

[54] **WELL FLOW CONTROL SYSTEM AND METHOD**

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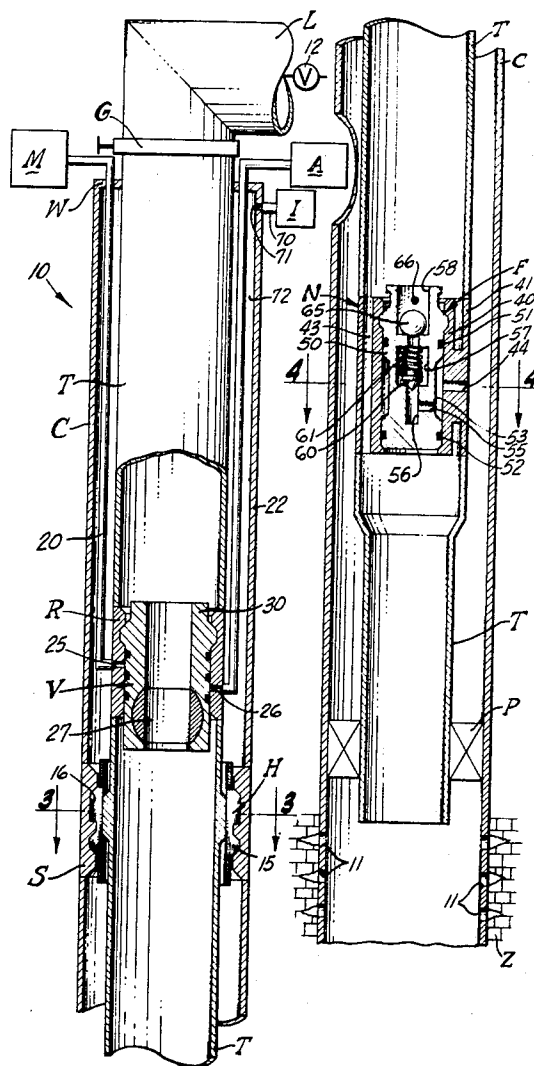
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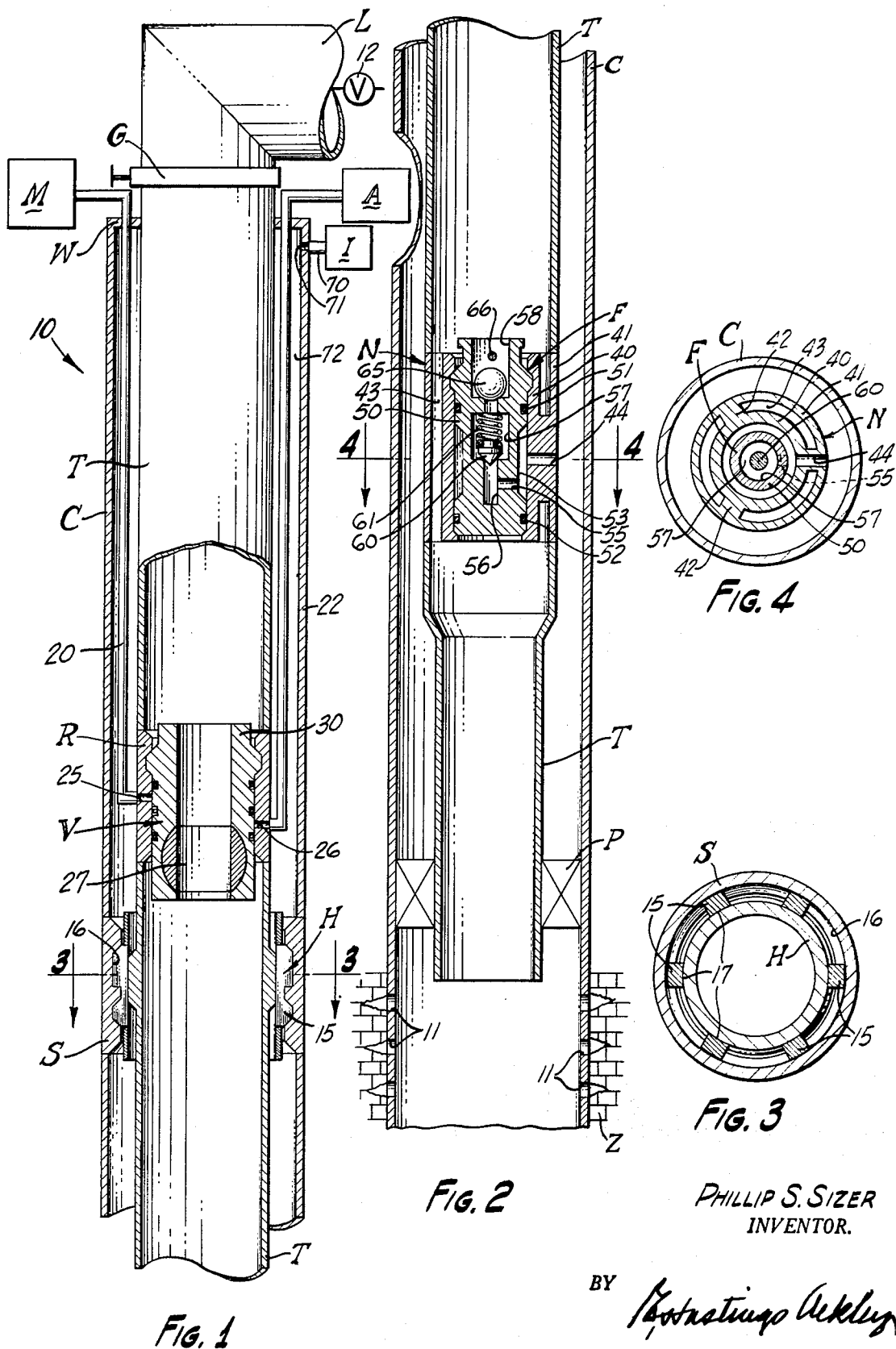
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[57] **ABSTRACT**

A well flow control system for producing high volumes of fluids from a well formation, the system having a flow conduit or conductor with a safety valve therein responsive to predetermined conditions of flow for shutting off flow through the flow conductor and operable under control from the surface. A means for injecting chemical corrosion inhibitors and other treating fluids into the well fluid is provided which also affords means for loading or killing the well in the event of damage to the surface connections of the well, or other conditions of need. Complete automatic shut-off is provided to prevent the well flowing wild, all controls are subsurface, and are removable by flexible line operated tools through the flow conductor.

17 Claims, 9 Drawing Figures





WELL FLOW CONTROL SYSTEM AND METHOD

This invention relates to well flow control systems, and is more particularly directed to a system of subsurface control of flow of fluids in a well and a combination chemical injector system and kill string arrangement.

A particular object of the invention is to provide means supporting a flow conductor in place in a well, with a subsurface flow control safety valve installed in the flow conductor below the surface and controlled from the surface for automatically shutting off fluid flow through the well flow conductor in the event of damage to the well surface connections or other disaster or need, and having a system for injecting chemical treating fluids into the well flow stream controlled from the surface and providing a means for killing the well by injecting loading fluid into the well under circumstances in which such is desirable.

A further object of the invention is to provide, in a system of the character described, means for controlling the injection of chemical treating liquids from the annulus into the well flow conductor and/or preventing back flow of fluids from the well flow conductor to the annulus through which the chemicals are injected from the surface.

An important object of the invention is to provide an installation in which the flow conductor is suspended from a point below the surface, as below the mud line in a submarine well or below the permafrost level in a well located in arctic areas, whereby damage to any of the surface connections will not result in turning the well loose to flow wild.

A further object of the invention is to provide a system of the character described wherein the control of flow in the well is effected to a subsurface point, particularly where the ambient temperatures are quite low, and likelihood of damage to the metallic elements of the flow control devices resulting from the cryogenic effects of the cold is reduced or substantially eliminated.

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 of the upper portion of a well flow control system or installation embodying the invention;

FIG. 2 is a continuation of FIG. 1 showing the lower portion of the well installation down to the producing formation;

FIG. 3 is a horizontal cross-sectional view taken on the line 3—3 of FIG. 1;

FIG. 4 is a horizontal cross-sectional view taken on the line 4—4 of FIG. 2;

FIG. 5 is a schematic illustration of a modified well flow control system of the character of the invention showing the upper portion of the installation;

FIG. 6 is a continuation of FIG. 4 showing the lower portion of the installation down to the producing formation in the well;

FIG. 7 is a horizontal cross-sectional view taken on the line 7—7 of FIG. 5;

FIG. 8 is a horizontal cross-sectional view taken on the line 8—8 of FIG. 5; and,

FIG. 9 is a fragmentary view, partly in elevation and partly in section, of a modified form of landing nipple or receptacle for the valves of the system.

In the drawings, FIGS. 1 and 2, a well flow control system 10 is illustrated wherein a well casing C extends downwardly in the well bore to a point below the producing formation Z, and a plurality of perforations 11 of the usual type are formed in the usual manner in the casing communicating with the producing formation for admitting well fluids from the formation into the bore of the casing. A tubing string T is sealed at its upper end to the casing by means of a well head system W at the upper end of the casing and extends downwardly through the casing C to a packer P which seals between the lower end of the tubing string T and the bore wall of the casing above the perforations 11. A flow line L is connected to the upper end of the tubing above the well head and a tubing gate valve G connected in the upper end of the tubing above the

well head W. The flow line extends in the usual manner laterally to a suitable point of gathering or disposal of the fluids produced from the well. A flow line valve 12 is connected in the flow line to control the flow of fluids from the well through the flow line. The tubing string T is supported in the well near but below its upper end by means of a hanger H which is removably landed in a supporting nipple or housing S connected in the casing string, below the mud line of the well if it is a submarine well or below the permafrost level if it is an arctic installation, or at any other desired subsurface position in other wells.

The hanger H may be of the type generally shown in the patent to Schramm, U.S. Pat. No. 3,054,449, issued Sept. 18, 1962, having expansible and retractable supporting dogs 15 which engage in suitable recesses 16 formed in the bore wall of a supporting nipple S, and the mandrel 17 of the hanger is connected in the tubing string T at a point which will support the tubing at the desired level in the well and extends upwardly from the mandrel to a receptacle or landing nipple R, for a subsurface flow control ball type safety valve V which is removably anchored in place in the receptacle or landing nipple in the usual manner. Such a valve is illustrated in the patent to Fredd, U.S. Pat. No. 3,077,669, issued Nov. 7, 1965, or the patent to Taylor, U.S. Pat. No. 3,411,576, issued Nov. 19, 1968. The valve V is normally closed and is moved to the open position shown in FIG. 1 by means of a control fluid pressure from a source M which is conducted by means of a control fluid pressure conductor line 20 extending through the well head W downwardly to a lateral inlet 25 in the wall of the receptacle R to communicate with the safety valve V to move the valve closure member 27 to the open position. A biasing force is applied to the valve, in addition to the usual resilient or spring load which normally urges the valve toward closed position, by means of fluid pressure from an accumulator A at the surface which is conducted downwardly through a back pressure control line 22 extending through the well head W and downwardly to a lateral port 26 in the receptacle R through which it enters the valve V to maintain a biasing force urging the valve toward closed position. The force of the fluid pressure from the accumulator is overcome by the pressure from the pressure source M to normally hold the valve in open position.

Should a condition occur which would result in loss of pressure in the control fluid line 20 from the pressure source M, the valve will automatically be moved to its closed position by the back pressure fluid pressure from the accumulator A acting through the back pressure control line 22. In the event both the control fluid line 20 and the back pressure line 22 are damaged, the valve will be moved to its normally closed position by means of the resilient biasing spring in the mandrel 30 of the valve V.

In the lower portion of the tubing string T, a bypass landing nipple N is connected. This bypass landing nipple is generally of the type illustrated in the patent to Wilhoit et al, U.S. Pat. 2,756,724, issued Dec. 19, 1955. The bypass nipple N has a central smaller tubular receptacle or landing nipple 40 which is smaller in external diameter than the bore of the outer housing or sleeve 41 of the bypass nipple. The inner receptacle 40 is supported in the outer sleeve or housing 41 by a plurality of circumferentially spaced radial rib members 42 which are spaced from each other to provide a substantially annular flow passageway 43 longitudinally exteriorly of the inner landing nipple from end to end of the bypass nipple N. A lateral port 44 is formed in one of the ribs extending from the exterior of the outer sleeve 41 to the interior of the landing nipple 40, and fluid from the outside of the tubing string T will pass through the port 44 into the bore of the landing nipple 40.

Seated in the landing nipple is a removable flow controlling regulator device F which has an elongate mandrel 50 provided with external annular seal rings 51 and 52 on its exterior above and below the lateral port 44 and sealing between the mandrel and the bore wall of the landing nipple 40. The exterior portion 53 of the mandrel between the seal members is reduced in

diameter to provide an annular flow course, whereby fluids entering through the port 44 may circulate around the mandrel to a lateral inlet port 55 formed in the wall of the mandrel between the spaced O-ring seal members and communicating with a longitudinal bore 56 in the lower end of the mandrel. The bore 56 is closed at its lower end and opens upwardly through an enlarged valve chamber 57 in the mid-portion of the mandrel of the flow controlling device, and then with an enlarged exit bore 58 in the upper end of the mandrel. A spring pressed regulating valve 60 is disposed in the enlarged valve chamber 57 and maintains a back pressure on the fluids entering through the lateral port 44 of the nipple and the lateral port 55 of the mandrel into the bore 56 thereof. The fluids passing the valve will flow upwardly through the bore of the mandrel and out through the exit bore 58 at the upper end of the mandrel past a downwardly seating check valve 65 which is positioned in the upper enlarged exit bore of the mandrel and is held against displacement therefrom by a cross pin 66 extending diametrically across the bore 58.

Chemical treating fluids are injected by means of an injecting control device I through a lateral conductor 70 and a lateral port 71 into the annular space 72 between the casing C and tubing T, and the treating fluids will pass downwardly to the packer P and build up a column of treating fluid in the annular space 72 extending upwardly to and above the lateral ports 44 in the bypass nipple N. The chemicals for treating the well fluids will enter through the lateral port 44 of the bypass nipple and pass inwardly through the lateral port 55 in the flow controlling regulator device F into the bore 56 thereof and act upwardly on the spring-pressed regulating valve 60 to bias the valve upwardly against the force of the spring 61. The fluid present in the tubing string above the valve 60, together with the spring acting on the valve 60, will resist opening movement of the valve by a predetermined amount controlled by the size of the valve seat and the spring pressure, and will thus control entry of the treating fluid into the tubing string through the regulating device. When the pressure of the treating fluids in the annulus is sufficient to unseat the valve 60, the chemicals will pass upwardly through the bore of the regulator past the check valve 65 and then outwardly through the upper enlarged exit bore 58 into the bore of the tubing string, where the chemicals will act on the fluids flowing through the well tubing to the surface to prevent corrosion of the tubing, paraffin deposits, and so forth. The corrosion inhibiting fluid injected to act on the pipe will act to maintain the same free of corrosion or to reduce corrosion thereof.

While the well is being produced in the normal manner, fluids will flow from the producing formation Z inwardly through the perforations and upwardly in the casing C to the packer. The fluids will then enter the lower end of the tubing T and pass upwardly therein through the bypass passages 43 in the bypass landing nipple N and upwardly thereabove through the tubing string to the surface controlled subsurface flow controlling safety valve V, which is maintained in an open condition by the control fluid pressure from the pressure source M acting through the control fluid line 20 on the valve to hold the closure member 27 thereof open. The well fluids will flow through the valve upwardly in the tubing string T past the gate valve G to the surface flow lines L and to storage or other facilities for handling the well fluids. During the production of the fluids, chemicals for inhibiting corrosion of the flow conductors may be injected into the annular space by means of the injector I at the upper end of the casing and flow downwardly in the annular passage to the lateral port 44 in the bypass nipple N. If desired, a substantial column of liquid may be maintained in the annular space sufficient to barely overcome the pressure effect of the well fluids flowing in the tubing string past the regulating flow controlling device F and acting on the valve 60 therein. The pressure of such flowing well fluids and the force of the spring 61 will maintain the valve closed until an additional volume of treating chemical is injected from the surface by means of the injector I, and the amount of chemical entering the tubing string may be accu-

5 rately controlled by controlling the amount of chemical injected into the annulus at the surface. If other chemicals than corrosion inhibitors are desired to be used for treating the fluids, as for example to prevent paraffin from depositing on the walls of the flow conductor or tubing string, that type of chemical may be injected into the annulus through the chemical injector I.

10 The longitudinal opening through the valve V, including the ball closure member 27, is larger in diameter than the maximum external diameter of the flow regulator device F, so that the regulator device may be moved in the flow conductor or tubing string into or out of the landing nipple 40 of the bypass nipple N through the bore of the valve V while the valve V is open. This permits servicing the regulator device F with the safety valve V in place in the receptacle R, if desired.

15 In the event of the occurrence of a disaster or failure of the well head connections for any reason, resulting in a loss of control fluid pressure in the line 20, the ball valve surface controlled flow controlling safety valve V will be moved automatically to the closed position by the back pressure from the accumulator A acting through the back pressure control line 22 on the valve. Should the line 22 or the accumulator be damaged simultaneously with the control fluid line 20, the valve will be automatically moved to its closed position by the spring or other resilient means in the valve which normally biases the valve to closed position.

20 If the damage to the well surface connections occurs, so that the valve V is closed and it is necessary to handle the tubing string T, as by removing it from the well or the like, the well may be killed by injecting loading fluid into the annular space 72 from the surface through the injector connection 70. The fluids will flow downwardly in the annular space to the lateral port 44 of the bypass nipple N and enter through the lateral port, pass the regulating valve 60 of the flow controlling regulator F and flow inwardly into the bore of the tubing string at the valve and downwardly in the tubing string to the well producing formation F, where they will overcome the force of the fluid pressure in the formation and result in killing the well, whereby the well may be worked upon without flowing wild, and in safety.

25 In the event loading fluid is not available to inject into the annular space, it will readily be seen that the pressure of the well fluids in the tubing string T acting on the check valve 65 and the regulating valve 60 will move those valves to closed positions preventing flow of the well fluids outwardly through the lateral port 55 in the mandrel of the flow controlling regulating valve F and the lateral port 44 in the bypass nipple. With the subsurface flow controlling safety valve V closed and the check valve and regulating valve closed by fluid pressure in this manner, the well is completely closed in below the surface and the well fluids cannot escape or produce unsafe conditions at the surface. This safety condition is obtained automatically as a result of the installation of the system just described in the well.

30 Should the well be located in an offshore location and the well head connections above the mud line and the well in the body of water be damaged, the same conditions will obtain. In addition, the loading effect of the water in the body of water acting through the annular space will assist to kill the well and prevent escape of the well fluids through the annulus.

35 A modified form of the well flow control system installation is shown in FIGS. 5 through 8, inclusive, wherein the casing C-2 extends downwardly in the well bore through the producing formation Z-2. The casing is perforated at 111 in the formation whereby fluids may enter the bore of the casing and flow upwardly therein in the usual manner. A packer P-2 is secured in the well casing below the mud line of a submarine well or below the permafrost line of a well located in arctic areas. The packer P-2 has an upwardly opening bowl 120 on its upper end forming an integral part thereof and providing an inclined seating member 121 for supporting a spider hanger 122 which is secured to the tubular extension string T-3 near the upper end thereof. The tubing extension string hands

downwardly from the spider in the bore of the casing to a point adjacent the producing formation.

The upper cylindrical portion 123 of the bowl 120 of the packer is provided with an internal sealing surface 124 and internal threads 125, which may be of the buttress or coarse Acme type, to provide a connection for the reduced tubular lower end 132 of a bypass nipple N-2 which is threaded on its lower end with threads 131 mating with the threads 125 in the bowl of the packer. The tubular extension 132 on the lower end of the bypass nipple has external packing 133 mounted in an annular external groove thereon for sealing between the extension and the bore well or sealing surface 124 in the bowl of the packer. The lower end of the extension 132 of the bypass nipple abuts against the upper end of and provides a means for retaining the spider 122 in place in the bowl 120 of the packer mandrel.

The tubing extension string T-3 is run into a well bore by means of a running in string or other suitable lowering device having a J-slot or similar connection engaging a pair of diametrically opposed lugs 127 on the exterior of the upper projecting end of the tubing extension string T-3 above the spider 122. The running string is then disconnected from the tubing extension and removed from the well and the landing bypass nipple N-2 inserted.

The bypass nipple has an outer tubular housing 141 and an inner tubular landing nipple 140 disposed centrally of the bore of the housing and held in such central relation by means of a plurality of circumferentially spaced supporting ribs 142. The substantially annular space 143 between the inner landing nipple 140 and the bore wall of the outer housing 141 provides a flow passage through the bypass nipple housing exteriorly of the landing nipple. One of the wings or ribs 142 is provided with a lateral port or flow passage 144 which provides for flow from the exterior of the housing 141 of the bypass nipple into the bore of the internal landing nipple 140.

A flow controlling regulating device F-2 is releasably anchored in the bore of the landing nipple 140 in the same manner as the flow regulating device F of the form first described. In this form, the mandrel 150 of the regulating device has a fishing neck at its upper closed end and is provided with an enlarged exit bore 158 extending upwardly from its lower end to a reduced bore 156 closed at its upper end and having a regulating valve chamber 157 intermediate its ends. A lateral port 155 extends outwardly from the upper closed portion of the bore 156 to the exterior of the mandrel 150. External annular packing means 151 and 152 are mounted in external annular grooves formed in the outer cylindrical surface of the mandrel above and below the lateral port 155 of the flow regulating device F and these seal rings seal also between the mandrel and the bore wall of the landing nipple 140 on either side of the lateral port 143 which extends inwardly into the bore of the landing nipple. An external annular recess 153 is formed in the periphery of the mandrel 150 to permit fluids to flow from the lateral inlet port 144 into the bore of the landing nipple 140 and be confined therein between the seal rings 151 and 152. The lateral port 155 directs fluid inwardly from the annular recess 153 to the bore 156, where the fluid flows downwardly to the valve chamber 157 through a seat at the upper end thereof and then past a spring pressed regulating valve 160 which is resiliently biased into engagement with the seat at the upper end of the chamber 157 by a spring 161. Below the valve chamber 157, the bore 156 communicates with the enlarged downwardly facing exit opening 158 of the mandrel in which a spring supported ball check valve 165 is disposed. The check valve engages against a downwardly facing seat at the upper end of the enlarged exit bore and is pressed lightly against said seat by the spring 167 confined between the ball check valve and a shoulder 166 at the lower end of the exit bore. Above the lateral opening 155, the bore of the mandrel is closed, whereby fluids flowing inwardly through the lateral port 144 in the outer housing 141 into the bore of the landing nipple 140 will enter the lateral ports 155 in the mandrel 150 and pass into the upper end of the bore

156 thereof to act on the upper end of the spring pressed regulating valve 160. When the pressure is sufficient to move the valve downwardly away from its seat, against the force of the spring 161 and the pressure of the fluids in the flow tubing acting on the opposite lower side of the valve, the regulating valve will be moved to open position to permit the fluids to pass the valve and flow through the valve chamber 157 and the seat above the check valve 165. Since the check valve is pressed only lightly against its seat by the spring 167 the valve will readily open to permit the fluids to pass outwardly through the exit bore in the lower end of the mandrel and thence into the bore of the extension tubing T-3 therebelow.

Since the ball check valve 165 is pressed against its seat only very lightly by the spring 167, it is readily apparent that the valve will be easily opened by a very small pressure differential, and, since the differential is small, the velocity of flow through the restriction is low and the ball valves will not be flow cut to any appreciable degree.

Therefore, the device is provided with a flow regulating valve which controls admission of chemicals from the annulus into the tubing extension T-3 in the same manner as that of the form first described. Also, the entire flow regulator valve P may be removed by flexible line mechanism through the tubing string T-2 thereabove.

A receptacle R-2 for receiving and seating a removable surface controlled ball type subsurface flow controlling safety valve is connected in the tubing string T-2 above the bypass nipple N-2 and the tubing string T-2 extends upwardly from the receptacle to the surface through the well head W-2 in the same manner as the form first described. A gate valve G-2 is provided on the tubing string above the well head and lateral flow line L-2 and flow line valves 112 are provided in the same manner.

A control fluid flow line 120 extends downwardly through the well head from a pressure source M-2 at the surface and communicates through a lateral port 125 in the receptacle R-2 with the mandrel of the safety valve V-2 for moving the valve to the open position. A back pressure line 122 extends downwardly from an accumulator or similar pressure chamber A-2 at the surface in the annular space 172 to the receptacle R-2 and communicates through a lateral port 126 with the mandrel of the valve V-2 for biasing the valve toward the closed position. The valve is also biased toward the closed position by a spring or other suitable resilient means, in addition to the fluid pressure of the accumulator, and the valve operates in the same manner as the valve V of the system first described.

A chemical injecting device or mechanism I-2 at the surface is connected by means of a conduit 170 to a lateral port 171 at the upper end of the casing and is used for injecting treating chemical into the annular space 172 between the tubing T-2 and the casing C-2, for inhibiting corrosion of the pipes, etc., for preventing the depositing of paraffin or for other purposes, as desired. The chemicals so injected will flow downwardly in the annular space to the lateral flow port 144 in the bypass nipple N-2 and will enter the landing nipple 140 and pass downwardly through the bore of the flow control regulating device F-2 past the regulating valve 160 therein and past the check valve 165 and outwardly into the bore of the tubing extension T-3, wherein it will flow downwardly in the well to a point adjacent the producing formation Z-2 and will then flow upwardly with the well fluids in the casing to the packer P-2, and will enter and flow through the bore of the packer P-2 past the spider 122 through the bypass passage 144 of the bypass nipple N-2, then upwardly through the tubing string T-2 to the safety valve V-2 and thence through the tubing thereabove to the surface flow line L-2.

In this form of the device, should any of the wall surface connections be damaged or destroyed or otherwise affected to prevent normal operation of the well, so that the pressure of the control fluid in the control fluid line 120 acting on the ball safety valve V-2 is ineffective to retain the ball in the open position, the ball closure 127 will move to the closed position

to cut off flow through the tubing. Likewise, the well fluid pressure present in the tubing extension T-3 acting on the ball valve check valve 165 and on the regulating valve 160 of the regulator device F-2 will move those valve members to closed positions engaging the seats with which they co-act to prevent flow of well fluids from the casing upwardly through the tubing extension and outwardly through the lateral port 144 of the bypass nipple into the annulus above the packer. Thus, the well is held under control and may be safely worked upon in the same manner as the installation first described.

The flow regulator device F-2 is movable through the tubing string T-2 and the bore of the ball type safety valve V-2 into and out of the landing nipple 140 of the bypass nipple N-2 while the safety valve V-2 is positioned in the receptacle R-2 and is open. This permits servicing or adjusting the flow regulator device, if desired, without removing the safety valve from its position in the receptacle R-2.

In this form of the device, the full casing area is utilized to flow the well fluids from the producing formation upwardly to the packer P-2, which is located just below the mud line of a submarine well and just below the lower end of the permafrost in arctic locations, and the fluids will then pass upwardly through the well tubing string T-2 above the packer to the surface so that the flow is relatively unrestricted and the well may be produced at a high rate or volume.

It is to be noted that it is desirable that the bypass nipple N-2 be located a sufficient distance below the receptacle R-2 for the fluids flowing through the bypass passages of the bypass nipple to resume a substantially linear type of flow in the tubing string T-2 above the bypass nipple and below the receptacle R-2 and the subsurface safety valve V-2 so that the stream of the fluids becomes linearly stabilized in the chamber formed between the bypass nipple and the receptacle having the safety valve therein, and turbulence of the flowing fluids in thereby reduced or substantially eliminated in the stream of fluids flowing through the well. The same condition would obtain in the installation shown in FIGS. 1 and 2, where the distance between the bypass nipple N and the receptacle R is substantial.

Other advantages of the installation or system of this form are the same as that of the form first described. The well may be readily loaded or killed by fluids injected into the annulus at the surface through the injector mechanism with the fluids passing downwardly through the annulus inwardly through the lateral port of the bypass nipple and into the tubing extension T-3, through which they will flow downwardly to the producing formation to act thereon to overcome the pressure of the producing formation and load or kill the well.

It is also believed readily apparent that, rather than introducing treating chemical fluids or loading fluids into the annulus and therefrom through the lateral flow passages of the bypass landing nipple members N and N-2, air or other gaseous lifting fluids may be injected into the casing annulus through the injectors I or I-2 to pass downwardly in the casing annulus to the lateral flow passages of the bypass landing nipple members N or N-2 and then inwardly through such lateral flow passages past the regulating valve members F or F-2 into the tubing strings in the well, where the gas will aerate or slug liquids from the well formation present in the tubing strings or flow conductor to the surface in the usual gas lift manner.

In the form of FIGS. 1 and 2 the gas will enter the valve V and pass upwardly past the regulating valve 60 and the ball check valve 65 and out the open upper end of the mandrel into the tubing T thereabove to aerate or slug the liquids from the well.

In the form shown in FIGS. 5 and 6 the lifting fluid will enter the flow regulator device F-2 and pass downwardly in the bore thereof past the regulating valve 160 and the check valve 165 and out the open lower end of the mandrel into the upper end of the tubing extension T-3 therebelow. The lifting fluid or gas will then fill the tubing extension to its lower end and either bubble and aerate, or pass out and slug, the liquids present in the casing upwardly to the well surface.

Should any damage to the system occur or should an emergency arise which would result in shutting the subsurface ball type safety valve V or V-2 or need for closing in the wall, the well pressure from the producing formation would then act on the regulating valve and ball check valve of the flow regulator devices F or F-2 to close the same to prevent escape of well fluids therepast outwardly through the lateral passages of the bypass nipple to the casing annulus, and would so shut in the well producing formation. This result would be particularly accomplished when the lifting gas pressure in the annulus is drained off as a result of damage to the well head or the like.

A sliding sleeve type side port valve may be incorporated in the landing nipple 140 of the bypass nipple N-2, or the landing nipple 40 of the bypass nipple N, for the purpose of closing the lateral ports 144 and 44, respectively, when the flow regulating valves F-2 or F, respectively, are removed from their position in the bypass nipple. Such a sliding sleeve valve structure is illustrated generally in the patent to George G. Grimmer, U.S. Pat. No. 3,211,232, issued Oct. 12, 1965, and is shown in FIG. 9 of the drawings.

The bypass nipple N-3 has the landing nipple 240 disposed centrally thereof and spaced from the walls of the housing 241 to provide the longitudinal bypass flow passages 243 between the housing and the exterior of the landing nipple in the manner already described in connection with the bypass nipples N and N-2. In the form of the bypass nipple shown, the landing nipple 240 is slightly longer than those previously illustrated, and has an enlarged longitudinal bore 270 formed therein between the upper locking recess portion 275 at the upper end of the nipple and the lower internal annular stop shoulder 273 thereof. A valve sleeve 280 is slidable longitudinally in the enlarged bore 270 between the upwardly facing shoulder 273 at the lower end and a downwardly facing shoulder 274 at the upper end of the enlarged bore.

When the valve sleeve is in the lower position shown in FIG. 9, a lateral port 281 formed in the wall of the sleeve is disposed in registry with the lateral inlet flow passage 244 formed in one of the ribs 242 supporting the landing nipple 240 in the housing, so that fluids may flow inwardly through the lateral port 244 and the valve sleeve port 281 into the bore 282 of the sleeve. Seals, such as O-rings 276 and 277, are disposed in recesses above and below the lateral port 244 in the enlarged bore of the landing nipple and seal between the landing nipple and the sliding valve sleeve. An internal annular relief groove 286 is formed in the bore 270 between the O-rings 276 and 277 to assure the fluids flowing inwardly through the port 244 will also enter and flow through the port 281 in the sleeve. When the valve sleeve 280 is in an upper position in which the upper end of the sleeve is adjacent the downwardly facing shoulder 274, the port 281 is disposed above the upper seal ring 276, and the imperforate central portion of the sleeve 280 is disposed between the O-ring seals 276 and 277 to close off flow of fluids in either direction through the lateral port 244.

The sliding valve sleeve 280 has a plurality of circumferentially spaced inward tapering lateral openings 284 formed therein in its lower portion, spaced above the inwardly facing beveled supporting seat 283 at the lower end of the bore 282 of the sleeve, and a locking member or ball 285 is disposed in each lateral opening and is prevented from displacement inwardly into the bore of the sleeve by the reduced annular inner end of the bore 284, the size of the tapered bore 284 being such as to permit the ball to project as shown in FIG. 9, but not to be displaced from the bore. A seal, such as the O-ring 279 is disposed in an external annular recess formed in the valve sleeve below the lateral bore 284, and this seal ring seals between the valve sleeve and the landing nipple 240 below the lateral bores to prevent fluid leakage therepast.

The balls 285 will retract into an internal annular recess 278, formed in the enlarged bore 270 of the landing nipple below the lower seal ring 277, when the valve sleeve 280 is in the upper position with its upper end adjacent the downwardly facing shoulder 274. In this position the balls will retract and

not project into the bore of the valve sleeve, whereby a flow regulating valve device F-3 may be inserted into the upper end section 271 of the landing nipple and be moved downwardly therethrough into the bore 282 of the valve sleeve until the lower end of the mandrel 250 of the flow regulating valve device engages the upwardly facing shoulder 283 in the bore of the valve sleeve, whereupon further downward movement of the flow regulating valve device will move the valve sleeve downwardly until its lower end engages the upwardly facing shoulder 273 at the lower end of the enlarged bore of the landing nipple.

As the regulating valve mandrel 250 enters the valve sleeve in its upper position, the mandrel will pass the balls 285, since the balls will be displaced or retracted into the recess 278 in the landing nipple and not project into the bore of the valve sleeve. As the valve sleeve is moved downwardly by the valve F-3, the balls will be cammed inwardly into the bore of the sleeve by the beveled shoulder at the lower end of the annular recess or groove 278 and will be projected into the bore of the valve sleeve above the upwardly facing beveled shoulder 253a at the lower end of the external annular flow groove 253 on the central portion of the mandrel 250 between the sealing rings 251 and 252 which seal with the wall of the bore of the valve sleeve above and below the lateral port 281 to direct fluid entering through said port into the bore of the sleeve and through the lateral opening 255 of the mandrel into the bore of the mandrel of the flow regulating valve device F-3 in the usual manner. The O-ring seal 279 prevents fluids escaping through the lateral tapered bores downwardly between the valve sleeve and the landing nipple.

The locking members 290 on the upper end of the mandrel engage in the locking recess 272 in the upper portion 271 of the nipple, whereby the flow regulating valve device F-3 is locked in place in the landing nipple and the valve sleeve is positively held in the lower position shown in FIG. 9 admitting fluids from the tubing-casing annulus through the lateral port 244 in the housing and through the port 281 in the valve sleeve into the bore 282 of the sleeve for direction into the lateral opening 255 in the mandrel 250 of the flow regulating valve. The fluids entering the flow regulating valve will be controlled in the manner already described, flowing therethrough into the tubing string or flow conductor in the well.

When the flow regulating device F-3 is removed from its position in the bypass nipple, the locking members 290 are disengaged from the locking recess 272 in the upper end of the landing nipple, and the mandrel is lifted. The shoulder 253a on the mandrel then engages the locking balls 285 and lifts the valve sleeve 280 upwardly until the upper end of the sleeve is adjacent the downwardly facing shoulder 274 in the bore of the landing nipple and the imperforate central portion of the valve sleeve is again disposed between the upper and lower seal members 276 and 277, respectively, to close off the lateral port 244. With the valve sleeve in this upper position, the balls 285 will be cammed into the recess 278 in the landing nipple, and retracted from projection into the bore 282 of the valve sleeve, to permit the mandrel of the regulating valve device to move upwardly out of the sleeve, out of the landing nipple and out of the well.

It is obvious that the same type sliding side port valve structure may be utilized in either of the bypass landing nipples N or N-2 for closing the lateral ports in such nipples to prevent passage of fluids in either direction through such lateral ports. This will prevent treating chemicals from entering the bore of the tubing string when the regulating valve F-3 is removed, and will also provide a positive closure preventing escape of well fluids from the tubing into the annulus.

It is also believed readily apparent that a similar sliding side port valve structure may be incorporated in the receptacles R and R-2, in which the subsurface safety valves V and V-2 are releasably anchored, and that such sleeve valves could be used to close the lateral control fluid ports 25 and 125 and the back pressure fluid ports 26 and 126, respectively, of such receptacles.

It will therefore be seen that the system provides a means for gas lifting large volumes of liquid in a large flow conductor by injection of lifting gas or air through the flow regulator devices F or F-2, while, at the same time, providing means for completely closing in the well formation below the well surface in the event of damage to the surface controls or other emergency.

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. A well installation comprising: a well casing extending from the surface to the producing formation of the well and having an inlet for well fluids from the producing formation into said casing; a tubing string in said casing extending from the surface of the well downwardly to a packer disposed in the bore of the casing above the producing formation and sealing between the tubing string and the casing to direct well fluids flowing upwardly in the casing into the tubing string for flowing to the surface; a fluid pressure responsive surface controlled subsurface safety valve mounted in the tubing string above the packer, said safety valve being normally biased closed and movable to open position by control fluid pressure directed thereto from the surface; bypass landing nipple means connected in the tubing string below the safety valve and having a lateral flow passage between the interior thereof and the annular space exteriorly thereof; flow regulating valve means disposed in said landing nipple means for controlling admission of fluids through the lateral flow passage of said landing nipple means into the flow tubing string; said flow regulating means having means preventing back flow of fluids through said flow regulating means to the annular space exteriorly of the landing nipple; control fluid pressure means at the surface; control fluid conductor means from the control fluid pressure source at the surface to the safety valve; back pressure conduit conductor means from the back pressure means at the surface to the safety valve for conducting back pressure from the back pressure means to the valve to bias the valve to closed position; injector means at the surface having flow communication with the annular space between the tubing and casing at the surface for injecting chemical treating fluids into the annular space to enter through the lateral port in the landing nipple and through the flow regulating valve means into the tubing string for treating the well pipe or well fluids; said injector means at the surface also providing means for injecting loading fluid into the well through the annular space, the landing nipple, the regulating device, and the tubing string to load the well when desired.

2. A well installation of the character described in claim 1 wherein the subsurface surface controlled safety valve is insertable into and removable from the tubing string while the tubing is in place in the well.

3. A well installation of the character set forth in claim 1, wherein the flow regulating device in the bypass landing nipple means is movable through the tubing string, through the safety valve into and out of the landing nipple means while the tubing string and safety valve are in place in the well to permit servicing the regulating valve device.

4. A well installation of the character set forth in claim 1 wherein: valve means is provided in the bypass landing nipple means for closing the lateral flow passage therein when said flow regulating valve means is removed therefrom.

5. A method of controlling a flowing well having a well casing therein communicating with the producing formation of the well and a well head system at the surface comprising: installing a packer and tubing string in the well with the packer sealing between the tubing string and the casing above the producing formation; locating a flow controlling safety valve in the tubing string at a point below the safety valve and establishing a lateral passage for communication between the

bore of the tubing string and the annulus between the tubing and casing above the packer and below the safety valve; controlling flow of fluids through the tubing string by means of the safety valve to prevent uncontrolled flow of such fluids; and controlling flow of fluids between the annular space and the tubing string below the safety valve through the lateral passage while controlling flow of fluid through the tubing string by means of the safety valve.

6. The method of claim 5 including the additional steps of: injecting treating fluid into the annular space at the surface of the well, and controlling the admission of such treating fluid in the tubing string through the lateral passage.

7. The method of claim 5 and the additional step of: injecting loading fluid into the annular space between the tubing and casing at the surface and through the lateral flow passage into the tubing string below the safety valve to load the producing formation with loading fluid to prevent uncontrolled flow of fluids from the formation.

8. The method of claim 5 wherein the packer and safety valve are located in the upper portion of the well below the surface and the well is produced through the casing to the packer and safety valve then through the tubing from the packer and safety valve to the surface.

9. The method of claim 5 including the step of: supporting the tubing string below the safety valve at a point in the well casing below the surface.

10. The method of claim 5 including the additional step of: closing the lateral passage into the tubing string below the safety valve to prevent flow therethrough in either direction.

11. A well system for a well having a string of casing extending downwardly therein from the surface to the producing formation and having an inlet for well fluids from said formation and a well head closure assembly thereon at the surface, said system including: an elongate tubing string; means for supporting said tubing string in the casing at a location below the surface of the well and above the producing formation, said tubing string extending downwardly from the supporting means to a point adjacent the producing formation; a packer sealing between the tubing and casing below the supporting means and above the producing formation; a flow conductor extending upwardly from the supporting means through the well head closure assembly; a receptacle in said flow conductor above said supporting means and above said packer; a removable fluid pressure responsive subsurface safety valve mounted in the receptacle, said safety valve having means normally resiliently biasing it closed; a back pressure fluid control conduit extending from the surface to the receptacle and the safety valve for conducting back pressure fluids from the surface to the safety valve for closing the same in addition to said biasing means; control fluid conduit means extending from a source of control fluid pressure at the surface to the receptacle and the safety valve for conducting control fluid pressure to said safety valve to move said safety valve to open position against the back pressure fluid acting thereon and the resilient biasing means; bypass landing nipple means connected with the tubing string below the safety valve receptacle and above the packer between the casing and tubing, said bypass landing nipple means comprising a housing having an internal landing nipple therein and a longitudinal flow passage through said housing exteriorly of the internal landing nipple, and having a lateral flow passage connecting the bore of the internal landing nipple with the exterior of the housing and the annular space between the tubing and casing above the packer; flow regulating valve means removably disposed in the landing nipple of said bypass landing nipple means and having valve

means biased toward closed position regulating flow of fluid inwardly through the lateral passage of said bypass landing nipple means into the bore of the internal landing nipple and to the tubing string in communication therewith and preventing back flow of fluids from said tubing string outwardly through said passage to said annular space; means for injecting fluid into the annular space at the surface to be admitted through the lateral passage and flow regulating means into the tubing string; said safety valve being operable to close off flow from the well through the flow conductor thereabove and said flow regulating means being operable to prevent flow of fluids from the well producing formation through the lateral passage to the annulus.

12. A well system of the character set forth in claim 11 wherein the subsurface safety valve is insertable into and removable from the receptacle while the flow conductor is in place in the well.

13. A well system of the character set forth in claim 11 wherein the flow regulating means of the bypass landing nipple means is movable into and out of the internal landing nipple of the bypass landing nipple means through the safety valve thereabove while the safety valve is in place.

14. A well system of the character set forth in claim 11 wherein the means at the well surface for injecting fluid into the annular space comprises: means for introducing lifting gas under pressure into the annulus to flow through the lateral passage of the bypass landing nipple means through the flow regulating valve means into the tubing to aerate well liquids in the tubing and casing to cause said well fluids to be lifted to the surface of the well.

15. A well system of the character set forth in claim 11 wherein: means is provided in said system for closing off the means for conducting fluids into the tubing string above the producing formation.

16. A well system of the character set forth in claim 11 wherein: valve means is provided in the bypass landing nipple means movable to close the lateral flow passage therein to prevent fluids flowing in either direction through said flow passage when said flow regulating valve means is removed from the landing nipple.

17. The method of controlling a flowing well having a well casing therein communicating with the producing formation of the well and a well head system at the surface comprising: installing a packer and tubing string in the well with the packer sealing between the tubing string and the casing above the producing formation; locating a flow controlling safety valve in the tubing string at a point above the packer and below the surface of the well; locating a flow regulating device in the tubing string at a point below the safety valve and establishing a lateral passage for communication between the bore of the tubing string and the annulus between the tubing and casing above the packer and below the safety valve; controlling admission of fluid from the annular space through the lateral passage into the tubing string below the safety valve; controlling flow of fluids through the tubing string by means of the safety valve to prevent uncontrolled flow of such fluids; controlling flow of fluids between the annular space and the tubing string through the lateral passage while controlling flow of fluid through the tubing string by means of the safety valve; and wherein the packer and safety valve are located in the upper portion of the well below the surface and the well is produced through the casing to the packer and safety valve then through the tubing from the packer and safety valve to the surface.

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