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3,043,323 7/1962 Mark et al. 137/67
 3,053,278 9/1962 Verheul..... 137/614.21
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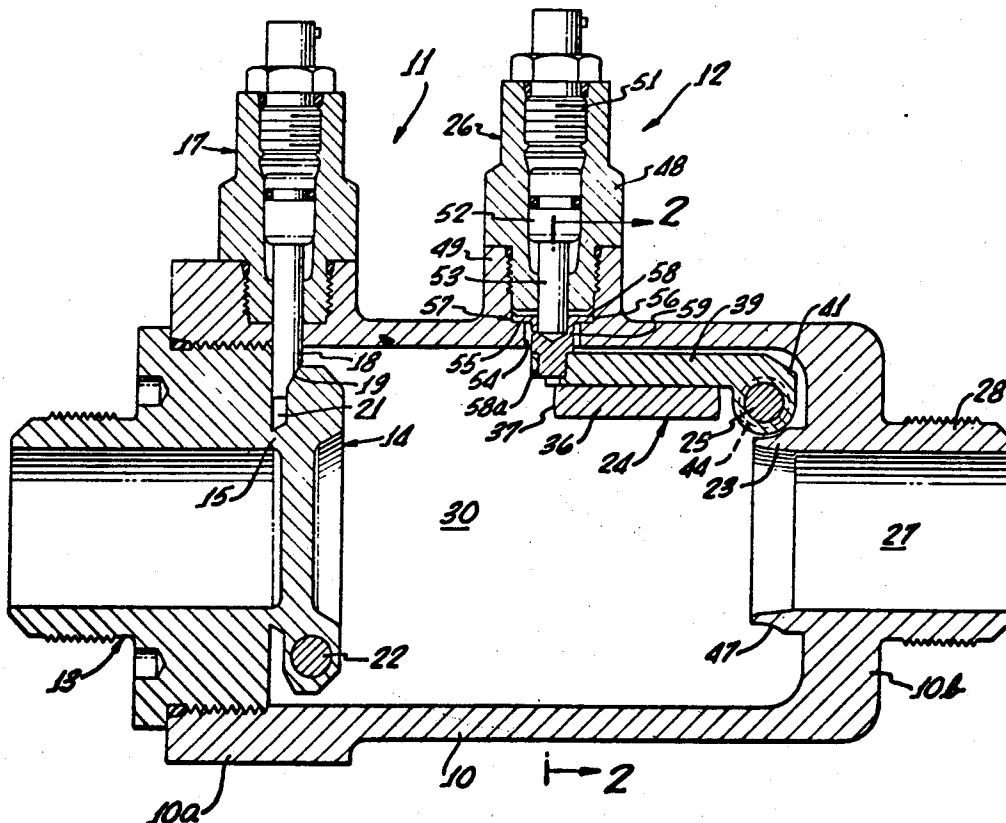
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[54] **NORMALLY-OPEN EXPLOSIVE-OPERATED VALVE, AND COMBINATION THEREOF WITH A NORMALLY-CLOSED VALVE**
21 Claims, 7 Drawing Figs.

[52] U.S. Cl. 137/67,
 137/68, 137/614.21, 251/228
 [51] Int. Cl. F16k 13/04
 [50] Field of Search..... 137/67-
 — 71, 614.21; 251/228

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UNITED STATES PATENTS
 2,744,719 5/1956 McRae 251/228X

ABSTRACT: A normally open explosive-operated valve in which the movable valve element is pivotally connected to the housing, and is explosively actuated through about a 90° arc when shifted to closed position. The movable valve element and the associated valve seat are so constructed that slight misalignments do not prevent achievement of a very effective metal-to-metal seal after actuation. The invention further relates to the series combination of a normally open valve with a normally closed valve, in order that a start-stop fluid-flow operation may be achieved.



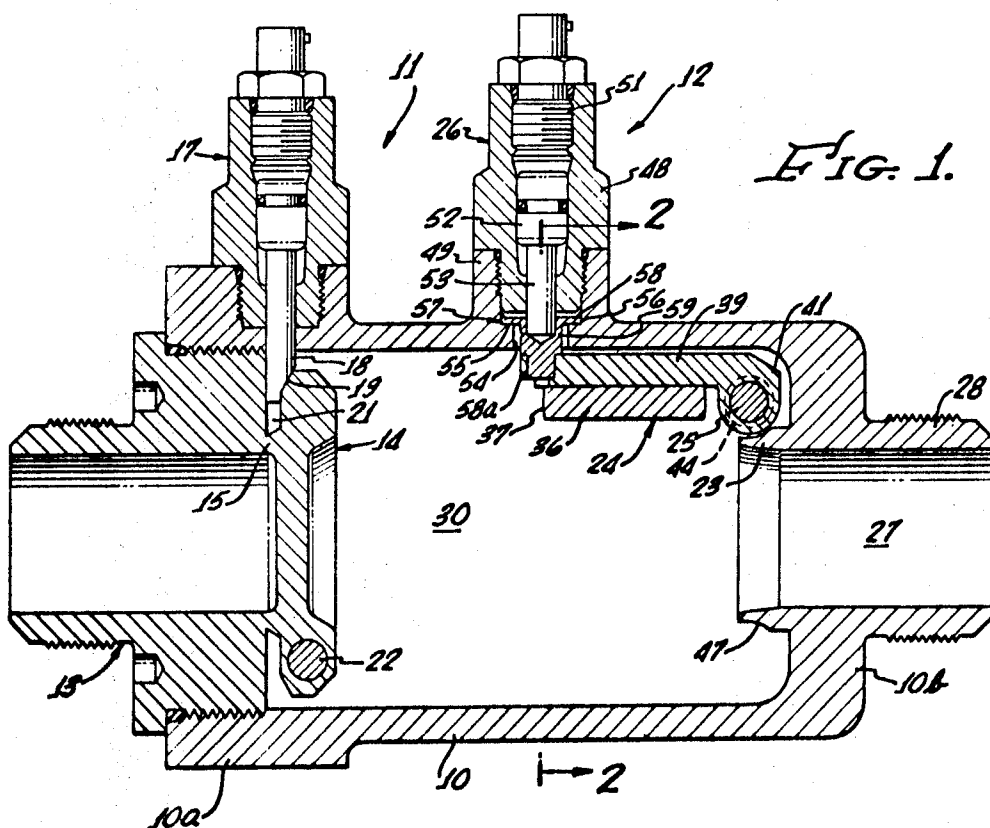


FIG. 1.

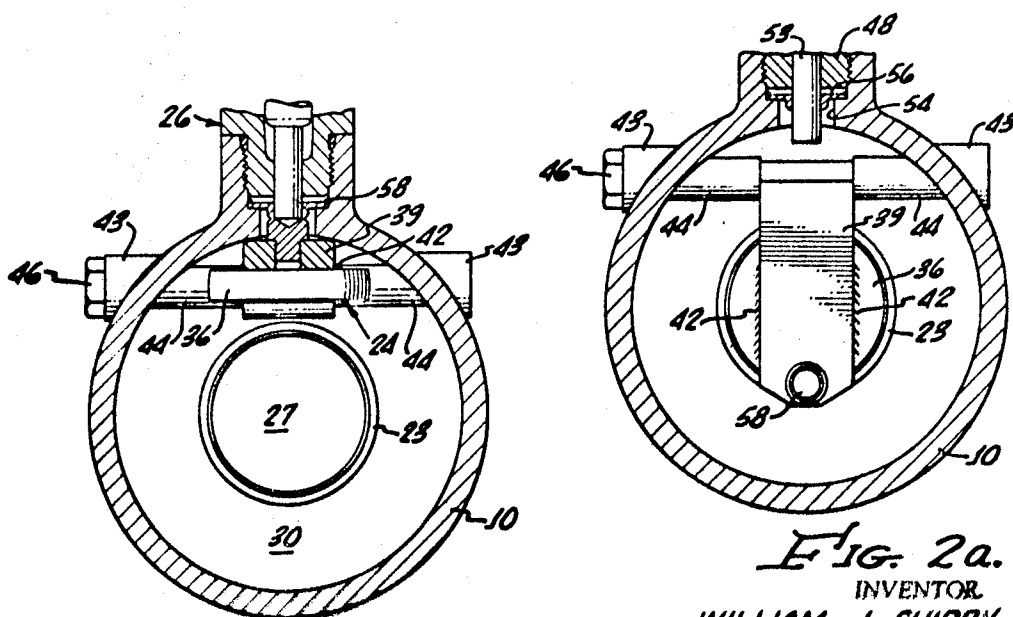


FIG. 2.

FIG. 2a.

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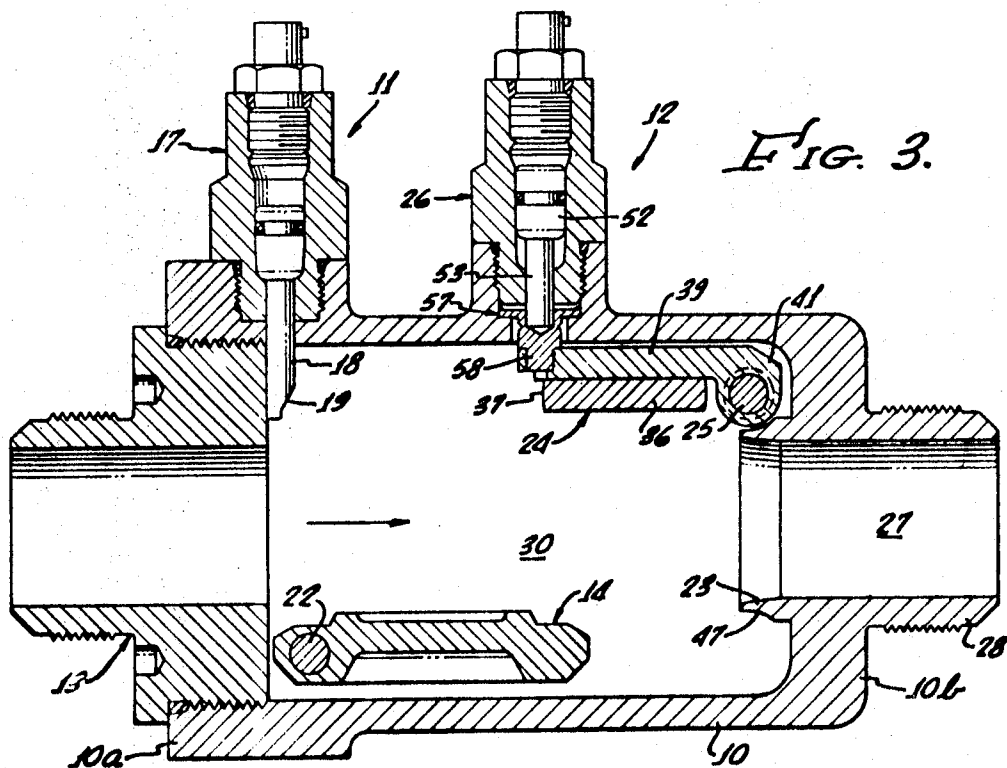


FIG. 3.

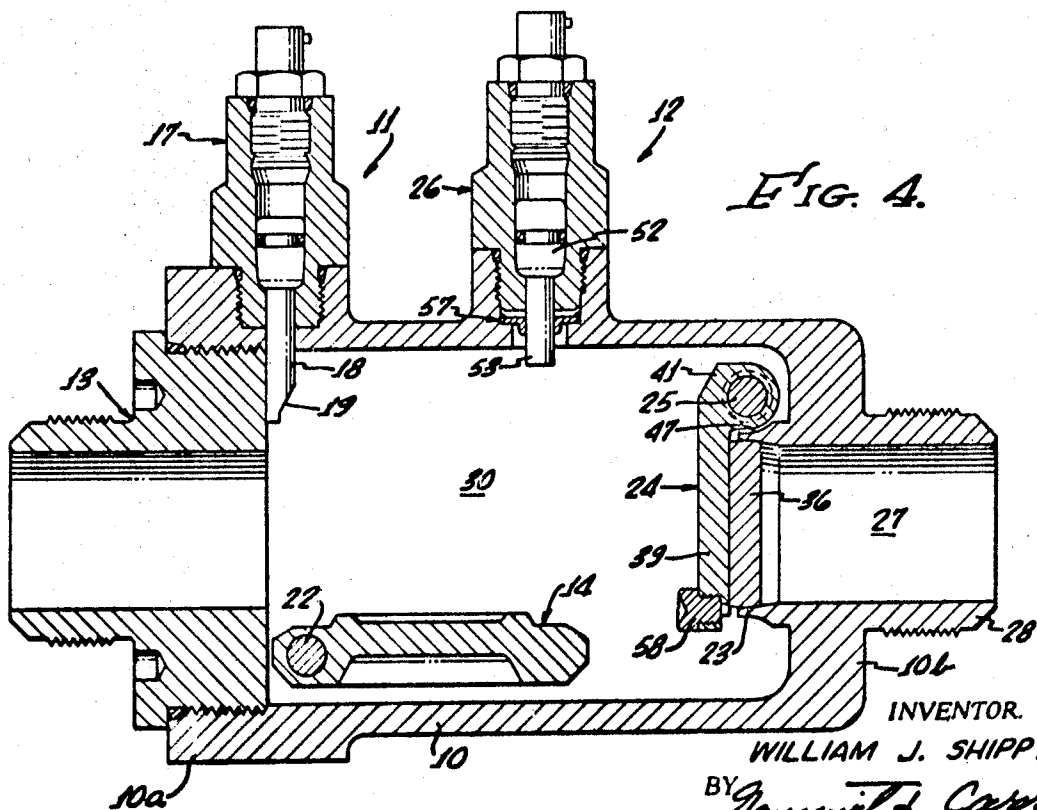


FIG. 4.

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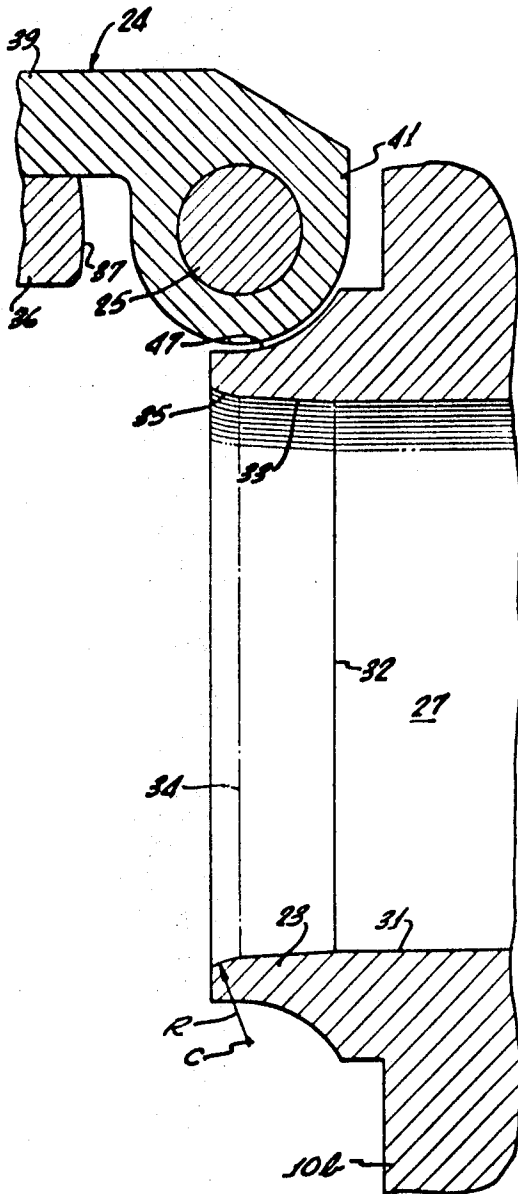


FIG. 5.

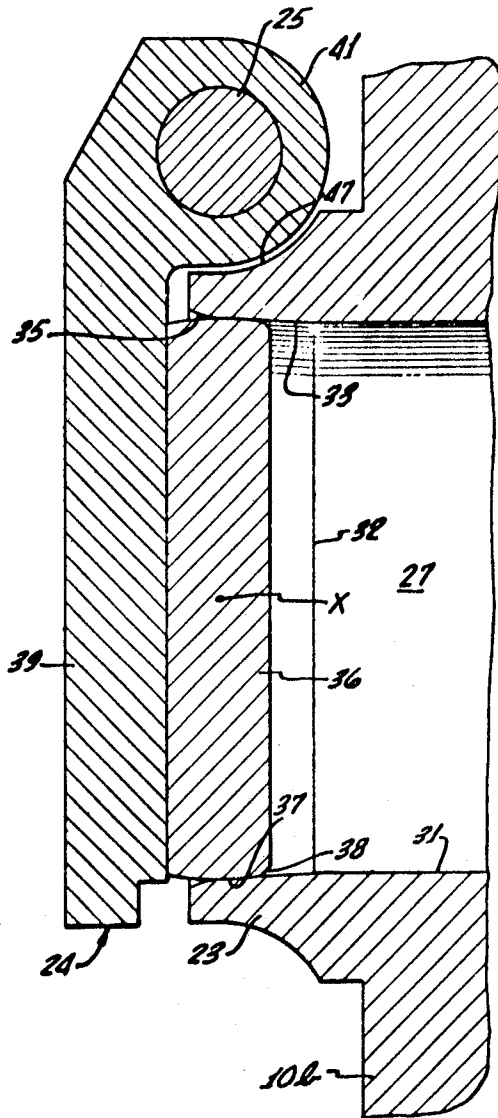


FIG. 6.

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NORMALLY-OPEN EXPLOSIVE-OPERATED VALVE, AND COMBINATION THEREOF WITH A NORMALLY-CLOSED VALVE

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The invention relates to the field of explosive-operated valves, and more particularly to the field of high-flow explosive-operated valves in which it is necessary that the degree of sealing be extremely close to 100 percent.

2. Description of the Prior Art:

U.S. Pat. No. 3,332,432 for an Explosive-Operated Valve, assigned to the assignee of the present application, shows in FIG. 5 a "start-stop" valve in which the explosive shifting of one valve element effects initiation of fluid flow, and the shifting of the other element effects cessation thereof. Although such valve has been extremely satisfactory and successful, the models marketed to date have not been of the very high-flow (large orifice) variety.

There exists a need for high-flow explosive-operated valves in various systems in the aerospace and other fields. This need has been partially met by the normally closed explosive-operated valve described and claimed in copending U.S. Pat. application Ser. No. 516,226, filed Dec. 27, 1965, and also assigned to the assignee of this application. The present invention results from a sustained effort to provide a normally open valve for combination with such normally closed valve in order to achieve the desired start-stop function. Also, of course, such normally closed valve and the present normally open valve may be used independently of each other when desired.

Prior-art explosive-operated valves of the normally open type have sometimes been of the "cork in a bottle" variety, in which the movable element is linearly actuated into a seat in response to detonation of the explosive charge. In such a construction, however, the fluid must either turn a corner when passing through the valve or must flow past numerous supports, obstructions, etc. Both of such arrangements are unsatisfactory in very many cases, for reasons including the fact that the pressure drop across the valve is increased to an excessively high degree, or the amount of turbulence is excessive.

Prior-art valves of the nonexplosive variety, for example the one shown in U.S. Pat. No. 3,334,858, are totally unsuitable for explosive operation or for many operations in the aerospace field. The reasons for this are numerous, and include inability to operate in the very short time period which results when explosive actuation is employed, inability to achieve the extremely effective metal-to-metal seal required in aerospace work, inability to operate satisfactorily in highly corrosive environments, etc. It is further pointed out that the valve of U.S. Pat. No. 3,334,858 is not completely straight-through and turbulence-free since various elements are in the flow path even when the valve is in the open position of FIG. 2.

SUMMARY OF THE INVENTION

In accordance with the present invention, a straight-through and minimum-turbulence valve is achieved by causing the axis of pivotal movement of the movable valve element to be in substantially the same plane as the valve seat, and by shaping the seat and the associated movable valve element in such manner that small amounts of misalignment will be automatically compensated for to thereby permit achievement of a substantially perfect metal-to-metal seal. Very importantly, the relationships are such as to effect permanent plastic deformation of the metal in the sealing area. The present invention also provides a combination normally closed and normally open valve having high-flow straight-through characteristics yet requiring only a relatively short and compact housing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal central section of the present normally open valve, showing the same as combined with a normally closed valve to provide the desired start-stop function;

FIG. 2 is a transverse sectional view taken on line 2-2 of FIG. 1;

FIG. 2a is a sectional view corresponding to FIG. 2 but showing the normally open valve in closed condition;

FIG. 3 is a longitudinal sectional view corresponding to FIG. 1 but showing the valve combination in fully open condition, after operation of the normally closed portion of the valve;

FIG. 4 is a longitudinal sectional view illustrating the valve combination after reclosing thereof, this being effected by causing operation of the normally open portion of the valve;

FIG. 5 is an enlarged fragmentary longitudinal sectional view of the normally open valve, illustrating the valve seat and the relationship thereof with the movable valve element; and

FIG. 6 corresponds to FIG. 5 but shows the valve in closed condition.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, the explosive-operated valve is illustrated to comprise an elongated and generally cup-shaped cylindrical valve body or housing 10 the inlet region of which is illustrated as being at the left end (adjacent the rim 10a of the cup) and the outlet region of which is at the right end (the bottom 10b of the cup). The housing 10 forms part of both the normally closed portion 11 of the valve and the normally open portion 12 thereof.

The normally closed valve portion 11 may be identical to the one described and claimed in the above-cited U.S. Pat. application Ser. No. 516,226. Accordingly, such portion 11 will only be described in very general terms. It comprises an inlet element 13 which is threaded into the open rim portion 10a and has a movable valve element 14 integrally associated therewith by means of a stress-riser portion 15. An explosive actuator 17 operates a ram or plunger 18 radially-inwardly toward stress riser 15. This causes the inclined end portion 19 of the ram to wedge into the annular groove 21 which separates the movable valve element 14 from inlet element 13, thereby effecting shifting of the movable valve element from the position in FIG. 1 to that shown in FIGS. 3 and 4.

During such shifting of the movable valve element 14, it pivots about a pin 22. The pin is mounted in the valve housing or body 10 at one side of a central plane which is parallel to such pin 22 and contains the axis of body 10. Pin 22 is shown as being at the lower portion of the rim 10a of the valve body when such body is lying on its side as illustrated in the present drawings.

There will next be described, in detail, the normally open valve portion 12 which forms the major component of the present invention. The normally open valve 12 comprises a seat 23 and a pivotally-mounted movable valve element 24. Element 24 is pivoted on a pin 25 for pivotal or rotational shifting from the open position of FIGS. 1 and 5 to the closed position of FIGS. 4 and 6. Such shifting is effected by means of an explosive actuating assembly 26 to be described in detail subsequently.

Proceeding first to a description of the valve seat 23, this is annular in shape and is illustrated as being integral with housing portion 10b although it is to be understood that the seat may be separately formed and suitably brazed or otherwise sealingly secured to the housing. Seat 23 is preferably coaxial with the valve body or housing 10 and communicates with a cylindrical outlet orifice or passage 27 which extends through the bottom wall 10b of the cup which forms the housing. A suitable fitting 28 is integrally formed with the housing in order to effect communication between the valve and an outlet pipe or conduit, not shown.

The valve seat 23 protrudes (in the manner of a lip) from bottom cup wall 10b into the chamber 30 formed within housing 10. The construction of such seat 23 is important to the in-

vention and is best illustrated in FIGS. 5 and 6. Referring particularly to FIG. 5, the interior surface of the seat 23 has three portions one of which, number 31, is cylindrical and preferably flush with the wall of outlet passage 27. At a line or circle 32, the cylindrical surface 31 meets a conical surface 33 which diverges in a direction away from passage 27, that is to say toward the normally closed valve portion 11. At a second line or circle, numbered 34, the conical surface 33 meets a radiused surface 35, such surface extending to the edge of seat 23 which is farthest from the bottom 10b of the valve body.

The conical interior or female surface portion 33 of valve seat 23 lies at a small cone angle relative to the longitudinal axis of the valve. The cone angle relative to such longitudinal axis is, for example, between $2\frac{1}{2}^\circ$ and 3° . The radiused surface portion 35 is caused to be tangential to conical surface 33 at line or circle 34. In a typical valve, wherein the diameter of cylindrical wall portion 31 is about 1.294 inches, the radius R of each portion of surface 35 may be on the order of 0.20 inch. Such radius R of surface portion 35 is indicated at the lower portion of FIG. 5, being drawn about the center C. Center C is located in substantially the same radial plane as circle 34 and which also contains the axis of pin 25. Center C is actually an infinite series of centers located on a circle centered on the valve axis and lying in a plane perpendicular thereto.

All of the surfaces 35, 33 and 31 are coaxial with each other and, preferably, with the longitudinal axis of the valve, the latter relationship providing a straight-through flow condition relative to the normally closed valve 11 so that minimum turbulence and pressure drop are created.

Proceeding next to a description of the movable valve element 24, this comprises a disc-shaped poppet 36 the peripheral surface or edge 37 of which is spherical about the center X (FIG. 6) of the poppet. The diameter of spherical edge 37 of poppet 36 is larger than the diameter of circle 34 which forms the common boundary between cone surface 33 and the radiused surface 35 (FIG. 5). For example, if the diameter of circle 34 is about 1.319 inch, then the diameter of the spherical poppet edge 37 may be about 1.323 inch.

The leading edge of the poppet 36, that is to say the edge which first enters the valve seat 23, should be beveled, for example at a 45° angle relative to the longitudinal axis of the valve (as indicated at 38 in FIG. 6). The width of the bevel may be on the order of one or two hundredths of an inch in the present example, the overall thickness of the poppet 36 being (in the example) on the order of 0.25 inch.

It is emphasized that the above-stated dimensions, angle, etc., and also those stated below, are for the purpose of providing a specific example of a fully satisfactory and operative valve. They are not to be construed as constituting limitations.

The poppet 36 and also the valve seat 23 are formed of a suitable metal, such as aluminum, which is capable of permanent plastic deformation. In the valve of the specific example, the metal is 6061-T6 aluminum or the equivalent thereof.

The explosive assembly 26 must be capable of generating sufficient force to effect the necessary permanent plastic deformation of metal at the valve seat. In the stated specific example, such force is created by employing an explosive charge capable of generating many thousands of pounds per square inch pressure.

The remaining component of the movable valve element 24 is a rigid strap 39 having a rigid, protuberant bearing portion 41 at one end thereof and which is pivotally associated with the pin 25. The poppet 36 should be associated with strap 39 by welding, the two welds being indicated at 42 in FIGS. 2 and 2a, it being pointed out that the strap 39 is much narrower than the diameter of poppet 36. The narrowness of the strap 39 permits the strap to closely approach the upper surface of the interior wall of valve chamber 30, as shown in FIGS. 1, 2 and 3, the poppet 36 then lying in a plane parallel to the axis of the valve.

The procedure followed in welding poppet 36 to strap 39 is such as to assure the maximum possible alignment between

the poppet and the valve seat 23. This may be accomplished, for example, by mounting the poppet 36 in the valve seat 23 (but not in force-fit relationship), assembling strap 39 with pin 25, thereafter temporarily connecting strap 39 to poppet 36, and thereafter disassembling the movable valve element 24 from pin 25 and forming the welds 42, following which the temporary connections between elements 36 and 39 are removed. Movable valve element 24 is then remounted in housing 10.

Proceeding next to a description of the pivot pin 25, this is a rigid cylindrical element which extends through boss portions 43 (FIG. 2) of the valve body and also through the bearing portion 41 of strap 39. The tolerances are caused to be small, so that the amount of play is reduced to a minimum. First and second spacer sleeves 44, FIGS. 1, 2 and 2a, are mounted around pin 25 on opposite sides of strap 39 in order to maintain the strap centered relative to the axis of the valve. The pin 25 may have a head 46 at one end thereof and may be threadedly associated with a boss portion 43 and thus with the valve body 10. Suitable sealing means are provided to prevent leakage of liquid around the pin.

It is important to the invention that the axis of pin 25 lie in or close to a plane containing the circle or line 34 shown in FIG. 5. For a valve of the size stated in the above-indicated specific example, wherein the diameter of surface 31 is on the order of 1.29 inch, the distance between the axis of pin 25 and a plane containing circle 34 should be less than approximately 0.005 inch.

The inwardly protuberant or reentrant nature of the valve seat 23 permits achievement of several functions, one of which is permitting the axis of pivot pin 25 to be located radially outwardly from circle 34 as indicated above. A second function of the inwardly protuberant seat 23 is to permit the wall thickness of the seat, radially outwardly from the circle 34 and the adjacent seat regions, to be controlled as desired in order that permanent plastic deformation may be readily achieved when the valve closes. The peripheral surface of the seat 23 is radiused at 47 in such manner that space is provided between such radiused portion 47 and the adjacent surface of the bearing portion 41 of the strap. There is, accordingly, no interference between these elements during closing of the valve.

To summarize and augment the description of some of the factors and elements indicated above, it is pointed out that all portions of the movable valve element 24 are rigidly and permanently connected to each other before, during and after actuation of the movable valve element to closed position. This is effected, for example, by the welds 42. Accordingly, poppet 36 is, at all times, controlled and guided by the strap 39 which, in turn, is associated (in close-tolerance relationship) with the fixed pivot pin 25.

The interior wall or surface 33-35 of valve seat 23 is a surface of revolution about a first central axis, preferably the longitudinal axis of valve chamber 30. The peripheral surface 37 of poppet 36 is a surface of revolution about a second central axis, namely an axis which is perpendicular to the poppet 36 and extends through the center X of the sphere (FIG. 6). When the valve 12 is in the open position of FIGS. 1, 3 and 5, such second central axis is transverse, and preferably perpendicular, to the first central axis. On the other hand, after the movable valve element 24 has been shifted to the closed position of FIGS. 4 and 6, the first and second central axes are coincident or substantially coincident.

The entire poppet 36 may be referred to as a male element, and the seat 23 as a female element, the relative diameters being such that the male element first freely enters the portion of the female element farthest from passage 27 (closest to normally closed valve 11), following which permanent plastic deformation of the seat and/or the poppet is required in order to permit inward shifting of the male element 36 to the fully closed position shown in FIG. 6.

Although the portion 35 (FIG. 5) of the valve seat 23 is referred to as "radiused," other constructions such as suitable

cam curves may be employed. Such curves should, however, be tangential to the cone 33 at circle 34.

To complete the specific example indicated above, the length of the radiused portion 35 in a direction parallel to the axis of the valve chamber may be on the order of 0.07 inch. The length of the conical surface 33 in a direction longitudinal of the valve is sufficient that the seating regions of the poppet never penetrate to the circle 32.

Proceeding next to a description of the explosive assembly 26, this includes (as shown in FIG. 1) a housing 48 which is threadedly connected in sealed relationship to a boss portion 49 of the valve housing 10. An explosive device or squib 51 is mounted in the portion of the housing 48 remote from chamber 30, being adapted to be electrically or otherwise detonated in a manner well-known to the art. A piston 52 is movably mounted in the housing 48 and is associated with a ram or plunger 53 which projects through the bottom of housing 48 and into a passage or port 54 communicating with chamber 30.

The diameter of port 54 is smaller than the inner diameter of boss portion 49, resulting in the formation of a shoulder 55. Mounted on such shoulder 55 is a generally disc-shaped portion 56 of a frangible mounting and sealing element 57. The periphery of the disc portion 56 may be welded to the boss portion 49, as indicated at 58, in order to provide a complete seal insuring that no fluid from valve chamber 30 enters the housing 48.

Mounting and sealing element 57 also includes a nipple portion 58a which receives the lower end of ram 53, there being an external annular groove 59 adjacent the lower ram end in order to provide a stress riser at which the nipple portion will fracture when the squib is detonated. Portion 58a is inserted at its lower end into a recess or opening provided in strap 39 at a location remote from pivot pin 25. The lower nipple end is threaded and is secured to the internally threaded recess in strap 39 by rotating element 57 prior to formation of weld 58.

With the described construction, the movable valve element 24 is normally maintained in a plane generally parallel to the valve axis and out of the way of fluid flowing through the valve chamber 30. Furthermore, leakage of fluid into housing 48 is positively prevented.

The axis of rotation of the movable valve element 24 (namely pivot pin 25) is located to one side of the valve seat 23 and is perpendicular to an extended radius of the valve seat 23. The pivot pins 25 and 22 are parallel to each other and are sufficiently close together that the movable valve elements 14 and 24 overlap somewhat (as shown in FIG. 3) when both are in open positions. The pins 22 and 25 are on opposite sides of housing 10, the illustrated pin 25 being on the upper side whereas (as previously stated) pin 22 is on the lower side.

OPERATION

The valve is initially in the condition shown in FIG. 1, fluid flow being blocked by the normally closed valve portion 11 despite the fact that the valve portion 12 is in its normal open condition.

To start flow of fluid through the valve, the explosive actuator 17 of normally closed valve 11 is operated to effect shifting of the movable valve portion 14 thereof to the open position shown in FIG. 3. A straight through and relatively turbulence-free flow path is therefore created between the inlet and outlet regions of the valve combination.

To effect closing of the valve, the explosive actuator assembly 26 of the normally open valve portion 12 is operated by detonating the squib 51. This causes downward shifting of piston 52 and ram 53, fracturing the nipple portion 58a adjacent annular groove 59 and causing a sudden pivotal shifting of the entire movable valve element 24 about pivot pin 25 from the open position to the closed position of FIGS. 4 and 6.

It is emphasized that such shifting occurs with extreme rapidity, taking place within approximately 5 to 10 milliseconds in the valve described in the specific example. The

acceleration forces are therefore enormous and may result in some misalignment despite the rigid construction and mounting of the valve elements and despite the fact that all parts are constructed and assembled with minimum tolerances. It is a major feature of the invention, however, that despite any such slight misalignment the poppet 36 will effectively and permanently seat in the seat 23 and close the valve so effectively that the amount of leakage from chamber 30 into outlet passage 27 will be maintained (in the valve described in the specific example) at a value on the order of less than one-millionth of a standard cubic centimeter of helium per second at a pressure of several thousand pounds per square inch.

The poppet 36 first engages the radiused surface 35 and then engages the conical valve seat region 33 adjacent circle 34. Subsequent inward movement of the poppet, due to the extreme force of the explosive detonation, can then only occur as the result of deformation of the valve seat 23 and/or the poppet. Such deformation is initially elastic but immediately thereafter becomes permanent plastic deformation as is desired. By the time the poppet reaches the fully closed position shown in FIG. 6, the valve seat and/or poppet have been permanently plastically deformed and are in very intimate sealing relationship with each other.

It is pointed out that the poppet is seated in the seat 23 with such force that a high fluid pressure is required in order to subsequently effect reopening of the poppet. In a typical installation, using the valve of the specific example, a fluid pressure on the order of 1800 pounds per square inch, applied within outlet passage 27, is required to reopen the poppet.

Because the axis of pivot pin 25 is in or closely adjacent the plane containing circle 34 (FIG. 5), it follows that the poppet 36 is moving in a direction substantially perpendicular to a plane containing circle 34 (that is to say, parallel to the axis of the valve) when the peripheral poppet surface 37 first engages and thereafter moves into the valve seat. This results in an effective and efficient sealing action, and in uniform distribution of force throughout the entire periphery of the poppet.

Because the poppet periphery 37 is spherical, and also because the region of the valve seat 23 inwardly adjacent circle 34 is conical, it follows that a slight misalignment of the poppet relative to the seat will not destroy the relationship whereby uniform and effective seating forces are applied. In other words, even if the poppet 36 is slightly cocked, there will still be created an effective metal-to-metal sealing relationship between the peripheral poppet surface 37 and the conical surface 33 of the valve seat. The resulting permanent plastic deformation of the valve seat 23 will therefore be achieved with uniformity, there being no leakage areas through which fluid may discharge from the valve chamber 30.

It will therefore be understood that the invention provides a high-flow valve the flow diameter of which may be large in comparison with that of prior-art straight-through valves.

Because the pivot pins 22 and 25 of the valve portions 11 and 12 are disposed at opposite sides of the valve body, such body 10 may be caused to be relatively short. Referring to FIG. 3, it is emphasized that when the movable valve element 14 of the normally closed valve portion 11 is in open condition, it overlaps somewhat the movable portion 24 of the normally open valve 12. This would not be possible if the pins 22 and 25 were located on the same side of the valve body 10. Since the pins 22 and 25 are located on opposite sides, there is clearance for closing of the normally open valve after the normally closed valve has opened.

Referring to FIG. 5, it is pointed out that the surface 33—33 diverges toward chamber 30. Surface portion 35 is relatively adjacent such chamber, whereas surface portion 33 is spaced from such chamber.

I claim:

1. A high-flow normally open explosive-operated valve which creates a highly effective seal when in closed condition, which comprises:

 a) wall means to define a chamber having an outlet port or passage therefrom,

means to form a metal valve seat portion at said outlet port or passage,

a movable valve element having a metal portion shaped to mate sealingly with said metal valve seat portion,

means to effect pivotal mounting of said movable valve element in such manner that said movable valve element when actuated toward said seat portion pivots about a fixed axis,

means to normally maintain said movable valve element in an open position pivoted away from said seat portion, and explosive means to effect sudden pivoting of said movable valve element about said fixed axis into contact with said seat portion and with sufficient force to effect permanent plastic deformation of the metal forming at least one of said metal portions whereby highly effective sealing contact is achieved.

2. The invention as claimed in claim 1, in which said metal valve seat portion lies generally in a plane, and in which said fixed axis is disposed substantially in said plane and to one side of said seat portion.

3. The invention as claimed in claim 2, in which said metal valve seat portion is generally circular, and in which said pivot axis is substantially perpendicular to an extended radius of said seat portion.

4. The invention as claimed in claim 2, in which said metal valve seat portion forms part of an annular valve seat element extending into said chamber in the manner of a lip, in which said pivot axis is located radially outwardly of said annular valve seat element, and in which said pivot axis is substantially perpendicular to an extended radius of said valve seat element.

5. The invention as claimed in claim 1, in which all parts of said movable valve element are rigidly connected to each other before, during and after said pivoting of said movable valve element to seated position.

6. A high-flow normally open explosive-operated valve, which comprises:

wall means to define a valve chamber having an outlet port or passage therefrom,

means to form a valve seat adjacent said port,

said valve seat having an interior surface which is a surface of revolution about a first central axis and is adapted to receive a poppet,

said interior surface diverging in a direction toward said chamber,

means to form a fixed pivot axis radially outwardly of said valve seat and lying adjacent a plane containing said valve seat,

said fixed pivot axis being perpendicular to an extended radius of said surface of revolution,

a poppet having a peripheral surface which is a surface of revolution about a second central axis,

at least one of said poppet and said valve seat being formed of deformable metal,

the radius of the leading part of said peripheral poppet surface being smaller than the radius of the portion of said divergent valve seat surface which is relatively adjacent said chamber, whereby the leading part of said poppet may freely enter and be received within said valve seat,

the radius of a trailing part of said peripheral poppet surface being greater than the radius of a portion of

said divergent valve seat surface which is spaced from said chamber, the radius difference being sufficient that said trailing part of said poppet surface may effect permanent plastic deformation of at least one of said poppet and said valve seat adjacent said last-mentioned portion of said valve seat surface when said poppet is forced into said valve seat,

means to pivotally connect said poppet to said wall means for pivotal movement about said fixed pivot axis from a position at which said second central axis is transverse to said first central axis to a position at which said central axes are substantially coincident, and

explosive means to effect said pivotal movement with sufficient force that said trailing part of said peripheral poppet surface will effect permanent plastic deformation of at least one of said poppet and said valve seat.

7. The invention as claimed in claim 6, in which said peripheral poppet surface is spherical.

8. The invention as claimed in claim 6, in which said portion of said divergent valve seat surface which is spaced from said chamber is conical.

9. The invention as claimed in claim 6, in which said peripheral poppet surface is spherical, and in which said portion of said divergent valve seat surface which is spaced from said chamber is conical.

10. The invention as claimed in claim 6, in which said peripheral poppet surface is spherical, in which said portion of said divergent valve seat surface which is adjacent said chamber is radiused and in which said portion of said divergent valve seat surface which is spaced from said chamber is conical.

11. The invention as claimed in claim 10, in which the diameter of said spherical poppet surface is greater than the diameter of said divergent valve seat surface at the circle where said conical surface meets said radiused surface.

12. The invention as claimed in claim 11, in which said radiused surface is tangential to said conical surface at said circle.

13. The invention as claimed in claim 10, in which the circle where said conical surface meets said radiused surface lies in substantially the same plane as said pivot axis.

14. The invention as claimed in claim 6, in which both said poppet and said valve seat are formed of deformable metal.

15. The invention as claimed in claim 14, in which said metal is aluminum.

16. The invention as claimed in claim 6, in which said valve seat is an annular element extending into said chamber from said wall means, and in which said means to form a fixed pivot axis is a pin mounted in said wall means.

17. The invention as claimed in claim 16, in which said means to pivotally connect said poppet to said wall means is a rigid metal strap fixedly and permanently connected to said poppet and having a protuberant bearing portion mounted on said pin.

18. The invention as claimed in claim 17, in which said strap is welded to said poppet.

19. The invention as claimed in claim 17, in which said explosive means is a squib and piston assembly mounted on said wall means and communicating with said valve chamber through a port in said wall means, and in which a frangible fitting is welded to said wall means at said port to completely seal said port, said fitting having a portion connected to said strap, said fitting having a stress riser adapted to break and permit shifting of said fitting portion with said strap in response to detonation of said squib and consequent shifting of the associated piston.

20. A stop-start explosive-operated valve combination, which comprises:

an elongated valve housing defining a valve chamber,

a normally closed explosive-operated valve provided at one end of the valve chamber,

said normally closed valve incorporating a movable valve element and also incorporating pivot means to effect pivotal mounting of said movable valve element for pivoting toward the other end of said valve chamber about an axis located adjacent the interior wall of said valve housing on one side thereof,

a normally open explosive-operated valve provided at said other end of said valve chamber,

said normally open valve incorporating a movable valve element and also incorporating pivot means to effect pivotal mounting of said movable valve element for pivoting toward said one end of said valve chamber about an axis located adjacent the interior wall of said valve housing on the other side thereof,

said pivot means of said normally closed and normally open valves being sufficiently close to each other in directions axially of said housing that said movable valve elements of said normally closed and normally

open valves overlap when both of said valves are in open condition.

21. The invention as claimed in claim 20, in which said pivot means are substantially parallel to each other.

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