A-1 will move downwardly in the depending sealing sleeve V to move the imperforate section T-1 of the tubing into position between the packers to close off admission of well fluids from the producing formation F into the tubing. Thus, any escape of well fluids from the producing formation to the surface is prevented at the lower end of the well bore and the danger of fire or other loss of well fluids which would result in pollution or contamination of the surrounding area is eliminated.

The tubing might also be dropped accidentally or intentionally, as when a vessel struck the tubing head H or Christmas tree of the well head in a submarine installation, or the hanger or suspension of the tubing head H is destroyed by shooting the same off with a charge of dynamite or a cannon, or in the event a leak occurs at the Christmas tree resulting in fire and sufficient damage to the well head, which would cause the tubing head to release the hanger and permit the tubing to drop in the well casing.

Upon occurrence of any of the conditions which would result in dropping the tubing, the well would otherwise flow wild through the casing and tubing if the imperforate section T-1 of the tubing string were not moved downwardly from the position shown in FIG. 1 to the position shown in FIG. 2 to close off flow of well fluids from the producing formation into the tubing and upwardly through the tubing or casing to the surface and thus prevent such uncontrolled escape of well fluids from the well.

Thus, a positive and quick closure is provided for preventing escape of well fluids in an uncontrolled manner from the producing formation through the casing or tubing to the surface, to prevent pollution of surrounding areas, or water if a marine installation, and eliminating the danger of fire from combustible well fluids which would otherwise exist.

It will be seen that the system includes the dropping of the tubing or flow conductor, either intentionally by

releasing the hanger K or accidentally by damage to the well head H, such freeing of the hanger from suspended position permitting downward movement of the tubing string to close off flow.

The downward movement of the tubing T in FIGS. 1 and 2 is limited by the engagement of the lower end of the tubing string with the cement plug B at the bottom of the well or by engagement with the bottom of the well bore itself. However, if desired, in wells in which the depth of the well below the lower packer P-1 is sufficiently great to prevent the use of the lower end of the tubing string as a stop to position the sealing assemblies A-1 and A-2 in the packers P-2 and P-1, respectively, a stop and shock absorber W may be connected in the tubing string above the upper packing assembly A-1 as shown in FIG. 3. This stop and shock absorber assembly would engage the downwardly tapered surface S-2 of the upper packer P-2 to suspend the tubing from the upper packer with the upper packing sub A-1 engaged in sealing position in the sleeve V and the lower packing sub A-2 in sealing engagement with the lower packer P-1. It would not be necessary that the lower end of the tubing extend to the bottom of the well or the plug therebelow, in this case.

The stop and shock absorber comprises of a piston 20 having a vent port 21 therein, in a cylinder 22 slidable on the tubing and having its lower end closed by an inwardly projecting stop flange 23 with a seal ring 24 disposed in an internal annular recess in the flange slidably sealing against the exterior of the tubing string. The stop flange has a beveled or tapered lower surface 25 which is disposed to engage the complementary beveled or tapered surface S-2 of the upper packer to stop downward movement of the tubing. When the flange 23 engages the beveled surface S-2, a shear pin 26 which releasably connects the cylinder 22 to the piston 20 will be sheared and the cylinder may move upwardly with respect to the piston. A heavy grease, such as water pump grease or the like, confined within the chamber 27 in the bore of the cylinder below the piston will be extruded slowly through the port 21 to permit the tubing string to be stopped in a gradual manner to absorb the shock of stopping downward movement of the tubing string, and so prevent damage to the packer and the tubing string thereabove.

The spacing of the stop and shock absorber W from the upper packing assembly A-1 and the lower packing assembly A-2 is such that when the downward movement of the tubing string is stopped by the stop and shock absorber engaging the surface S-2 of the upper packer P-2 the lower seal assembly A-2 is disposed in the bore of and in sealing engagement with the lower packer P-1, while the upper seal assembly A-1 seals with the sealing sleeve V.

While, in each case, the seal assemblies have been described as being on the tubing string, it is believed obvious that suitable seals may be provided in the bore of the packers P-1 and P-2 and in the bore of the sleeve V, and sealing subs having polished sealing surfaces connected in the tubing string if desired.

A modified form of well installation is shown in FIG. 4, wherein the tubing T is suspended at the upper end of the casing in a different manner from the suspension illustrated and described in connection with FIGS. 1 and 2. In this form, the tubing extends through the tubing head H-1 and is slidable through a hanger seal ring X having seal members 31 and 32 disposed in external and internal annular grooves in the ring and sealing between the tubing head H-1 and the tubing string T. The upper end of the tubing extends upwardly through the Christmas tree U, which may have the usual master valve M and flow cross X-1 and swabbing valve M-2 connected therein above the tubing head. The upper end of the tubing is connected to a rod 42 which extends upwardly through an internal seal flange head 35 at the lower end of a suspension cylinder 36 in the hanger K to a piston 37 connected to the upper end of the rod and which has a seal 38 disposed in an external annular recess thereon for sealing between the piston and the cylinder bore wall in the chamber 39. Operating control fluid pressure from a supply source Z-1 is conducted by means of a control fluid line Y-1 to a lateral port opening into the chamber or cylinder bore 39 below the piston 37 for acting on the piston to move the piston upwardly and lift the rod and tubing suspended therefrom. A vent 40 is formed in the upper end of the cylinder 36 to permit free upward movement of the piston in the cylinder. The control fluid is confined in the chamber 39 by the seal ring 41 disposed in an internal annular groove in the inwardly projecting head or flange 35 of the hanger K connected to the upper end of the valve M-2 and sealing around the solid rod 42 for lifting and lowering the tubing suspended therebelow. A plurality of lateral ports 45 are formed in the wall of the tubing string below the rod 42 and communicate with the flow cross X-1 above the hanger seal ring X for permitting well fluids produced upwardly through the tubing string to flow outwardly through the lateral flow wing 44 connected to the flow cross X-1 and to the usual surface flow lines of the well installation. It will thus be seen that the tubing string may be moved upwardly or downwardly by introducing or withdrawing or venting control fluid from the chamber 39 to permit the piston to move in the cylinder and lift or lower the tubing string suspended therefrom.

In the well casing, on the lower side of the producing formation F, the lower packer P-1 is identical to that of the installation first described. The upper packer P-3 is substantially identical to the packer P-2, but does not have the depending sealing sleeve V connected thereto. Also, the tubing string below the stop member W-1 is provided with an upper seal assembly A-3 immediately below the stop member, and the seal assembly A-1 is spaced therebelow and seals with the bore of the packer P-3 when the tubing is in the normal well flowing position shown. The lower seal assembly A-2 is spaced below the seal assembly A-1 near the lower end of the tubing string and below the imperforate section T-1 between the seal assemblies A-1 and A-2. Thus, when the tubing string is lowered until the stop W-1 engages the tapered surface S-3 of the upper packer P-3, the seal assembly A-3 will engage the packer P-3 and seal between the tubing and the packer to close off flow upwardly through the annular space. Similarly, the lower seal assembly A-2 will engage the lower packer P-1 to seal off between the tubing and the packer and position the imperforate tubing section T-1 between the packers to close off flow from the formation through the perforations I into the tubing string.

Thus, the well formation may be closed off in the same manner as in the form previously described. In this installation, however, it is not necessary that the tubing string be dropped, as by releasing a hanger or destroying the tubing head. Instead, the control fluid

pressure in the chamber **39** may be released or reduced and the piston **37** will move downwardly to lower the rod **42** and the tubing string T connected therewith downwardly to permit the seal assemblies A-3 and A-2 to engage the packers P-3 and P-1 to close off flow from the producing formation upwardly through the well casing or tubing. Otherwise, this form of the device functions in the same manner as that of the form first described.

When it is desired to again place the well in production, control fluid pressure may be introduced into the chamber **39** to move the piston upwardly to lift the rod **42** and the tubing string T to the position shown in FIG. **4**, wherein the lower open end of the tubing is again in communication with the producing formation through the perforations I. By use of this form of the device, the well may be shut in at the producing formation between the packers by movement of the imperforate section and seal members into position between the packers to close off admission of well fluids into the tubing string. This will permit any service operation desired to be performed on the surface connections of the well without danger of the well flowing wild, or fire, or the like.

A futher modified form of the suspension and seal arrangement is shown in FIG. **5**, wherein the tubing string T extends upwardly through the well head H-2 and a hanger seal ring X-1 disposed in said well head and having internal and external seal rings **51** and **52**, respectively, sealing between the tubing and the well head and permitting longitudinal movement of the tubing through the hanger seal ring. A piston **53** is connected to the upper end of the tubing string T and has a seal member **54** disposed in an external annular groove thereon and sealingly engaging the bore of the well head H-2 above the hanger seal ring X-1. The chamber **55** between the hanger seal ring X-1 and the piston receives control fluid from a source Z-1 of control fluid pressure conducted through a control fluid line Y-1 to a port **56** opening into the chamber **55** in the well head. A master valve M-3 may be connected to the upper end of the well head and the usual Christmas tree components (not shown) may be connected to the upper end of the master valve in the usual manner. The open upper end of the tubing string T opens through the piston **53** and flows through the master valve M-3 and the well Christmas tree thereabove in the usual manner. The tubing is raised and lowered by movement of the piston **53** as a result of the introduction of withdrawal of control fluid into the chamber **55** in the upper portion of the well head H-2. The tubing may thus be raised or lowered in the same manner as in the installation of FIG. **4**.

At the lower end of the tubing string a single packer P-4 is secured in the well casing C above the producing formation F and the inlet perforations I. This packer has a depending valve or sealing sleeve V-1 connected to its lower end and extending downwardly therefrom. A lateral port **57** is formed in the wall of the valve sleeve V-1 intermediate its ends and the lower end of the tubing string has a closure head **58** closing its lower end and is provided with a pair of longitudinally spaced seal assemblies **61** and **62**, respectively, below and above the lateral port **63** formed in the side wall of the tubing and disposed to communicate with the lateral port **57** in the valve sleeve V-1. An upper seal assembly **64** is also connected in the tubing below a stop member W-1 and spaced longitudinally above the seal assembly **62** to provide an imperforate section **65** between said seal assemblies above the lateral port **63** in the tubing. Thus, when the tubing is lowered until the stop member W-1, which may be a solid external annular flange having a tapered lower surface **66**, engages the upwardly facing tapered seat or stop surface S-4 of the packer P-4, the imperforate section **65** of the tubing is disposed across the lateral port **57** of the valve sleeve V-1 and the seal assemblies **62** and **64** seal with the sleeve V-1 on opposed sides of the lateral port **57** to close off admission of well fluids into the tubing. Similarly, the seal assemblies **61** and **62** seal against the bore wall of the valve sleeve V-1 to close off admission of fluids from the producing formation through the lateral port **63** in the tubing, and so close off entry of well fluids from the well producing formation into the tubing string.

This installation provides means for closing off the flow of well fluids from the producing formation in the tubing by utilizing a single packer with the sleeve valve structure described. The tubing is shown as movable by means of the piston arrangement shown, but obviously the other types of suspension for the tubing may be utilized and the tubing may be lowered in any other suitable manner. Similarly the stop flange W-1 might be replaced by the stop and shock absorber W of FIG. **3**, if desired. In each case the flow of well fluids from the producing formation into and upwardly through the tubing string and annulus is prevented by the positioning of an imperforate section of tubing and seal means in position to close off entry of fluids into the tubing string.

In FIG. **6** a modified form of shock absorber and seal structure is shown, wherein a single packer P-3, similar to the packer P-3 of FIG. **4**, is set in the casing C above the producing formation F, and the tubing extends downwardly therethrough. A stop W-1 is connected in the tubing string above the packers and is disposed to engage the upper downwardly tapered surface S-3 of the packer P-3 to limit downward movement of the tubing with respect to the packer. Lateral ports **70** are formed in the tubing near the lower end thereof and disposed below the packer between a lower external annular seal ring assembly **71** below the ports and an intermediate external annular seal ring assembly **72** on the tubing above the lateral ports **70**. Well fluids may enter through the lateral ports **70** and flow upwardly through the tubing from the producing formation F. A shock absorber W-3 is shown connected to the lower end of the tubing string T below the packer P-3.

The tubing is provided with a flow restricting closure **74** in its lower end having an orifice **75** therein and the tubing slides in a cup-like cylinder **76** which is closed at its lower end and is secured by means of a shear pin **77** to the tubing string in a position in which the cylinder **76** extends below the tubing string and provides a chamber **78** in the bore of the cylinder below the flow restricting closure **74** at the lower end of said tubing string. The lower seal ring assembly **71** on the tubing string seals between the tubing and the bore wall of the cylinder **76**.

The chamber may be filled with a heavy grease or the like so that when the tubing string moves downwardly or is dropped, the shear pin **77** will be sheared and the grease in the chamber **78** will be forced slowly through the orifice **75** as the tubing string moves further downwardly with respect to the cylinder. The downward

movement of the cylinder **76** is stopped by engagement of its lower end with the cement plug B at the lower end of the well casing and the tubing string will continue to move downwardly until the stop member W-**1** above the upper seal ring assembly **73** engages the tapered surface S-**3** of the packer P-**3**. The downward movement of the tubing string and the shock of stopping the same is damped by the shock absorbing effect of the grease contained in the chamber **78** being forced slowly outwardly through the orifice **75** as the tubing moves downwardly.

When the tubing has moved downwardly to its lowermost position with the stop shoulder W-**1** engaging the surface S-**3** of the packer, the intermediate seal ring assembly **72** is disposed in the bore of the cylinder **76** below the shear pin **77** and the ports **70** in the tubing well are thereby sealed off and closed by the imperforate cylinder walls of the cylinder **76** to prevent well fluids from flowing into the tubing string from the producing formation. Also, the upper seal ring assembly **73** seals with the packer P-**3** to prevent flow upwardly in the tubing-casing annulus thereabove. This modified form of shock absorber and seal assembly for use with the tubing string thus serves to close off flow of well fluids from the producing formation into the tubing and upwardly through the annulus.

A further modified form of the shock absorber and seal ring assembly is shown in FIG. **7** wherein the tubing string T has a flow restricting orifice member **84** connected therein below the lateral ports **80** which are disposed to receive well fluids from the producing formation F. An intermediate seal ring assembly A-**4** is connected to the tubing string above the lateral ports **80** and below the imperforate section T-**1** of the tubing, while the lower seal ring aseembly A-**5** is connected on the tubing string below the ports **80**. The tubing string extends downwardly from the orifice member **84** to provide a cylinder **86** having a chamber **88** therein in which an elongate closure plug **85** is slidable. The elongate closure plug **85** has an O-ring seal **87** thereon sealing between the upper end of the plug and the bore wall of the piston cylinder **86**, and a shear pin **83** connects the plug **85** to the lower end of the tubing string and holds the same against movement therein. The chamber **88** is filled with a heavy grease, such as water pump grease or the like, and when the tubing string is dropped or moved downwardly for any reason, the shear pin **83** is sheared when the plug **85** hits the cement plug closure B at the lower end of the casing C. The plunger **85** then moves upwardly in the cylinder **86** and forces the grease from the chamber **88** through the orifice **82** of the orifice member **84** to slowly stop downward movement of the tubing string and absorb the shock of stopping such movement. The engagement of the lower end of the skirt **86** with the concrete plug B may limit downward movement of the tubing string and position the intermediate seal ring assembly A-**4** in the packer P-**2** to seal off and prevent well fluids from entering through the ports **80** into the tubing string. Above the producing formation, an upper packer, stop member and upper seal ring assembly, not shown but identical to that of FIG. **6**, will prevent upward flow from the producing formation through the annulus.

Still another form of the shock absorber and seal assembly is shown in FIG. **8**, wherein a packer P-**1** is disposed below the producing formation while a packer P-**2** having the elongate sealing sleeve V connected to the lower end thereof and depending therefrom is positioned in the well casing C above the producing formation in the same manner as the installation of FIG. **1**. The tubing string T has an extension thereof extending through the lower packer P-**1** into the well bore below such packer. A lower seal assembly A-**5** is connected in the lower portion of the tubing string above an orificed plug closure **94** at the lower end of the tubing string having a flow restricting orifice **92** therein. The seal assembly A-**5** seals between the lower end of the tubing string and the packer P-**1**. Lateral inlet ports **90** are formed in the wall of the tubing string above the seal ring assembly A-**5** and below an intermediate seal assembly A-**2** which is disposed in sealing engagement with the lower portion of the bore wall of the valve sealing sleeve V. An upper seal assembly A-**1** also is disposed in the sealing sleeve V in the same manner as in the structure of FIG. **1**, and the imperforate section T-**1** of the tubing is connected between the seal ring assemblies A-**1** and A-**2** in the same manner as in FIG. **1**.

With this installation, the well fluids are permitted to flow from the formation through the perforations I inwardly through the lateral ports **90** in the wall of the tubing string and upwardly through the tubing string to the surface. When it is desired to shut off flow, the tubing string is lowered or dropped, in the same manner as has already been described in connection with the other forms of the invention, until the seal assembly A-**2** is disposed in the bore of the packer P-**1**. This positioning of the seal assembly A-**2** in the packer P-**1** is accomplished as a result of the lower end of the tubing string engaging the concrete plug or block B at the lower end of the bore of the casing C. The fluid contained in the bore of the casing below the packer P-**1** will slowly flow through the orifice **92** into the tubing string as the tubing string moves downwardly and so act as a shock absorber or damper for slowing movement of the tubing as it moves downwardly until the lower end thereof engages the concrete plug B. In such a lower position, the seal ring assembly A-**2** seals with the lower packer P-**1** while the upper seal ring assembly A-**1** seals against the bore wall of the sealing sleeve V, and the imperforate section T-**1** of the tubing is disposed between the upper and lower packers and closes off admission of well fluids from the producing formation into the tubing. This is a modified form of damper and shock absorber for limiting or dampening the effect of dropping and stopping downward movement of the tubing.

A further modified form of suspension for the tubing string and seal sub assembly, which is adapted to be lowered in the well to engage a pair of spaced packers on opposite sides of the producing formation in the well, is shown in FIG. **9**, wherein the upper end of the tubing string T is suspended at the surface from a hanger K in a tubing head H in the well known manner. The master valve M is connected to the upper end of the tubing head for controlling flow from the tubing. The casing lateral flow valve X and the casing flow line F are connected to the tubing head in the manner previously indicated.

The tubing string extends downwardly to a predetermined depth in the casing, and has a lower portion TS therebelow which is movably supported in an upper position by means of an actuating cylinder **100** having a bore in which a piston **101** is slidable. A seal **102** on the piston seals between the piston and the bore wall of the

cylinder **100** to provide a continuous flow path through the lower tubing section TS and the cylinder **100** to the tubing T and the surface in the usual manner. The lower end of the lower tubing section TS has a support and stop member W-1 connected thereto above an imperforate tubing section T-1 connected between an upper seal assembly A-1 and lower seal assembly A-2 near the lower end of the lower tubing section. An upper packer P-3 is disposed in the casing C above the producing formation F and a lower packer P-1 is mounted in the casing below the producing formation in the same manner as in the installation of FIG. **4.** The length of the imperforate tubing section T-1 and the packing subs or assemblies A-1 and A-2 is such that when the lower tubing section TS is lowered to move the stop member W-1 into engagement with the beveled surface S-3 of the upper packer P-3, the upper packing A-1 will engage and seal with the packer P-3 while the lower packing assembly A-2 will engage and seal with the lower packer P-1, and the imperforate section will close off flow from the producing formation into the tubing.

The tubing section TS and the imperforate tubing section T-1 connected thereto are held in the upper position shown in FIG. **9** by fluid pressure from the casing-tubing annulus **103** which is introduced into the annulus below the hanger K through the casing flow line F and valve X from a source of pressure **105** connected to said flow line. The pressure is sufficient to move the pistion **101** upwardly in the cylinder **100** against the pressure of well fluids in the cylinder above the piston and lift the lower tubing section TS and the imperforate tubing section T-1 to the upper position shown. Should a condition arise at the surface which reduces the pressure of the operating fluid from the source **105** acting on the piston **101**, the lower tubing section TS and the imperforate tubing section T-1 will move downwardly to close off flow from the producing formation into the lower open end of the tubing string below the seal assembly A-2 in the manner already described, by the imperforate section and the two packing assemblies A-1 and A-2 into flow closing engagement with the upper and lower packers P-3 and P-1, respectively.

A modified form of the device of FIG. **9** is shown in FIG. **10**, wherein a separate control fluid line CFL is directed from the surface to an enclosed cylinder **110** which has a closure head **116** at its lower end and a seal **117** in an internal annular groove therein slidably sealing between the closure head and the exterior of the lower tubing section TS. The piston **111** at the upper end of the tubing section TS is slidable in the bore of the cylinder **110** and the seal ring **112** in an external annular groove in the piston seals between the piston and the bore wall of the cylinder. Thus, a chamber **118** is formed in the cylinder between the closure head **116** and the lower side of the piston **111**, whereby control fluid pressure from the control fluid line CFL directed through an inlet port **119** into the chamber **118** will move the piston upwardly and so lift the lower tubing section TS and the stop member W-1 with the imperforate tubing section T-1 and the upper and lower seal subs A-1 and A-2, respectively, to the upper position. Control fluid is directed from a source **115** at the surface into the control fluid line entering through the well head H below the hanger K by which the tubing string T is supported in the usual manner.

The manner of sealing and closing off flow from the producing formation F in this modification is the same as that of the device of FIG. **9.** Rather than utilizing the casing tubing annulus as a conductor, the control fluid line CFL is used to direct the control fluid from the source of pressure **115** into the chamber **118** to lift the piston and the lower tubing section TS in the same manner as the same was lifted in the structure of FIG. **9.**

Other functioning of the installation is the same and any situation which destroys the pressure in the control fluid line CFL, or reduces such pressure, will result in the tubing section TS and imperforate tubing section T-1 moving down to close off flow from the producing formation.

Another form of support for the tubing string is shown in FIG. **11**, wherein the elongate string of tubing T has a stop member and shock absorber W connected therein near the lower end thereof and supports an upper seal assembly A-1 and a lower seal assembly A-2 between which the imperforate tubing section T-1 is positioned. The seal assemblies and imperforate tubing section are designed to engage the upper and lower packers P-3 and P-1, respectively, to seal off therebetween in the same manner as the form of FIG. **9.**

To the upper end of the tubing string T is connected an enlarged cylinder **120** which telescopes over a tubular sleeve **130** supported at its upper end by a hanger K-1 in the reduced upper bore of a tubing head H-4 similar to that of the tubing head H of FIG. **1.** A flanged head **131** at the upper end of the cylinder **120** has external and internal seals **132** and **133** thereon for sealing between the tubing head H and the tubular sleeve, and the flanged head is supported on the locking rams D which are held in place by the pistons E and lock screws J in the same manner as that of the form of FIG. **1.**

When for any reason it is desired to close off the producing formation F, the rams D are withdrawn, permitting the flanged head **131** at the upper end of the cylinder **120** to move downwardly until the shock absorber and stop W engages the tapered surface S-3 at the upper end of the upper packer P-3 to stop further downward movement of the tubing string and to close off flow from the producing formation.

Any damage to the well head H which results in withdrawal of the rams D from supporting engagement with the flanged head **131** at the upper end of the cylinder **120** will permit the tubing string to drop or move downwardly to close off flow from the producing formation through the tubing string to the surface.

Obviously, a suitable spear or other tool may be lowered through the tubular sleeve **130** downwardly into the tubing string T to engage the same for lifting the tubing string upwardly to reposition the flanged head **131** above the rams D in the tubing head H. The functioning of the closure section of the tubing, consisting of the imperforate tubing section T-1 and the upper and lower seal assemblies or subs A-1 and A-2 with the packers P-3 and P-1, is the same as that of several forms previously described. The difference in this installation is in the suspension for the tubing string which provides a continuous flow path through the tubing while permitting the tubing to drop or be dropped in the event of an emergency or disaster. Obviously loading fluids may be pumped downwardly through the sleeve **130** and the tubing string T if desired after the

tubing string has been lifted to reposition the supporting flange **131** above the dogs or rims D if needed. Also, loading fluid may be introduced through the lateral casing flow line F and valve X into the tubing head to load the casing tubing annulus above the upper packer P-3 if desired.

Referring to FIG. **12**, the well installation illustrated is essentially that of FIG. **3** and is used with a well head system of the character shown in FIG. **1**. The well installation includes a casing and packer arrangement as previously described and illustrated in FIGS. **1** and **3** including the depending sealing sleeve V connected with the upper packer P-2. The well installation also includes a tubing assembly including the tubing T having seal assemblies or packing subs A-1, A-2, and A-3 in spaced relation along the lower end portion of the tubing. The imperforate tubing section T-1 extends between the packing subs A-1 and A-2. Above the packing sub A-3 the tubing is provided with a stop and shock absorber W. Additionally, the tubing is provided with one or more side ports **200** positioned between the packing subs A-1 and A-3 to communicate the flow passage or bore of the tubing with the annulus **201** between the tubing and the casing C when the tubing is at the upper position illustrated in FIG. **12**.

The operation of the well installation shown in FIGS. **12** and **13** is substantially identical to that of the installations of FIGS. **1** and **3** with respect to the raising and lowering of the tubing string T between the producing position of FIG. **12** and the shut-in or non-producing position of FIG. **13**. When the tubing is at the upper position of FIG. **12**, well fluids flow into the casing C through the perforations I, upwardly into the lower end of the tubing section T-1, and into the main or upper portion of the tubing string T above the packer P-2. At the port **200** a portion of the well fluids flow into the annulus **201**. The fluids then flow to the well head through both the tubing string T and the annulus **201** substantially reducing the frictional resistance to fluid flow as compaared with flow only within the tubing. When the tubing string T is lowered in the manner and for the various reasons previously discussed, the lower end of the tubing portion T-1 including the packing sub A-2 moves into sealed relationship in the lower packer B-1. The stop W seats on the surface S-2 of the upper packer P-2, while both the packing subs A-1 and A-3 on opposite sides of the port **200** engage the dependent sleeve V sealing around the tubing above and below the port. The imperforate tubing section T-1 extends along the producing formation F sealed with the lower packer below the formation and with the tube V above the formation so that the flow into the well tubing is prevented. Thus, the well installation of FIGS. **12** and **13** provides apparatus for flowing a well into both a tubing string and a casing annulus while being adapted to close off fluid flow responsive to downward movement of the tubing string.

Referring to FIG. **14**, the upper end of the tubing string T is supported in a well head H by a hanger K which seals between the well head and the upper end of the tubing string and directs fluids upwardly, as previously discussed, through the master valve M. A lateral casing flow port L is formed in the tubing head communicating with a flow line Y connected with the well head and provided with a casing flow valve X for control of flow from the casing annulus **220** in the casing C around the tubing string T. A lower longitudinally movable tubing assembly TS-1 is suspended for longitudinal movement from the lower end of the tubing T. The movable tubing assembly is supported from a cylinder **221** secured as by threading to the lower end of the tubing T. The cylinder includes an upper section **222** which is not only slightly larger in diameter than the tubing T and a still further enlarged lower section **223**. The tubing assembly TS-1 has an upper section **224** provided at the upper end thereof with an external annular piston **225** having a seal **230** for sealing with the reduced upper cylinder portion **222**. Below the annular piston **225** the tubing section **224** is spaced within the cylinder portion **222** defining an annulus **231** within the cylinder upper portion. An intermediate annular piston **232** is secured around the tubing section **224** within the lower cylinder section **223**. A side port **233** is provided in the cylinder section **223** communicating the annulus **231** above the piston **232** with the casing annulus **220**. A side port **234** is provided in the tubing section **224** below the annular piston **232** communicating the interior of the tubing with cylinder annulus **235** defined around the tubing **224** within the lower cylinder section **223**. A ring seal **240** is supprted at the lower end of the cylinder section **223** sealing around the tubing section **224** to permit the tubing to be extended downwardly and raised in sealed relationship with the cylinder. The lower end of the tubing section **224** is connected into a coupling **250** provided with internal recesses defining a landing nipple for a removable plug **251** which closes the tubing string at the coupling. A lower tubing section **252** is connected into the coupling **250** and is provided with a previously described annular stop W and the spaced seal subs A-1, A-2, and A-3. The well casing is fitted with the upper and lower packers P-2, and P-1, respectively and with the dependent valve tube V extending downwardly from the upper packer. A side port **260** is provided in the lower tubing section between the seal subs A-1 and A-3. The lower tubing section denoted as T-1 is imperforate, as previously discussed, between the seal subs A-1 and A-2. A suitable source of fluid pressure **270** is connected by a line **271** through a valve **272** into the well head to the upper end of the tubing string T to supply control fluid pressure for supporting and raising the lower suspended tubing assembly TS-1.

In the well installation shown in FIG. **14**, the suspended tubing assembly TS-1 is at an upper end position for producing the well. The suspended tubing assembly is held at the upper position by a suitable control fluid supplied under pressure from the source **270** through the line **271** and the valve **272** into the tubing string T. The control fluid pressure is communicated in the tubing string and outwardly through the port **234** into the cylinder annulus **235** below the annular piston **232**. The fluid presure in the annulus **235** applies an upward force to the piston **232** to hold the piston and suspended tubing assembly TS-1 at the upper position illustrated. The side port **233** in the cylinder communicate the pressure in the casing annulus **220** to the top of the piston **232**, and obviously the control fluid pressure must exceed the casing annulus pressure. The plug **251** prevents pressure communication downwardly in the tubing below the couping **250**. At this upper position of the suspended tubing assembly, well fluid flows from the formation F into the casing through the perforations I, upwardly in the lower tubing section T-1 past the upper packer P-2, and outwardly into the casing an-

nulus **220** through the side ports **260.** The well fluids all flow upwardly to the well head in the casing annulus **220** and outwardly from the well through the side port L and the flow line Y and valve X. When closing off flow in the well is desired, either responsive to a dangerous condition sensed by the pressure source **270** or intentionally by control of the pressure source, the fluid pressure is reduced in the tubing string T to the cylinder annulus **235** through the side port **234.** The control pressure through the tubing string is reduced to at least a pressure level at which the casing annulus pressure as applied through the side port **233** above the piston **232** and the weight of the lower suspended tubing assembly TS-1 causes the tubing assembly to drop downwardly. The tubing assembly drops until the stop W seats on the surface S-2 of the upper packer P-2. The side port **233** in the cylinder secton **223** above the annular piston **232** allows the piston to move downwardly within the cylinder without a suction effect impeding the downward movement. The lower seal sub A-2 moves into the lower packer P-1 while the port **260** moves into the valve tube V, whereby the seal subs A-1 and A-3 seal within the valve tube above and below the port. The imperforate tube section T-1 extends along the producing formation F so that no fluid from the formation can flow into the tube. Thus, at the lower end position of the suspended tube assembly, TS-1 the well is shut-in with respect to any fluid flow from the formation F. Thus, the well installation of FIGS. **14** and **15** permits casing annulus flow from the producing formation to the well head controlled by a vertically movable tubing assembly raised and lowered responsive to control fluid pressure communicated to the tubing assembly through the well tubing string from the well head. Preferably, the tubing assembly TS-1 should be low enough in the wall that the weight of the tubing which is dropped when the well is shut-in is minimized. Also, the tubing assembly should be at a sufficient depth that the cross sectional area of the annular piston **232** is minimized to provide maximum flow space around the cylinder section **223** within the casing C. The tubing assembly must not, however, be at such a depth that the assembly will not fall downwardly to a closed position against the upward force applied by the bottom hole pressure in the well. When flow is again desired from the well, fluid pressure from the source **270** may be applied through the tubing string T to the piston **232** to raise the tubing assembly TS-1 back to the position of FIG. **14.** It will be noted that if desired the lower packer P-1 is not required to shut in the well as the tubing is plugged at the coupling **250** and the port **260** is sealed at the lower position of the tubing assembly as shown in FIG. **15.**

It will be seen that a well flow controlling method has been provided for lowering a tubing string, either intentionally or as a result of damage or destruction of the suspension at the surface, to close off flow from the producing formation of the well. In several of the structures illustrated the tubing string may be repositioned by lifting the same upwardly to place the well back on production after the emergency has ceased to exist and the damage to the surface has been corrected. It will also be seen that at least one form of the invention has been illustrated and described wherein a single packer is utilized with an imperforate section and seal members to close off flow from the producing formation into the tubing string. Also, it will be seen that shock absorbing means has been provided for reducing damage to the tubing string as a result of the lowering or dropping of the same. It will further be seen that certain of the structures permit resumption of flow from the well by application of control fluid pressure in either a control line or the well tubing to a piston head for lifting a lower tubing section to reopen the tubing to flow therethrough when desired.

It will also be seen that in some forms of the invention production may flow in the casing annulus to the well head.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. Apparatus for controlling flow of well fluids from a well having a string of well casing in place in the well, said casing having flow communication with a producing formation surrounding the well bore, which includes: a well flow conductor disposed in said casing and having flow inlet means providing flow communication with said producing formation and having at least a portion movable longitudinally in said well; a well packer disposed in said well above the communication of said casing and said flow conductor with said producing formation; means for sealing between said packer and said casing and said flow conductor to close the annulus therebetween against fluid flow therethrough; means for isolating said flow inlet means of said flow conductor from flow from said producing formation below said packer upon downward movement of said movable portion of said flow conductor from an upper position to a lower position in the well; said flow conductor movable portion being provided with a port positioned above said well packer when said movable portion of said flow conductor is in said upper position for flow into said casing above said packer and said port is sealed when said movable portion of said flow conductor is in said lower position; support means for supporting said movable portion of said flow conductor in said upper position in which said flow inlet means is open to permit fluid flow from said producing formation through said inlets means and to the surface in said well, said support means being operable between supporting and release conditions to permit controlled downward movement of said movable portion of said flow conductor to said lower position to close said flow inlet means to close off fluid flow from said producing formation.

2. Apparatus in accordance with claim **1,** wherein said support means comprises fluid pressure responsive means; and means for supplying control fluid through said flow conductor to said support means.

3. Apparatus for controlling flow of well fluids from a well in the event of the occurrence of a disaster or hazardous condition which includes: a string of well casing in place in the well having flow communication with the producing formation surrounding the well bore; an upper packer disposed in the casing in sealing engagement therewith above the communication of the casing with the producing formation; a lower packer disposed in the casing in sealing engagement therewith below the communication of the casing with the producing formation and above the bottom of the well; a well flow conductor extending from the surface down-

wardly to a point below the upper packer; an imperforate sealing section connected in the flow conductor having a sufficient length to extend between the upper and lower packers, when moved to position in the casing in which said imperforate sealing section is disposed between the packers, for closing off flow of well fluids from the producing formation through the casing and flow conductor; first support means operable between holding and release conditions for supporting the flow conductor in a position in which the lower portion of said imperforate sealing section thereof is in sealing engagement with the upper packer, said first support means being selectively controllable to permit the flow conductor to be moved downwardly to a position in which said imperforate sealing section is between and in sealing engagement with both of said packers for closing off flow of well fluids from the producing formation through the casing and flow conductor; second support means for supporting the flow conductor in said last mentioned position; said flow conductor being provided with a side port about said imperforate sealing section, said side port being above said upper packer before said flow conductor is moved downwardly for flow into the casing annulus above said packer; and means for closing said side port when said imperforate section is disposed between said packer.

4. Apparatus in accordance with claim **2** wherein said first support means comprises means for raising and lowering said imperforate sealing section responsive to fluid pressure communicated downwardly in said well through said well flow conductor and said flow conductor is closed above said side port; and means for supplying control fluid to said first support means in said flow conductor.

5. Apparatus for controlling flow of well fluid from a well having a string of well casing in place therein in flow communication with the producing formation, which includes: a packer disposed in said casing in sealing engagement therewith above communication of the casing with the well producing formation; a well flow conductor extending from the surface downwardly through said packer and having at least a portion thereof movable longitudinally between upper and lower positions; inlet opening means in said flow conductor below said packer; means for isolating said inlet means from flow from said producing formation upon downward movement of said movable portion of said flow conductor from said upper to said lower position; first means comprising a piston and cylinder on said flow conductor above said inlet opening and operable between holding and release conditions to permit holding said movable portion of said flow conductor in said upper position to hold said inlet means open to permit fluid flow from the producing formation through said inlet means and said flow conductor to the surface; said first means being selectively controllable to permit said movable portion of said flow conductor to move from said upper position downwardly to said lower position for isolating said inlet means from fluid flow from the producing formation and to return said movable portion upwardly to reopen said inlet means; means communicating control fluid pressure to said piston and cylinder through said flow conductor including a first side port in said flow conductor; means providing a second side port in said flow conductor located to be positioned above said packer when said flow conductor portion is in said upper position; means closing said flow conductor between said side ports; means for closing said second side port when said flow conductor portion is in said lower position and second means supporting said movable portion of said flow conductor in said lower position isolating said inlet means from fluid flow from said producing formation.

6. Apparatus for controlling flow of well fluids from a well in the event of the occurrence of a disaster or hazardous condition which includes: a string of well casing in place in said well having flow communication with a producing formation surrounding said well; a packer disposed in the casing in sealing engagement therewith above the communication of the casing with said producing formation; a well flow conductor extending from the surface downwardly to a point above said packer; an extendable flow conductor assembly supported from the lower end of said well flow conductor, said assembly including a cylinder secured to the lower end of said well flow conductor, a tubing section having an upper end portion telescopically engaged in said cylinder and having a lower end portion extendable through said packer for shutting off flow from said producing formation upwardly through said packer at a lower position and for permitting flow from said formation upwardly through said packer into the annulus of said casing around said well flow conductor and tubing section at an upper position, an annular piston on said tubular section within said cylinder, port means in said tubular section below said annular piston for applying control fluid pressure from said well flow conductor into said cylinder below said annular piston for raising said flow conductor to and supporting said conductor at said upper position for well flow from said producing formation upwardly through said packer into said annulus and for releasing said tubular section for downward movement through said packer for shutting off fluid flow upwardly through said packer, and plug means in said tubing section below said port means to cause control fluid from said well flow conductor to flow through said port means and to prevent upward flow of well fluids in said flow conductor from below said plug means whereby well fluids flow into said casing annulus above said packer.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,893,512 Dated July 8, 1975

Inventor(s) Albert W. Carroll and Phillip S. Sizer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 62, cancel "each" and insert -- such --.
Column 2, line 25, insert -- is -- after "well".
line 48, insert -- a -- after "of".
line 54, "fluid" should read "fluids"
Column 3, line 1, cancel "wall" and insert -- well --.
Column 6, line 18, insert -- string -- after "tubing".
Column 7, line 48, cancel "of" first occurrence and insert -- or --.
Column 14, line 6, cancel "not".
line 32, cancel "a" and insert -- the --.
Column 15, line 40, insert -- annular -- after "maximum".
Column 16, line 45, "inlets" should read "inlet".
Column 17, line 21, cancel"about" and insert -- above --.
line 26, "packer" should read "packers".

Signed and Sealed this

Tenth Day of August 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks