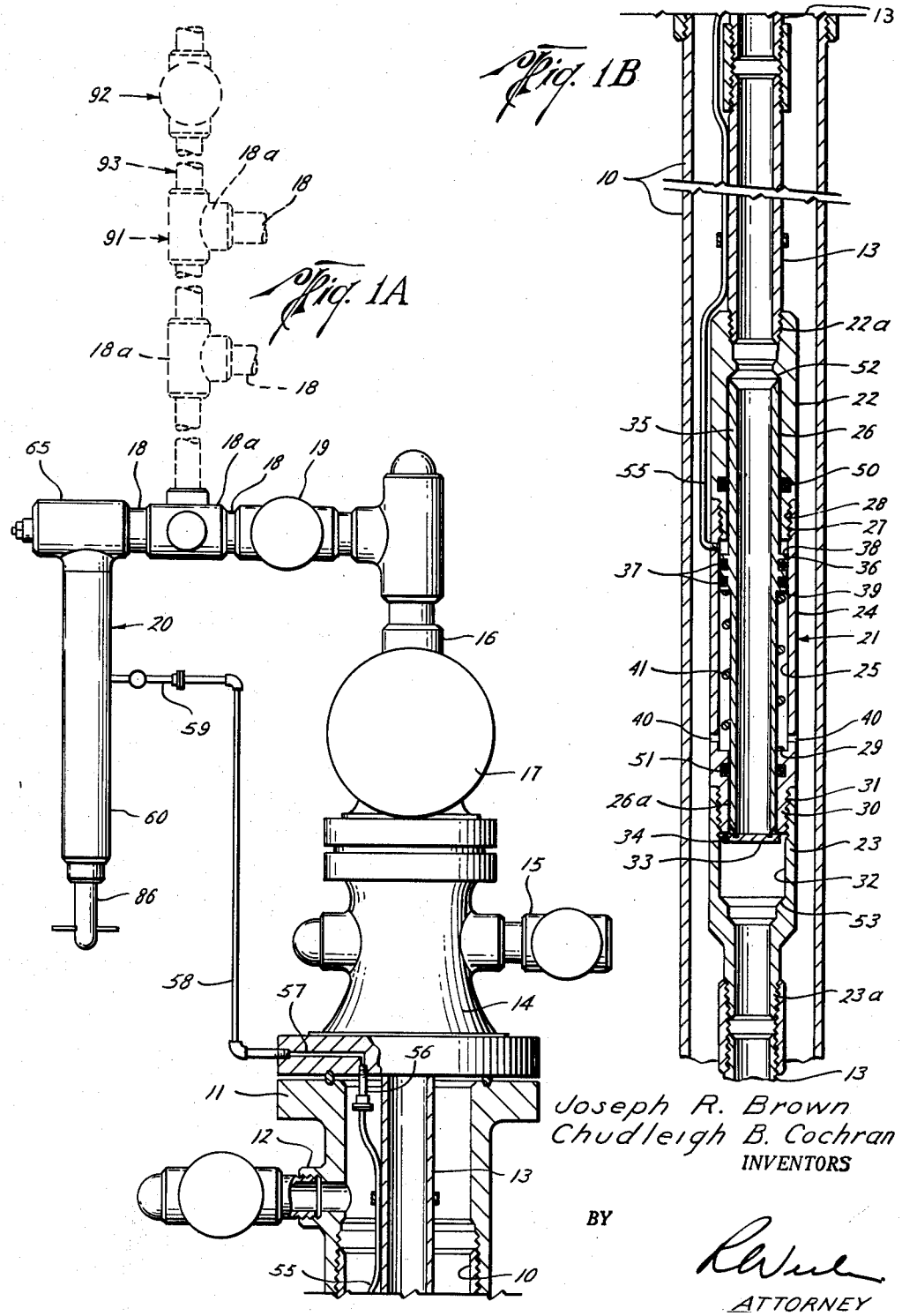
June 4, 1963 J. R. BROWN ET AL 3,092,135

FULL OPENING SAFETY VALVE FOR PIPE STRINGS

Filed April 27, 1956 3 Sheets-Sheet 1



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3 Sheets-Sheet 2

Fig. 3

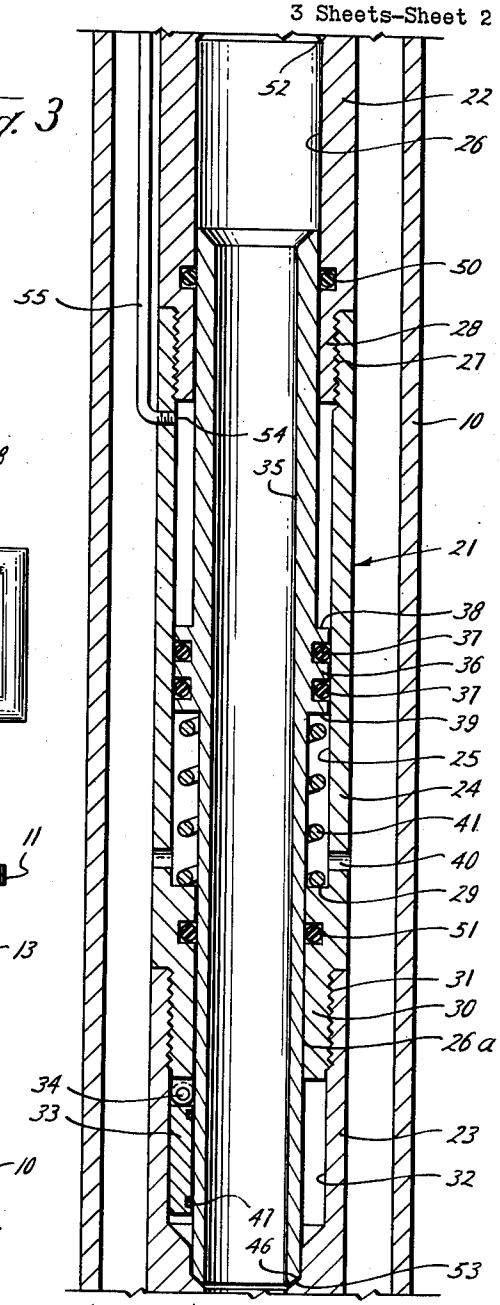
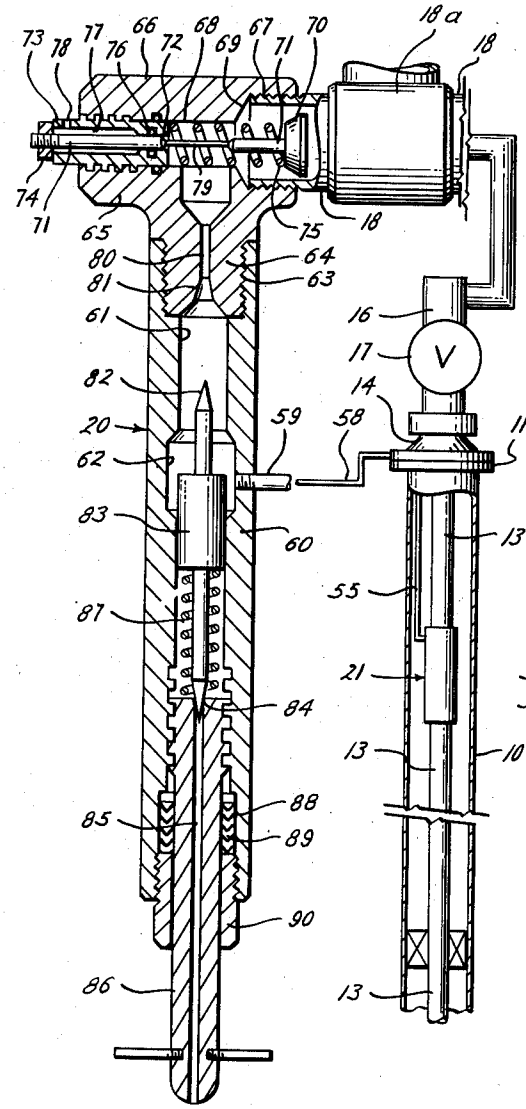


Fig. 2



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Fig. 5

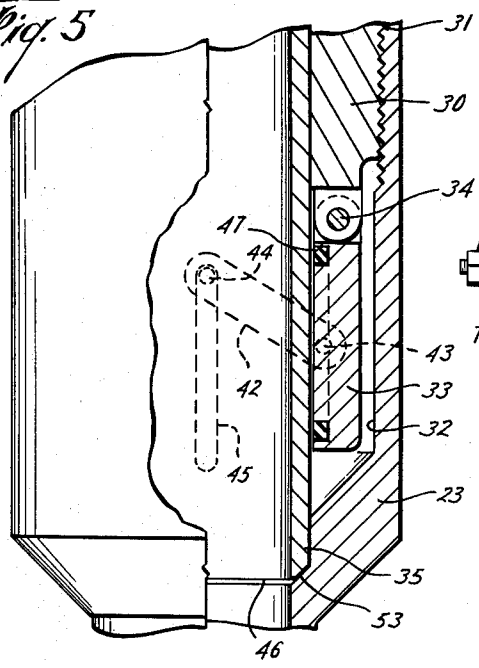
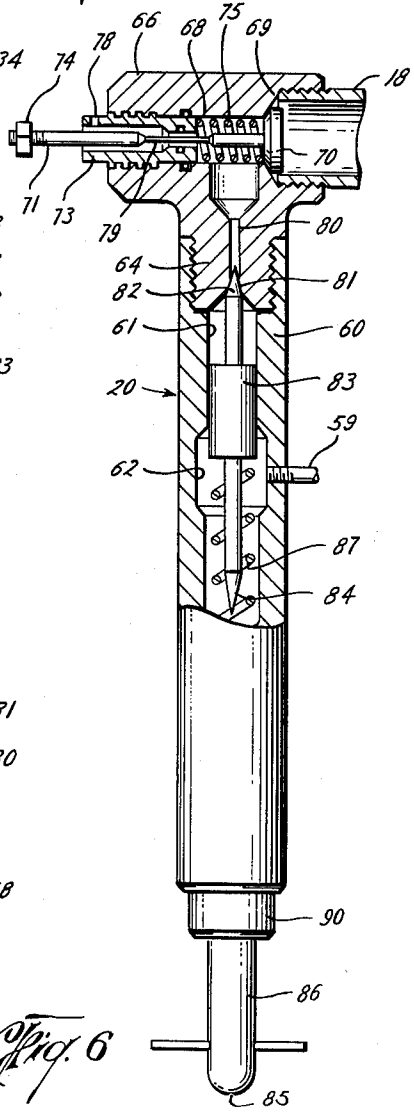


Fig. 4



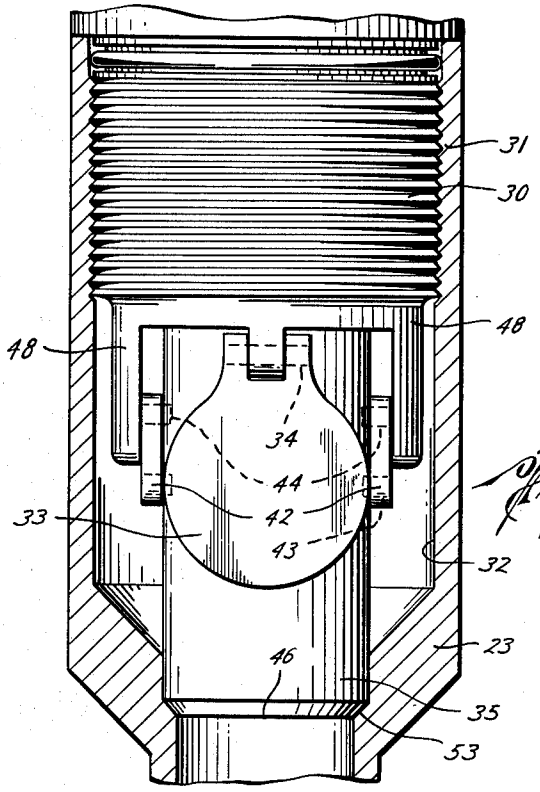


Fig. 6

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FULL OPENING SAFETY VALVE FOR PIPE STRINGS

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Filed Apr. 27, 1956, Ser. No. 581,167
14 Claims. (Cl. 137—458)

This invention relates to a safety valve for use with pipe strings and particularly to a safety valve adapted to be inserted in a pipe string extending into a well for automatically closing the pipe string when fluid pressures inside the string exceed or fall below a predetermined range of pressures.

In many installations in oil and gas wells it is particularly desirable to have some type of automatic control to automatically shut off the production string to prevent run-away flow in the event pressures inside the pipe string suddenly rise to an excessive value and to likewise shut off at the production string when the pressure suddenly falls below some predetermined value, as when a connection breaks or other mishap occurs in which the pressure is released and falls very rapidly.

A frequent occurrence in the oil and gas fields is when a well head breaks or is blown off, whereupon the well will blow wild since the control valves usually will have been destroyed. In such an instance, it will be most desirable if there is present in the pipe string down the well a valve mechanism which would automatically close when the pressure is released as a result of the loss of control at the surface.

An important application for such an automatic safety valve is in wells being drilled in off-shore locations. If, as a result of some accident, as by collision of a vessel or floating object with a well head, the surface control should be destroyed, it would become even more difficult to gain control of the well than it is on land, where regaining of control is often a very hazardous and expensive operation.

The present invention, therefore, has for its principal object the provision of a safety valve which is designed to be inserted in a pipe string extending into a well, which will automatically close-off the production pipe string whenever the pressure in the pipe string exceeds or falls below a predetermined operating range in which the valve normally remains open.

A further object is to provide an automatic safety valve of the kind described in which the valve has a full open bore to permit free movement of the tools into and out of the pipe, as may be required in connection with operation of the well.

An additional object is to provide a valve of the flapper type installed in the bore of the pipe string and connected to a sleeve-type actuating member which is, in turn, responsive to predetermined pressure differences between the interior and exterior of the pipe string to automatically close the flapper valve across the bore of the pipe string.

Still another object is to provide an automatic safety valve comprising a tubular body which is adapted to be inserted in, and form a part of, a well pipe string and including a flapper valve movable to and from a closed position across the bore of the body and employing an actuating sleeve which is responsive to pressure differences between the interior and exterior of the pipe string to automatically close the flapper valve, the actuating sleeve being held in the valve-opening position in response to fluid pressures inside the pipe string which are in a predetermined range.

Other and more specific objects and advantages of this invention will become apparent from the following detailed description when read in conjunction with the accompanying drawing which illustrates a useful embodiment in accordance with this invention.

In the drawing:

FIGS. 1A and 1B, together, illustrate, largely in longitudinal section, an automatic safety valve in accordance with this invention installed in a well pipe, the valve being shown in its closed position;

FIG. 2 is a longitudinal sectional view of the control means employed in conjunction with the valve structure for controlling the fluid pressure employed to operate the valve, the parts of the control means being shown in the positions occupied when maintaining the safety valve in the open position;

FIG. 3 is an enlarged longitudinal sectional view of the automatic valve installed in a well pipe and showing the valve in its open position;

FIG. 4 is a view, generally similar to FIG. 2, showing the parts of the control means in the positions occupied after releasing the valve for movement to the closed position;

FIG. 5 is a longitudinal sectional view showing some of the details of the flapper valve member, the valve being shown in the open position; and

FIG. 6 is an elevation of the flapper valve member in open position.

Referring first to FIGS. 1A and 1B, there is shown a conventional well casing 10 which extends into a well bore, the upper end of the casing being connected to the usual well head 11 having the valve controlled side outlet 12. A string of tubing 13 extends through casing 10 and casing head 11 in the usual manner, and forms the production pipe string through which well fluids, such as oil or gas, are brought to the surface. The upper end of tubing string 13 is connected in the usual manner into a tubing head 14, of generally conventional form, which is mounted on casing head 11 and fitted with valved outlet branches 15. The upper end of the tubing string is connected to the well head fitting 16 controlled by master valve 17 and communicates with a branch pipe 18 fitted with the valve 19. The outer end of pipe 18 communicates through a manifold fitting 18a with a pilot control means, designated generally by the numeral 20, which will be described in greater detail hereinafter.

The automatic safety valve, in accordance with the illustrative embodiment of this invention, is designated generally by the numeral 21 and includes a generally tubular body comprising upper and lower end sections 22 and 23, respectively, and an intermediate section 24. The latter has a bore 25 somewhat larger than bore 26 of the upper end section and is internally threaded at 27 near its upper end to receive an externally threaded pin 28 on the lower end of upper section 22. Bore 25 of the intermediate body section is reduced in diameter near its lower end to form the upwardly facing shoulder 29 and the lower end of section 24 terminates in an externally threaded

pin 30 having the bore 26a. Pin 30 is receivable in a threaded socket 31 formed in the upper end of lower section 23, which has a bore 32 larger in diameter than the bore 26a of pin member 30. As best seen in FIGS. 5 and 6, a circular flapper valve 33 is hingedly secured by the hinge pin 34 to the lower end of pin member 30 at one side thereof adjacent the inner wall of lower section 23, so as to swing from a position adjacent the wall of section 23 to a position across bore 26a, thereby swinging between open and closed positions with respect to the bore of the valve body. Upper section 22 has an internally threaded socket 22a in its upper end and lower section 23 has a threaded pin 23a at its lower end by which safety valve 21 may be connected into and form a part of tubing string 13, as best seen in FIG. 1B.

Slidably mounted in the several connected bores 25, 26 and 26a is a tubular sleeve member 35 having a through bore 35a of substantially the same diameter as pipe string 13. An enlargement 36 is formed or otherwise provided at an intermediate point on the exterior of sleeve 35 to be received in enlarged bore 25. The periphery of enlargement 36 is fitted with one or more seal rings 37 adapted to form a sliding seal with the wall of bore 25. Enlargement 36 has upper and lower end faces 38 and 39, respectively, lower end face 39 being larger in width than upper end face 38. It will be seen that enlargement 36 forms a barrier seal or piston slidable in bore 25 which forms a piston chamber or cylinder in which the barrier seal or piston is reciprocable. By making lower end face 39 larger in area than upper end face 38, piston 36 constitutes a differential area piston. A plurality of ports 40 provide communication between the portion of the chamber below piston 36 and the exterior of the valve body. A coil spring 41 is mounted about the lower portion of sleeve member 35 in compression between shoulder 29 and lower end face 39, the coil spring normally urging the sleeve member upwardly in the bore of the body. Seal rings 50 and 51 are positioned in the walls of bores 26 and 26a, respectively, to form seals slidably engaging the opposite end portions of sleeve member 35 which extend into these bores.

As best seen in FIGS. 5 and 6, flapper valve 33 is connected to the adjacent end portion of sleeve member 35 by means of a pair of links 42 which are pivotally connected to opposite sides of the flapper valve by means of the pins 43. The opposite ends of the links 42 carrying pins 44 which project into longitudinally extending grooves, cut into opposite sides of the outer wall of sleeve member 35. With this arrangement, it will be seen that as the sleeve member moves downwardly with respect to body of valve 21, flapper valve 33 will be caused to swing to one side of the adjacent end of the sleeve member to a position between the outside of the sleeve member and the wall of bore 32. When the sleeve member is moved upwardly, the linkage illustrated causes the flapper valve to swing across the bore 32 and as the sleeve member continues to move upwardly the flapper valve will be drawn over and against the lower end of the sleeve member. The latter is provided with a bevelled tip 46 which forms a seat for the flapper valve, and the inner face of flapper valve 33 has seated therein a circular gasket 47 which is adapted to register with tip 46 and form a fluid-tight seal therewith when the flapper valve has been drawn to the closed position, as described. The lower end of pin member 30 is provided with a pair of laterally spaced, parallel, longitudinal extensions 48 which serve as guides for the flapper valve and the linkage connecting the latter to the sleeve member. Shoulders 52 and 53 are provided respectively in the upper end portion of bore 26 and in the lower end portion of bore 26a to limit the extent of the reciprocating movement of sleeve member 33 in the valve body.

The wall of chamber 25 is provided at a point above the uppermost limit of travel of piston 36 with an opening 54 to which is connected a small diameter pipe 55 which is led along tubing string 13 and connected by means of a nipple 56 to a passage 57 extending through the body of tubing head 14. From the outer end of passage 57 a pipe 58 leads to a valved connection 59 which communicates with the interior of the casing 60 forming a portion of the pilot control means 20.

Casing 60 is generally tubular in shape having an axial bore 61 extending therethrough which is internally enlarged somewhat at a point opposite the point of connection of pipe 59 to form the chamber 62. One end of casing 60 has the internally threaded socket 63 into which is connected the vertical leg 64 of a T-shaped head 65 whose crossarm 66 is provided at one end with an internally threaded socket 67 to receive the end of pipe 18 which communicates with the interior of tubing string 13 through the several well head and manifold connections previously described. Crossarm 66 is provided with an axial bore 68 which extends entirely through the crossarm into communication with socket 67 and is smaller in diameter than the latter to define the shoulder 69 which is bevelled to form a valve seat for a disk-shaped valve 70 disposed in the bore of socket 67. Valve 70 is mounted on a stem 71 which extends axially through the bore 72 of an externally threaded bushing 73 which is screwed into the outer end of bore 68. The outer end of stem 71 carries a nut 74 which bears against the outer end of bushing 73 to limit the inward movement of valve 70. A coil spring 75 is mounted about stem 71 in compression between the inner end of bushing 73 and valve 70 to normally urge valve 70 inwardly away from seat shoulder 69, that is, to the open position. The inner end portion of bore 72 forms a close fit about stem 71 and is provided with a seal ring 76 adapted to slidably seal with the stem 71. Bore 72 is counter-bored from its outer end to form the enlarged diameter bore portion 77 which provides substantial annular clearance about the outer end portion of stem 71. A leak port 78 communicating with bore portion 77 is provided in the wall of bushing 73 near its outer end. Stem 71 is reduced in diameter at an intermediate portion 79 which will be positioned inwardly of seal ring 76 when valve 70 is in the open position illustrated in FIG. 2. The location of reduced diameter portion 79 is such that when valve 70 is engaged with seat shoulder 69, reduced diameter portion 79 will extend through bore 72, thereby providing annular clearance between portion 79 and bore 72 whereby to provide communication between bore 68 and bore portion 77 when valve 70 is closed, as will be best seen in FIG. 4.

Bore 68 in the crossarm 66 intersects a bore 80 which extends axially through leg 64 of head 65 into communication with bore 61 of casing 60. Bore 80 terminates at its outer end in an inwardly sharply tapered valve seat 81 which is adapted to receive the tapered needle valve 82 projecting axially from a cylindrical plunger 83 which is slidably mounted in bore 61. The opposite end of plunger 83 carries another needle valve 84 which projects axially therefrom and is adapted to be received in, and form a closure for, a narrow axial vent passage 85 which extends entirely through a plug 86 which is screwed into the outer end of bore 61. A coil spring 87 is mounted about needle valve 84 in compression between the inner end of plug 86 and the opposing end of plunger 83 to normally urge the latter away from vent passage 85 in the direction to open the latter to communication with the interior of casing 60. The outer end of casing 60 forms a stuffing box 88 about plug 86 which contains packing 89 under compression of the packing gland 90.

In the pilot control mechanism described, spring 75 will resist closing of valve 70 by fluid pressure interiorly of the tubing string until that fluid pressure exceeds the strength of the spring. Similarly, coil spring 87 will oppose outward movement of plunger 83 under fluid pressure exerted against the inner end of the plunger until that fluid pressure drops below the strength of spring 87, at which point the latter will propel the plunger inwardly of casing 60 to insert needle valve 82 into seat 81,

thereby closing flow passage **80**. At the same time, when the force exerted by the fluid pressure upon the inner end of plunger **83** is less than the strength of spring **87**, needle valve **84** will be withdrawn from vent passage **85**, placing the latter in open communication with the interior of chamber **62**, as best seen in FIG. 4. The strength of coil spring **75** is selected to be substantially in excess of that of coil spring **87**, for purposes which will appear more fully hereinafter.

The above described safety valve and its pilot control operate in the following manner: Safety valve **21** will be installed in tubing string **13** at a point ordinarily well below the surface so that any accidents occurring at the well head or in conjunction therewith, will not physically directly effect the safety valve. With the safety valve in the open position, illustrated particularly in FIG. 3, the force of spring **75** will ordinarily be set to hold valve **70** open against fluid pressures inside the tubing string, which are below some maximum figure appropriate for flowing of the particular well; for example, a maximum pressure of 1500 pounds p.s.i. Spring **87** may be loaded or otherwise set to exert a pressure against plunger **83** substantially less than the pressure selected for spring **75**; for example, 500 pounds p.s.i. Thus it will be seen that as long as the pressure in the upper portion of the tubing string remains below 1500 pounds, valve **70** will remain open and so long as this pressure remains above 500 pounds, plunger **83** will be in the position shown in FIG. 2; that is, with needle valve **84** closing vent passage **85**. As long as the fluid pressure in the tubing string remains in a range falling between the pressure limits represented at its upper end by the strength of spring **75**, and at its lower end by the strength of spring **87**, that is between 500 and 1500 p.s.i., the safety valve will be unaffected, since the pressure in the tubing string will be transmitted through the interior of the casing of the pilot control means to the interior of the portion of chamber **25** above piston **36** and will be greater than the pressure forces acting on the lower face of piston **36**, thereby holding sleeve member **35** in its downward position at which flapper valve **33** will be swung to one side, as shown in FIG. 3, leaving the bore of the tubing string open for the flow of fluid therethrough.

If the pressure inside the tubing string suddenly should increase to a value exceeding the strength of spring **75**, valve **70** will be moved against seat **69** closing communication between the interior of the tubing string and the pilot casing **60**, as shown in FIG. 4. When valve **70** is thus closed, the fluid pressure from the tubing will be removed from the interior of pilot casing **60**. At the same time, bore **80** will be placed in communication with the exterior of the pilot mechanism through the clearances provided in bushing **73** and leak-port **78**, as previously described. At this stage, the pressure interiorly of casing **60** will drop to a pressure approximately corresponding to the ambient atmospheric pressure. This drop in pressure will permit spring **87** to propel plunger **83** through bore **82** and move needle valve **82** into seat **81** closing communication between the tubing string and the interior of pilot casing **60**. At the same time, needle valve **84** will be withdrawn from vent passage **85** and the latter will thereby be placed in open communication through the interior of casing **60** with pipe **59** and thence with the portion of chamber **25** above piston **36**. Fluid previously held in this portion of chamber **25** will be vented through the conduit system provided by pipe **55**, nipple **56**, passage way **57**, pipe **58** and connection **59**. With the fluid pressure thus relieved from the upper end face of piston **36**, coil spring **41**, together with any fluid pressure in the annulus between well casing **10** and tubing string **13** acting through ports **40** against the larger area end face **39** of the piston, will urge sleeve member **35** in the upward direction to the position illustrated in FIG. 1B. This upward movement of sleeve member **35** will pull flapper valve **33** to the closed position over the lower end **46** of the sleeve member, thereby closing the bore of the tubing string to prevent further flow of fluid therefrom until the condition which caused the excessive pressure may have been overcome or corrected in accordance with practices employed in such cases.

In the event a connection at the upper end of the well head should break or for any other reason the fluid tends to suddenly discharge from the tubing string causing the pressure inside the tubing string to drop sharply, this drop in pressure will be reflected through the pilot control mechanism, and when the drop in pressure reduces the force exerted against the inner end of plunger **83** below that of spring **87**, the latter will move the plunger to the previously described position in which needle valve **82** closes passageway **80** and opens communication between the atmosphere and the portion of chamber **25** above piston **36**, thereby again venting the pressure fluid trapped in chamber **25** above piston **36** and automatically allowing the sleeve member **35** to move to the flapper-closing position.

From the foregoing, it will be seen that whenever the fluid pressure inside the tubing string exceeds a predetermined value, or drops below a lesser pre-determined value, the pilot mechanism will be caused to function so as to drop the pressure opposing the normal closing movement of sleeve member **35** and will result in automatically closing the safety valve.

The compression forces exerted by the springs **75** and **87** may be adjusted by suitable adjustment, respectively, of bushing **73** and plug **86** to vary the pressures which actuate the safety valve.

The particular range of pressures within which the flapper valve will remain open may be varied, of course, to suit the particular well and the conditions anticipated in the operation of such well. In any event, it will be seen that with the described mechanism any variation in pressure inside the tubing string above or below the predetermined range of pressures will automatically actuate the safety valve so that it will close.

When the valve has once closed, it may be re-opened by pumping fluid back through manifold connection **18*a*** into the pilot casing and through the conduit system connecting the pilot casing to the interior of chamber **25** above piston **36**. Sufficient fluid pressure will thus be introduced to force sleeve member **35** to the valve opening position. Valve **70** may be held open manually in any suitable manner while this introduction of fluid occurs.

By means of the herein described safety valve, a number of wells may be controlled from a single remote location in order to shut in the wells in the event hazardous conditions arise which means such action imperative. As illustrated in broken lines in FIG. 1A, a series of wells (not shown), equipped in the same manner as previously described, may be connected to a common manifold, indicated at **91**, which is a part of the same manifold to which the above-described well is connected.

A single shut-off valve, indicated at **92**, is connected into a common header **93** communicating with all of the several wells. By closing valve **92**, which may be at a point remote from all of the several wells, back pressure will be built up in the manifold to all of the wells until the shut-in pressure is built up in the several wells to a pressure exceeding that required to close the several valves **70** of the respective pilot controls. When that occurs then, as previously described, the safety valves in the several wells will be automatically actuated in the manner previously described to close off the several wells. Such an arrangement is particularly advantageous in off-shore fields where in the event a severe storm should occur which may threaten serious damage to the wells in the field, the operator may, by closing the remote shut-off valve, shut off all the wells at once.

By employing the flapper valve and sleeve actuator arrangement described, it will be seen that when the safety valve is in the open position, a full-open bore will be

provided through the valve which will permit passage of tools through the bore of the pipe string as may be required in connection with the operation of the well.

It will be understood that numerous alterations and changes may be made in the details of the illustrative embodiment within the scope of the appended claims but without departing from the spirit of this invention.

What we claim and desire to secure by Letters Patent is:

1. A safety valve for pipe strings, comprising, a tubular body co-axially connectible into a pipe string to form a part thereof, a sleeve member slidable axially in the body and having a full open bore of substantially the same size as that of the pipe string, a flapper-type valve member hingedly secured at one side to the body adjacent one end of the sleeve member, means pivotally connecting said valve member to said sleeve member operative by reciprocation of the sleeve member to move said valve member between open and closed positions with respect to the adjacent end of the sleeve member, and means operative upon said sleeve member in response to a pre-determined change in fluid pressure interiorly of said sleeve member to move the sleeve member to the valve-closing position.

2. A safety valve for a pipe string extending into a well, comprising, a tubular body adapted to form a part of a pipe string within a well, means forming an annular valve seat in said body, a sleeve member slidable axially in the bore of the body, a flapper valve hinged to the side of the body adjacent said seat, means pivotally connecting the valve to the sleeve member operative by reciprocation of the sleeve member to move said valve between open and closed positions with respect to said seat, and control means operative in response to fluid pressure inside said pipe string within a pre-determined range to apply said fluid pressure to said sleeve member to hold said sleeve member in the valve-opening position, said control means including control elements automatically operable in response to fluid pressures in said pipe string above and below said range to release said sleeve member for movement to the valve-closing position.

3. A safety valve for a pipe string, comprising, a tubular body adapted to form a part of a pipe string, a sleeve member slidable axially in the bore of the body, a flapper valve member hinged to the side of the body adjacent one end of the sleeve member, means connecting the valve member to the sleeve member operative by reciprocation of the sleeve member to move said valve member between open and closed positions with respect to said adjacent end of said sleeve member, means operative upon the sleeve member to urge it toward the valve-closing position, conduit means for directing fluid pressure from within the pipe string against the sleeve member in a direction to hold the sleeve member in the valve-opening position in opposition to the last-mentioned means, and means in said conduit means operable in response to said fluid pressures within the pipe string which are above and below a pre-determined pressure range to release the fluid pressure directed against the sleeve member whereby said last-mentioned means will move said sleeve member to the valve-closing position.

4. A safety valve for a pipe string, comprising a tubular body adapted to form a part of a pipe string, a sleeve member slidable axially in the bore of the body, a flapper valve member hinged to the side of the body adjacent one end of the sleeve member, means connecting the valve member to the sleeve member operative by reciprocation of the sleeve member to move said valve member between open and closed positions with respect to said adjacent end of said sleeve member, means operative upon the sleeve member to urge it toward the valve-closing position, conduit means for directing fluid pressure from within the pipe string against the exterior of the sleeve member in a direction to hold the sleeve member in the valve-opening position in opposition to the last-mentioned means, and control valve means in said conduit means operable in response to said fluid pressures within the pipe string which are above and below a pre-determined pressure range to release the fluid pressure directed against the sleeve member whereby said last-mentioned means will move said sleeve member to the valve-closing position.

5. A safety valve for a pipe string, comprising, a tubular body adapted to form a part of a pipe string, a sleeve member slidable axially in the bore of the body, said bore defining an annular chamber surrounding said sleeve member, a flapper valve member hinged to the side of the body adjacent one end of the sleeve member, means connecting the valve member to the sleeve member operative by reciprocation of the sleeve member to move said valve member between open and closed positions with respect to said adjacent end of said sleeve member, barrier seal means mounted on the exterior of the sleeve member extending into slidable sealing engagement with the wall of said chamber intermediate the ends thereof, means operative upon one side of the barrier seal means to urge the sleeve member toward the valve-closing position, a conduit for directing the fluid pressure from within the pipe string into the chamber on the opposite side of said barrier seal means to hold the sleeve member in the valve-opening position in opposition to the last-mentioned means, and control valve means in said conduit operable in response to said fluid pressures within the pipe string which are above and below a pre-determined pressure range to release the fluid pressure directed against said opposite side of said barrier seal means whereby said last-mentioned means will move said sleeve member to the valve-closing position.

6. A safety valve according to claim 5 wherein said barrier seal means comprises a differential area piston having its smaller area exposed to the fluid pressure inside the pipe string.

7. A safety valve for a pipe string, comprising a tubular body adapted to form a part of a pipe string, a sleeve member slidable axially in the bore of the body, a flapper valve member hinged to the side of the body adjacent one end of the sleeve member, pivoted linkage means connecting the valve member to the sleeve member operative by reciprocation of the sleeve member to move said valve member between open and closed positions with respect to said adjacent end of said sleeve member, means operative upon the sleeve member to urge it toward the valve-closing position, a conduit for directing the fluid pressure from within the pipe string against the exterior of the sleeve member in a direction to hold the sleeve member in the valve-opening position in opposition to the last-mentioned means, and control valve means in said conduit operable in response to fluid pressures within the pipe string which are above and below a pre-determined pressure range to release the fluid pressure directed against the sleeve member whereby said last-mentioned means will move said sleeve member to the valve-closing position, said control valve means including a valve casing interposed in said conduit and having an inlet and an outlet communicating with the conduit and having a flow passage providing communication between the pipe string and the interior of the valve casing, and a vent passage from the interior of the casing communicating with the exterior of the casing, and separate valve elements controlling each of said passages.

8. A safety valve for a pipe string, comprising a tubular body adapted to form a part of a pipe string, a sleeve member slidable axially in the bore of the body, a flapper valve member hinged to the side of the body adjacent one end of the sleeve member, pivoted linkage means connecting the valve member to the sleeve member operative by reciprocation of the sleeve member to move said valve member between open and closed positions with respect to said adjacent end of said sleeve

member, means operative upon the sleeve member to urge it toward the valve-closing position, a conduit for directing the fluid pressure from within the pipe string against the exterior of the sleeve member in a direction to hold the sleeve member in the valve-opening position in opposition to the last-mentioned means, and control valve means in said conduit operable in response to fluid pressures within the pipe string which are above and below a pre-determined pressure range to release the fluid pressure directed against the sleeve member whereby said last-mentioned means will move said sleeve member to the valve-closing position, said control valve means including a valve casing interposed in said conduit and having an inlet and an outlet communicating with the conduit and having a flow passage providing communication between the pipe string and the interior of the valve casing and a vent passage from the interior of the casing communicating with the exterior of the casing, and separate valve elements controlling each of said passages, the valve element controlling the vent passage being operative to open the vent passage when the pressure in said casing is below the lower limit of said range.

9. A safety valve for a pipe string, comprising, a tubular body adapted to form a part of a pipe string, a sleeve member slidable axially in the bore of the body, a portion of said bore being substantially larger in diameter than the sleeve member to define an annular chamber therebetween, a flapper valve hinged to the side of the body adjacent one end of the sleeve member, pivoted linkage means connecting the valve to the sleeve member operative by reciprocation of the sleeve member to move said valve between open and closed positions with respect to said adjacent end of said sleeve member, a barrier seal mounted on the sleeve member to extend into slidable sealing engagement with the wall of said chamber intermediate the ends thereof, means operative on one side of said barrier seal to urge the sleeve member to the valve-closing position, a conduit for directing fluid pressure from the interior of the pipe string into the chamber against the opposite side of said barrier to hold said sleeve member in the valve-opening position against the opposition of the last-mentioned means, and control means in said conduit operable in response to fluid pressures within the pipe string which are above and below a pre-determined pressure range to release the fluid pressure from said chamber whereby said last-mentioned means will move the sleeve member to the valve-closing position.

10. A safety valve for pipe strings, comprising, a tubular body co-axially connectible into a pipe string to form a part thereof, a sleeve member slidable axially in the bore of the body, said bore defining a cylinder surrounding said sleeve member, a flapper-type valve hingedly secured at one side to the body adjacent one end of the sleeve member, means pivotally connecting the flapper valve to the sleeve member operative by reciprocation of said sleeve member to move said flapper valve between an open position at one side of the sleeve member and a closed position over the end of the sleeve member, and a barrier seal carried on the exterior of said sleeve member extending into slidable sealing engagement with the wall of said cylinder to form opposed chambers therein, said sleeve member being movable in said body in response to differences between pressure on opposite sides of said seal barrier.

11. In combination with a pipe string extending into a well, an automatic safety valve, comprising, a tubular body co-axially connectible into the pipe string to form a part thereof, a sleeve member slidable axially in the bore of the body, said bore defining an annular chamber surrounding said sleeve member, a flapper valve hingedly secured to the side of the body adjacent the lower end of the sleeve member, pivoted linkage means connecting the flapper valve to the sleeve member operative by reciprocation of the sleeve member to swing the flapper valve between an open position at one side of the sleeve member and a closed position over the end of the sleeve member, an annular barrier seal mounted on the exterior of the sleeve member and extending into slidable sealing engagement with the wall of said chamber, means operative upon the sleeve member to urge it to the valve-closing position, conduit means for conducting fluid pressure from the interior of the pipe string to the portion of said chamber above the barrier seal, port means through the wall of the chamber below the barrier seal, and control means in said conduit means operable in response to fluid pressure in said pipe string within a pre-determined range of pressures to hold said sleeve member in the valve-opening position and to release said sleeve member for movement to a valve-closing position when the fluid pressure in the pipe string is above or below said range.

12. In combination with a pipe string extending into a well, an automatic safety valve, comprising, a tubular body co-axially connectible into the pipe string to form a part thereof, a flapper valve hinged to the wall of the body to swing between positions opening and closing the bore of said body, valve-actuating means operative in response to the difference in fluid pressures interiorly and exteriorly of the pipe string to move said valve between said positions, said valve-actuating means including a sleeve member slidable in the bore of said body and carrying a barrier seal slidably engaging the bore wall of said body, conduit means placing the portion of said bore on one side of said seal in communication with the interior of said pipe string, and port means placing the portion of said bore on the opposite side of said seal in communication with the exterior of said pipe string, control means operably connected to the valve-actuating means and responsive to fluid pressures inside the pipe string above and below a pre-determined range of pressures to move said valve-actuating means to the valve-closing position.

13. A safety valve for pipe strings extending into a well, comprising, a tubular body co-axially connectible into the pipe string to form a part thereof, a sleeve member slidable axially in the body and having a full open bore of substantially the same size as the pipe string, a flapper valve hinged to the side of the body adjacent the lower end of the sleeve member, pivoted linkage means connecting said valve to said sleeve member operative by reciprocation of said sleeve member to move said valve between open and closed positions with respect to the lower end of the sleeve member, a longitudinally extended annular chamber in the casing surrounding said sleeve member and sealed at its opposite ends about the sleeve member, a differential area piston mounted on the sleeve member inside the chamber and extending into slidable sealing engagement with the wall of the chamber, means operative upon the sleeve member to urge it to the valve-closing position, conduit means providing fluid pressure communication between the interior of the pipe string and the interior of said chamber above the piston, port means through the wall of the body below the piston, and control means including a valve controlled vent in said conduit means operative in response to fluid pressure in said pipe string to release pressure fluid from the chamber above the piston when the pressure in said pipe string is above or below a pre-determined range of pressures whereby to automatically cause said sleeve member to move to the valve-closing position.

14. A safety valve for well pipe strings, comprising, a tubular body coaxially connectible into a pipe string to form a part thereof, a flapper-type valve member hingedly connected to one side of the body for swinging movement across the bore of said body between positions opening and closing said bore, a valve-actuating sleeve member having a full open through-bore longitudinally slidable in the bore of said body cooperating with said valve member, seal means arranged between the sleeve

member and the body at longitudinally spaced points to define an annular chamber between the sleeve and the body, barrier means carried by the exterior of the sleeve member constructed and arranged to define a differential area piston having slidable sealing engagement with the wall of the body within said chamber, port means through the wall of said body providing communication between the exterior of the pipe string and the interior of the chamber on one side of said barrier means, conduit means providing communication between the interior of said pipe string and the interior of the chamber on the opposite side of said barrier means, said sleeve member being operable in response to a predetermined fluid pressure differential across the barrier means between the interior and exterior of the pipe string to effect movement

of said valve member between said positions, and control means in said conduit means operable in response to move said sleeve member to the valve-closing position. fluid pressure inside the pipe string above and below a predetermined range of pressures to establish a fluid pressure differential across said barrier in a direction to

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