ABSTRACT OF THE DISCLOSURE

On a petroleum well having a tubing safety valve in the tubing string, constructed to remain open so long as the differential pressure across the valve does not exceed a predetermined amount and to close when the pressure drop exceeds said predetermined amount: a surface well head element having means defining at least one tortuous passageway therethrough, an inner end of the passageway being in communication with the tubing string bore and an outer end of the passageway being in communication with the atmosphere exteriorly of the well head; a plug of fusible material such as lead is cast in situ in the tortuous passageway. The plug resists extrusion from the passageway under high pressure and leakage of well pressure around the plug; however, a fire in the vicinity of the surface well head element will melt the plug, opening its passageway. The diameter of the passageway allows a sufficient flow rate to cause the pressure drop to exceed said predetermined amount, closing the valve and thus shutting in the well.

Background of the invention

Tubing safety valves are commonly employed on petroleum wells and in many instances, especially on offshore wells produced from platforms, their use is required by law as a safety measure.

Several manufacturers currently market many variations of such tubing safety valves. (E.g. note Composite Catalog of Oil Field Equipment & Service, 1966-67 edition, Gulf Publishing Company, Houston, various pages, see index subheadings under Valves and various subheadings under Chokes, especially Chokes—Storm, and, for instance, pp. 3833-3844.) Some such safety valves are constructed to be mounted in the tubing string either as a segment of the string or as a pumped down, wire line lowered or submersed element packed or latched in place in the tubing bore. Downhole tubing safety valves are usually mounted below the paraffin level so that periodic service or workover operations to remove paraffin from the tubing need not require removal of the tubing safety valves. The paraffin level differs from well to well and field to field depending on subterranean pressures and temperatures and on composition of the base of the crude. As an example, it would not be unusual to mount a subsurface tubing safety valve about 2000 feet down in the well.

Other tubing safety valves are mounted at the surface, for instance on the Christmas tree, and are sometimes referred to as automatic chokes. The device of the invention may also be used with them.

Tubing safety valves may be further categorized according to the manner in which they are designed to be actuated. A first group, which may be referred to as the subsurface operated or differential pressure operated, is the simplest, since ones in this group require no control lines extending to the surface. A typical valve of this type is normally open, and closes solely in response to attainment of a predetermined pressure differential across the valve either due to a pressure surge from below the valve or a failure of some well element above the valve, for instance breakage of the Christmas tree due to wave action in a storm.

A second group of tubing safety valves may be referred to as being surface controlled. These, in addition to operating in response to a sensation of attainment of a pressure drop of a predetermined magnitude, have control lines extending to a control point at the surface where an operator sensing danger, such as a fire or a violent storm, may voluntarily close the tubing safety valve in order to forestall or limit the consequences of a disaster.

The device of the invention may be used with both these types of tubing safety values.

With the advent of wells completed to produce from multiple zones through the use of parallel tubing strings, it has become common to employ a tubing safety valve for each tubing string.

Especially in instances where many wells are completed on a single offshore platform, the spectre of a disastrous fire has become a thing to be reckoned with. If the platform is tended, for instance by personnel drilling, completing or servicing other wells on the platform, a fire represents a risk to life, since sufficiently rapid evacuation by boat or helicopter may not be possible and swimming to safety may also be impossible. Even where a well platform is tended, a multiple well fire could easily destroy millions of dollars worth of equipment and a loss of production of similar dollar magnitude. Such fires can result from any of several sources, including lightning, equipment malfunction and human error or negligence.

A problem which has become apparent, especially where well fires occur at wells having subsurface controlled tubing safety valves, is that even after a fire has gotten well under way, so that Christmas tree packing material has begun to burn and/or melt, allowing well fluids to escape at the wellhead and feed the fire, often the pressure drop above the tubing safety valve caused by seal destruction is insufficient to allow the tubing safety valve to close before additional wells catch fire. Thus the well continues to burn, endangering adjacent wells on the platform and endangering personnel and the platform structure itself (see Composite Catalog, op. cit., p. 3834, System 2, note 3).

To some extent, the problem just discussed may be overcome through use of tubing safety valves which may also be manually closed from the surface; however, this is an imperfect solution since no one may be present near the manual control station at the time of the fire, the control station may be unapproachable due to the fire, those present on the platform who first see the fire may not know how to actuate the control or may, through pre-dominating fear for their own lives in a rapidly worsening situation, decide to leave the platform as quickly as possible before actuating the manual control.

Summary of the invention

Because of the great pressures to which the flow containing controlling members of a petroleum well tubing string and Christmas tree are subject, for instance 10–20 thousand pounds per square inch, the problem of providing a thermal activated system for closing a petroleum well tubing safety valve is a more sophisticated one than the routiner would be tempted to imagine.

The present invention provides, in a preferred embodiment thereof, for use in association with a petroleum well tubing string tubing safety valve constructed to remain open so long as the differential pressure across the valve does not exceed a predetermined amount and to close when the pressure drop exceeds said predetermined amount: a surface wellhead element having means de-
fining at least one tortuous passageway therethrough, an inner end of the passageway being in communication with the tubing string bore and an outer end of the passageway being in communication with the atmosphere exteriorly of the well head; a plug of fusible material such as lead is cast in situ in the tortuous passageway. The plug resists extrusion from the passageway under high pressure and leakage of well pressure around the plug; however, a fire in the vicinity of the surface wellhead element will melt the plug, opening its passageway. The diameter of the passageway allows a sufficient flow rate to cause the pressure drop to exceed said predetermined amount, closing the valve and thus shutting in the well.

In the preferred embodiment, said wellhead element is an adapter body connected to a lateral part of the Christmas tree. A special plug-sealing element is provided thereon to protect the device against the initial impact of exposure to the high pressure within the tubing string.

The principles of the invention will be further hereinafter discussed with reference to the drawing wherein a preferred embodiment is shown. The specifics illustrated in the drawing are intended to exemplify, rather than limit, aspects of the invention as defined in the claims.

In the drawing

FIGURE 1 is an elevation view of part of a petroleum well, illustrating apparatus elements according to the preferred embodiment of the invention;

FIGURE 2 is a longitudinal sectional view of the safety release device of FIGURE 1 taken substantially along the line 2—2 of FIGURE 3;

FIGURE 3 is an outer end view of the safety release device of FIGURES 1 and 2; and

FIGURE 4 is an inner end view of the safety release device of FIGURES 1–3.

Description of the preferred embodiment

The well 10 shown in FIGURE 1 has been typically provided with a surface casing 12 on which is mounted a casing head 14, for instance as shown on page 2067 of the Composite Catalog. The casing head 14 receives and supports a hanger 16 in the bore thereof, for instance as depicted on page 2070 of the Composite Catalog. A casing string 18 is connected near its upper end to the hanger 16 and supported thereby. A casing bonnet 20, for instance as shown on page 2073 of the Composite Catalog, surrounds the hanger 16 at the upper end of the casing string 18. A tubing head 22, for instance as shown on page 2075 of the Composite Catalog, is mounted on the casing head 14 via a contractile-expansion clamp 24, for instance, as depicted on page 2105 of the Composite Catalog.

A string of tubing 26 is hung in the well via a tubing hanger 28, for instance as shown on page 2076 of the Composite Catalog. Lock screws 30 received through lateral openings in the tubing head engage the upper end of the tubing hanger 28 and hold it down. A tubing head bonnet 32 of the type shown on page 2083 of the Composite Catalog is shown mounted on the top of the tubing head 22 via a clamp 34, similar to the clamp 24. A tubular nipple 36 connects the through bore of the tubing head bonnet 32 with the through bore of the tubing hanger 28.

A conventional master valve 38 is mounted on the tubing head bonnet 32 via a clamp 40 similar to the clamps 24, 34. The conventional portion of the Christmas tree 42 is completed by a plurality of valves 44, gauges 46, plugs 48, clamps 40, T's 50, a choke 52 and a Christmas tree cap 54. The structure, use and reasons for the provision of such elements will be understood by those skilled in the art from a review of the silhouettes shown in FIGURE 1.

The tubing string 26 in the well 10 is shown provided, below the paraffin level, with a pressure differential actuated tubing safety valve 56 of conventional construction. The valve 56 is arranged to remain open so long as the pressure difference in the tubing string above and below the valve 56 does not exceed a predetermined pressure, for instance 300 p.s.i., and by way of example, may be as shown on page 2836 of the Composite Catalog.

It should now be noticed that the tubing string bore is communicated through the lateral outlet 58 of the T 50 immediately above the master valve 38 to the upstream side of a thermal activated safety device 60 (FIGURES 1–3) constructed in accordance with the present invention. The device 60 is connected to the T 50 by a clamp 40. On its downstream side a diverter pipe 62 is connected to the device 60 via a hub 64 on the pipe and a clamp 40 secured about the device 60 and hub 64. The diverter pipe functions to divert the flash of fire from the platform upon opening of the safety device 60; it extends past the edge of the production platform, for instance to the flare line.

Before proceeding to discuss the device 60 in greater detail, it should be noticed that the ends of the parts secured by clamps 24, 34, 40 are provided with friction-conical sealing surfaces which receive and seal with an oppositely tapered deflettable lip-sealing ring, for instance as shown in the commonly assigned earlier U.S. patents of Watts et al., 2,766,829; 2,766,998; 2,766,999; of Watts, 3,141,685; 3,216,746; of Latham, 3,301,577; of Brown, 3,507,862; or of Latham et al., 3,325,176. A further example is provided on pages 2098–2099 of the Composite Catalog.

Now with more particular regard to FIGURES 2–4, the device 60 comprises a generally cylindrical, spool-shaped body 66 of metal, for instance AISI 1040 (90/60) steel. As an example of dimensions, the body 66 may be about 5.25 inches long, have its central barrel 68 about 3.75 inches in diameter and wedging flanges 70 at its opposite ends about 4.75 inches in diameter.

The wedging surfaces 72 on the flanges 70 are engaged by the clamps 40 in securing the device 60 in position as shown in FIGURE 1.

Centrally of each axial end surface 74 of the body 66, a generally cylindrical recess 76, 78 is formed, having an axially outwardly flaring frusto-conical sealing surface 80 closely adjacent the mouth thereof, for sealing with the exterior, frusto-conically tapered sealing surface of a sealing ring of the type aforementioned with reference to commonly assigned earlier U.S. patents. These clamping and sealing connector means, although preferred for use in the present instance because of their accepted trustworthiness under operating conditions at high pressures, are exemplary.

Centrally of the floor 82 upstream recess 76, a socket 84 is formed in the body coaxially therewith and opening outwardly of the floor 82. For the major portion of its length, the socket 84 is internally threaded at 86; axially inwardly of the threaded portion, the socket 84 has a short cylindrical region 88, merging with a tapering frusto-conical region 90, which in turn terminates in a circular, disk-shaped floor 92 coaxial with the body 66.

Three equiangularly spaced, axially directed passageways 94, 96, 98 are shown formed in the body 66 through the floor 92; these extend upwardly toward the downstream recess 78 floor 100. In the example, the passageways 94, 96, 98 are centered on a circle of 3/4 inch radius. Three equiangularly spaced, axially directed passageways 102, 104, 106 are shown formed in the body 66 through the downstream recess 78 floor 100; these extend upwardly toward the upstream recess 76. These passageways are 94, 96, 98 are angularly offset from respective of the passageways 102, 104, 106 by about 60 degrees. In other words, the passageway 96 lies about halfway angularly between the passageways 102, 104, 106. The passageways 94, 96, 98 extend axially to lateral adjacency with and somewhat axially beyond the inner ends of the passageways 102, 104, 106 as shown best in FIGURE 2. The passageways 102, 104, 106 are centered on a circle of 8/3 inch radius.
A lateral passageway 108 formed in the body 66 intermediate the ends thereof intersects the passageways 94 and 102 near their inner ends. The outer end of the passageway 108 is threaded at 110 and provided with an exteriorly threaded plug 112 to close off the outer end. Thus a tortuous or labyrinthine passageway 94, 102, 108 is provided which communicates between the upstream and downstream axial ends of the body 66. The tortuousness of the passageway 94, 102, 108 is contributed to by the short axial extensions of the passageways 94 and 102 and the connecting passageway 108 and the short portion of the passageway 108 which extends between the passageway 102 and the inner end of the plug 112.

A second lateral passageway 114 formed in the body 66 intermediate the ends thereof intersects the passageways 96 and 104 near their inner ends. The outer end of the passageway 114 is threaded at 116 and provided with an exteriorly threaded plug 118 to close off the outer end. Thus a second tortuous or labyrinthine passageway 96, 104, 114 is provided which communicates between the upstream and downstream axial ends of the body 66. The tortuousness of the passageway 96, 104, 114 is contributed to by the short axial extensions of the passageways 96 and 104 past the connecting passageway 114 and the short portion of the passageway 114 which extends between the passageway 104 and the inner end of the plug 118.

A third lateral passageway 120 formed in the body 66 intermediate the ends thereof intersects the passageways 98 and 106 near their inner ends. The outer end of the passageway 120 is threaded at 122 and provided with an exteriorly threaded plug 124 to close off the outer end. Thus a third tortuous or labyrinthine passageway 98, 106, 120 is provided which communicates between the upstream and downstream axial ends of the body 66. The tortuousness of the passageway 98, 106, 120 is contributed to by the short axial extensions of the passageways 98 and 106 past the connecting passageway 120 and the short portion of the passageway 120 which extends between the passageway 106 and the inner end of the plug 124.

The passageways 94, 102, 108; 96, 104, 114 and 98, 106, 120 are each about %4-inch in diameter; thus these passageways have a collective, total transverse cross-sectional area of about .147 inch and a volume of about .098 cubic inch.

Prior to installation in the Christmas tree as shown in FIGURE 1, a low temperature melting, soft metal composition 126 is poured in a liquid condition into the passageways 94, 102, 108; 96, 104, 114 and 98, 106, 120, filling the same and is allowed to cool, congeal and solidify therein. Surplusage of the composition 126 is machined away from the region 88, 90, 92, and in fact, these surfaces may be finish machined on the body after the composition 126 is in place. A disk or annulus of low temperature melting, soft metal composition 128 corresponding configuration to the surfaces 90, 92 is inserted in the disk so defined. The element 128 in the example is about %6 inch thick, %2 inches in diameter at its larger diameter end and %6 inches in diameter at its smaller diameter end.

A steel washer 130 having an O.D. approximating the larger diameter of the element 128 is placed against the larger diameter end of the element 128. The steel washer 130 has an I.D. large enough to encompass the three passageways 92, 94, 96. The element 128 is forced tightly against the surfaces 90, 92 by an elongated tubular nut 132, exteriorly threaded at 134 so as to be threadable into the socket 84 at 86 and tightenable by application of a wrench to the external wrenching region 136 of the elongated nut. The I.D. of the nut is also large enough to encompass the three passageways 94, 96, 98.

In the example, the metal poured into the passageways of the device 60 consists of lead. The cover wafer 128 is made of the same material. The melting point of lead is 621° F. It has been found that when the pressure differential upstream and downstream of the device 60 is 10,000–15,000 p.s.i., the lead of the wafer 128 in the passageways will extrude out of the passageways, opening them when the temperature of the device 60 has reached 325 degrees Fahrenheit. Should thermal activation at higher or lower temperatures be desired the lead of the example may be partly or wholly replaced or supplemented with other materials such as bismuth, antimony, tin, and the like, as alloys or as mixtures.

With some compositions, it may be possible to pour the passageway filling and wafer 128 as an integral unit. However, it has been found that where the composition shrinks somewhat upon cooling, the initial impact of high pressure upon the wafer, after the device has been installed as in FIGURE 1, may cause highly undesirable fluid pressure leaks between the wafer/passage filling integral unit and the socket and passageways. The separate wafer 128 inserted after machining of the device 60 as described above, tightened in place with the elongated nut 132 (with the steel washer 132 interposed therebetween to prevent gouging of the wafer by the nut) forms a positive seal which will not leak when high pressure is applied thereto.

It should be apparent that when the device 60 of FIGURES 2–4 is installed in a Christmas tree as exemplified by the tree of FIGURE 1, and its upstream side communicated to the tubing string pressure, a fire at the wellhead will cause the fusible or flowable material in the body 66 socket and passageways to extrude, flow or melt out being then pushed downstream by the well pressure, opening the passageways through the device 60. The combined cross sectional area of the passageways, when opened, is more than enough to cause the predetermined pressure drop which will close the tubing safety valve, shutting in the well. Any blast or pressure surge which might momentarily occur as the passageways open, just before the tubing safety valve closes, is carried safely from the well platform by the diverter pipe 62.

The tortuousness of the device 60 passageways is needed to ensure that premature extrusion of the filling material will not occur due to the high pressure to which the upstream side of the device is subject during use and in view of the relatively plastic nature of the filling material.

Of course there is nothing mystic about the provision of three passageways 94, 102, 108; 96, 104, 114 and 98, 106, 120; any number from one to several of such passageways may be provided, so long as they are sufficiently tortuous that the filling material will not extrude from them prematurely, i.e. before a fire, and so long as their effective transverse cross-sectional area, when opened, is sufficient to allow the pressure drop needed to close the tubing safety valve to occur.

It should be noted that the device of the invention does not inhibit or interfere with the operation of the tubing safety valve as a means for automatically or manually limiting the flow rate of fluid being produced from the well.

The particular location of the device 60 on the Christmas tree of FIGURE 1 was chosen so that it does not interfere with the normal operation, servicing and repair of other elements on the Christmas tree, and so that it may be checked and replaced itself without need for disturbing production or requiring a major dismantling effort. However, the particular relative location is exemplary and other relative locations will occur to those skilled in the art.

It should now be apparent that the petroleum well thermal activated safety relief device for differential pressure closing tubing safety valve as described hereinabove possesses each of the attributes set forth in the specification under the heading "Summary of the Invention" hereinbefore. Because the petroleum well thermal activated safety relief device for differential pressure closing tubing safety valve of the invention can be modified to some extent without departing from the principles of the invention as they have been outlined and explained in this
What is claimed is:

1. For employment on a petroleum well having a tubing safety valve in a tubing string thereof, which tubing safety valve is constructed to remain open so long as the differential pressure across the valve does not exceed a predetermined amount and to close when the pressure drop exceeds said predetermined amount: a surface well head element having means defining at least one tortuous passageway therethrough, an inner end of the passageway being in communication with the tubing string bore and an outer end of the passageway being in communication with the atmosphere exteriorly of the well head; a body of hardened, heat softenable material filling said passageway and being susceptible to softening and flowing out of said passageway upon the occurrence of a fire in the vicinity of said well head element; the effective cross-sectional area of said passageway, when so opened, being sufficient to cause said predetermined pressure drop, thereby closing the valve and shutting in the petroleum well.

2. The apparatus of claim 1 wherein the hardened, heat softenable material is lead.

3. The apparatus of claim 1 wherein said at least one passageway comprises a first axially extending segment beginning at the inner end of said passageway and terminating intermediate the extent of said passageway through said well head element; a second axially extending segment beginning at the outer end of said passageway and terminating intermediate the extent of said passageway through said well head element; said first and second segments being out of axial registry and extending to lateral adjacency with one another; and a lateral passageway segment connecting said first and second axially extending segments intermediate the extent of said passageway through said well head element.

4. The apparatus of claim 3 wherein said at least one passageway furthher comprises at least one further passageway geometrically substantially like the first described passageway and being laterally displaced from the first described passageway within said well head element.

5. The apparatus of claim 4 wherein said well head element is generally cylindrical; means defining a recess in at least the upstream axial end of said well head element; means defining a socket in said recess, opening toward said upstream axial end and having means defining a floor; the inner ends of said passageways opening through said floor; a closely fitting wafer of hardened, heat softenable material received in said socket against said floor covering the inner ends of said passageways.

6. The apparatus of claim 5 wherein said passageway filling, hardened, heat softenable material is hardened in situ in said passageway; wafer being separate from said passageway filling, hardened, heat softenable material; said socket, axially beyond said wafer being provided internally with axially proceeding, incrementally usable cooperative securement means; and a tubular fastening element having external, axially proceeding, incrementally usable cooperative securement means thereon connectable with the first-mentioned said cooperative securement means to force said wafer into sealing engagement with said socket floor.

7. The apparatus of claim 6 wherein said wafer is peripherally frusto-conical exteriorly and wherein said socket, adjacent said socket floor is interiortly peripherally frusto-conical in conformance with said wafer and wherein said tubular fastening element bears against the larger diameter face of said wafer near the periphery thereof, forcing said frusto-conical peripheries into sealing engagement.

8. The apparatus of claim 6 wherein the cooperative securement comprises helical threading and the tubular fastening element comprising a material tubular nut having said helical threading thereon near one end thereof and having a wrenching region thereon near the opposite end thereof; the bore of said elongated tubular nut encompassing the inner ends of said passageways, and said elongated tubular nut bearing against said wafer.

9. The apparatus of claim 8 further comprising a steel washer interposed between the elongated tubular nut one end and said wafer; said elongated tubular nut one end engaging said steel washer and said steel washer engaging said wafer.

10. A petroleum well including at least one string of production tubing; a tubing safety valve in communication with the bore of said string of production tubing, said tubing safety valve being constructed to remain open so long as the differential pressure across the valve does not exceed a predetermined amount and to close when the pressure drop exceeds said predetermined amount; a surface well head element having means defining at least one tortuous passageway therethrough, an inner end of the passageway being in communication with the tubing string bore and an outer end of the passageway being in communication with the atmosphere exteriorly of the well head; a body of hardened, heat softenable material filling said passageway and being susceptible to softening and flowing out of said passageway upon the occurrence of a fire in the vicinity of said well head element; the effective cross-sectional area of said passageway, when so opened, being sufficient to cause said predetermined pressure drop, thereby closing the valve and shutting in the petroleum well.

11. The petroleum well of claim 10 further comprising a diverter pipe secured to said well head element in communication with the outer end of said at least one passageway, said diverter pipe extending a substantial distance away from said well to divert flame and combustion therefrom upon opening of said at least one passageway.

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