

1

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EXPLOSIVE ACTUATED VALVE

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This invention relates to valving devices and more particularly to so-called explosively actuated valves adapted to control highly fugitive fluids such as hydrogen or helium under pressures in the order of several thousand pounds per square inch.

Heretofore, valves of the before mentioned kind usually have been either of two single-operation types, namely, either a normally closed valve which may be opened to permit the flow of fluid therethrough, or a normally open valve which may be closed to prevent the flow of fluid therethrough. It is well known to employ explosives or combustible propellant materials for actuation of such valves, and such valves have heretofore usually relied upon the rupturing or perforating of a diaphragm barrier or the like member to effect the opening of the valve, or on the other hand, the driving of a plug or the like element into an opening to shut off the flow of fluid. Such valves, in the case of the normally closed, openable types usually have had the disadvantage of jeopardizing the cleanliness of the fluid systems in which they were connected; and in the case of the normally open, closeable types, they had the danger of not always succeeding in effecting a perfect shut-off. With both of the foregoing types of valves, unbalanced forces, resulting from both the static pressures and dynamic forces of the fluids to be controlled and from the residual pressure of the activating fluids or gases, tended to move the valve elements to undesired positions, particularly where such valves were used under conditions of severe vibration.

Such valves heretofore employed also often had valving elements, the functional surfaces of which were subject to deterioration both as to shelf and service life, with the result that they could not be relied upon to function satisfactorily at all times and over long periods of time of either inactivity or service with the kinds of fluids and under the conditions for which the valves of the present invention are especially intended.

It is accordingly an object of the present invention to provide a valve which is capable of controlling highly fugitive fluids under extremely high pressures, without leakage.

Another object of this invention is to provide such a valve which may be either singly or doubly operated by means of explosive or combustible gas-generating materials.

A still further object of this invention is to provide such a valve which neither in its static state nor in any of its operational cycles, jeopardizes the cleanliness of the fluid system in which it is connected.

It is another object of this invention to provide a valve having a high degree of reliability in fulfilling the foregoing objects at any time or after long periods of service or inactivity.

It is a still further object of this invention to provide such a valve, the moving components of which either

2

in opened condition or in closed condition are balanced both as to the pressures and dynamic forces of the fluids to be valved and the residual pressures of propulsive fluids or gases by which it is actuated, so that there is no force tending either to open or close the valve at any time other than at the instant of its intended actuation.

It is a still further object of this invention to provide a valve of the beforementioned kind in which there is at no time, either in its opened condition or in its closed condition, any opposition to the movement of the operative parts of the valve, either by reason of the pressure of the fluid in, or the flow of the fluid through the valve, and in which the only forces necessary to be overcome by the actuating means are the frictional forces of the moving parts of the valve.

The objects of this invention, broadly considered, are accomplished in brief, by employing a valve structure in which the valving elements and the bore of the valve housing in which the elements are positioned and move to perform the function of opening or closing the fluid flow passages therethrough, are of such relative sizes and shapes as to be in substantial dimensional interference with one another, or in other words, such as to make interference fits with one another, such that at the interfaces or areas of contact therebetween, the metals thereof are in extremely high-compressive, intimate contact, so much so that upon movement of the valve elements within the valve bore, deformation of the metals occurs at the areas of mutual contact. This deformation is fundamentally elastic with possibly a slight amount of permanent deformation or flow. This insures that at all times a perfect metal-to-metal seal will be maintained.

These and other objects, advantages and features of novelty of this invention will be evident hereinafter.

In the drawings which illustrate preferred embodiments of the invention and in which like reference characters designate the same or similar parts throughout the several views:

FIGURE 1 is a longitudinal sectional view of the body of a valve embodying the present invention and showing a normally or initially open version thereof before actuation to its closed position;

FIGURE 2 is a longitudinal sectional view of the valve of FIGURE 1, but showing the valve after having been actuated to its closed position; and

FIGURE 3 is a fragmentary longitudinal sectional view of a modification of the apparatus of FIGURES 1 and 2.

The apparatus of the invention is as follows:

Referring first primarily to FIGURE 1, the housing or body portion of the valve is shown at 10, such body portion being formed with laterally directed, longitudinally offset inlet and outlet ducts or openings 12 and 14 which are threaded at their outer end portions as shown at 15 and 16 to receive suitable connections with tubing or piping which may comprise a high pressure fluid system in which the valve is to be connected. The valve body 10 is also provided with a longitudinal valve bore 17 of uniform inside diameter except for intermediate, undercut sections 18 and 20, with which the connection openings 12 and 14 communicate through junction ports 19 and 21, respectively. The opposite ends of the bore 17 terminate in counterbored, internally threaded ends 28 and 29. The valve bore 17, in one version of the ap-

paratus as shown in FIGURES 1 and 2, is closed at one end by an externally threaded plug 22, and at the other end by an externally threaded, electrically actuated, gas pressure generating unit 24. O ring seals are provided in annular recesses at the outer ends of the threaded portions of the plug 22 and the gas pressure generating unit 24, as shown at 11 and 13, respectively.

The gas pressure generating unit 24 may be of several different kinds adapted to supply gas under pressure for operation of the valve, but in the preferred form herein illustrated it is provided with an inwardly extending initially closed cartridge portion 25 composed of a hollow, metal sleeve 26, which is normally closed at its outer end by a relatively thick transverse wall 43 and its inner end by a relatively thin detachable metal diaphragm 30 sealed, fluid tight, around its periphery to the inner end of the walls of sleeve 26 by suitable means such as by soldering, as shown at 31. The cavity, thus formed within the closed cartridge portion 25, contains a suitable quantity of a combustible material or explosive, gas-forming material, for example, a propellant such as gun powder.

The exterior part of the gas pressure generating unit 24 takes the form of an integral, electrical connector receptacle, which is formed with an outwardly extending cylindrical shell 32, threaded on the exterior thereof, as shown at 33, to receive a threaded connector retainer ring, and forming a cylindrical recess 34 on the interior thereof adapted to receive a conventional electrical connector plug.

A pair of separate electrical contact pins 36 and 37 extend axially outward within the receptacle recess 34 from the receptacle wall between the recess 34 and the cartridge portion 25, and are adapted to plug into tubular terminal members of the previously mentioned electrical connector plug. The electrical contact pins 36 and 37, extend through the receptacle wall 43 into the interior of the cartridge portion 25 through insulating bushings, as shown at 38 and 39. Such insulating bushings 38 and 39 may be made of glass, plastic or other suitable insulating materials as well known in the art, capable of withstanding the temperatures and gas pressures generated within the cartridge portion 25 upon ignition of the combustible material therein. By way of example of a suitable connector receptacle and assembly configuration which may be made integral with the gas pressure generating unit, as before described, is the type designated as United States Military Standard Drawing M.S. 33678, Style P.

A relatively fine, fusible igniter wire 40 extends between soldering lug portions 41 and 42 of the ends of the connector pins 36 and 37, which extend into the cartridge portion 25. Further detailed description of the pressure generating means including the cartridge portion 25 thereof, is not herein given, since devices of this kind suitable for use in connection with the valve of this invention are well known.

Referring again primarily to FIGURE 1, the valve bore 17 of the valve body 10 contains a valve spool 45 formed with three coaxial, longitudinally spaced-apart, generally disc-shaped valve elements 46, 47 and 48, centrally interconnected by integral stem portions of reduced outside diameter, as shown at 49 and 50. Each of the valve elements is formed with a longitudinally curved peripheral surface, preferably having or approximating the geometrical shape of a coaxial, equatorial, spherical or spheroidal zone. Such surfaces preferably have polished finishes and are of such maximum outside diameters as to make interference fits with the inside surface of the valve bore 17. An interference fit of $0.0012" \pm .0002"$ between the maximum outside diameter of the approximately spherical or spheroidal surface of the valve elements and the inside diameter of the valve bore 17 has been found suitable in effecting the desired fluid seal, where the materials use for the valve body and the valve elements are alloy steels or aluminum alloys. Such materials may

be used separately or in combination for both valve elements and valve body, but preferably the valve elements and the material of the inside surface of the valve bore are of the same material to minimize galvanic corrosion effects therebetween. Corrosion resistant or so-called stainless steel has been found to be satisfactory in most applications of the valve.

The valve spool 45 is provided with a passage 51, shown in dotted lines, of somewhat restricted cross section, extending coaxially therethrough from end-to-end, such passage being for the purpose of pressure equalization between the opposite ends of the valve bore 17, as will hereinafter be more fully explained in connection with the operation of the valve.

FIGURE 3 illustrates a modification of the apparatus of FIGURES 1 and 2 wherein, instead of the plug 22 closing one end of the valve bore 17, a gas pressure generating unit 24a, including a cartridge portion 25a similar or identical to that of the unit 24, is substituted therefor. A plug similar to that shown at 22 may be employed in place of the pressure generating unit 24 where it is desired to operate the valve from an initially closed to an opened condition instead of from an initially open to a closed condition. However, the gas pressure generating unit 24a may be used in addition to that at 24 where it is desired to effect a double operation of the valve, namely, either from a normally open to a closed condition and return to an open condition, or from a normally closed to an open condition and return to a closed condition.

The operation of the apparatus is as follows:

In an initial, unactuated condition of the valve, as shown in FIGURE 1, the valve spool 45 is located in its extreme left-hand position in the valve bore, at which location the valve element 46 of the valve spool is located adjacent the inner end of the propellant cartridge portion 25, and the other two valve elements 47 and 48 of the valve spool are located in spaced-apart positions bridging or straddling both of the inlet and outlet duct ports 19 and 21 at their points of juncture with the valve bore 17, and also straddling the intermediate section 23 of the valve bore extending therebetween. In this initial position of the valve spool, fluid may obviously flow freely through the valve in either direction between the inlet and outlet ducts 12 and 14.

To actuate the valve, a suitable current source is connected to the conductor pins 36 and 37 through a suitable connector, as beforementioned, whereby the igniter filament 40 is fused, thereby igniting the combustible propellant material within the cartridge portion 25 of the pressure generating unit 24, with the result that the sealing diaphragm 30 of the cartridge is detached therefrom and the resultant generated gas pressure acting against it and against the adjacent face of the valve element 46 forces the valve spool to move through the bore 17 to its right-handmost position, shown in FIGURE 2. Following this action, the pressures in the opposite ends of the bore will be gradually equalized by leakage of the higher pressure actuating gases in the left-hand end of the valve bore past the diaphragm 30 and through the pressure-equalization duct 51 to the right-hand end of the valve bore, whereupon due to the interference fit between the periphery of the valve elements and the inside surface of the valve bore, the valve spool 45 will be secured against subsequent axial movement, unless subsequently otherwise actuated as hereinafter described.

In this latter right-hand position of the valve spool 45 in the valve bore, following the beforementioned actuation thereof, the valve element 47 is positioned intermediate the duct ports 19 and 21, as shown at 35, thereby separating them from communication with one another and thereby cutting off communication between the inlet and outlet openings 12 and 14. In view of the fact that at this latter position of the valve spool the valve elements 46 and 47 straddle the port 19 and valve elements 47 and 48 straddle the valve port 21, all pressures and forces

communicated to the valve spool through either of the openings 12 or 14 are statically balanced such that there is no tendency for the valve spool 45 to be moved thereby axially in either direction in the valve bore 17. Likewise, in the opened condition of the valve, as hereinbefore described in connection with FIGURE 1, due to the straddling position of the valve elements 47 and 48 across ports 19 and 21, all forces acting upon the valve spool either by reason of the static pressure or fluid in the valve, or due to any dynamic force of flow of fluid in either direction through the valve, are balanced whereby there is no tendency for the valve spool to move through the valve bore in either direction from its opened position.

In event it is desired to arrange the valve to operate in a manner opposite to that hereinbefore described and shown in connection with FIGURES 1 and 2, that is, with the valve spool initially located in its right-handmost, valve-closing position as shown in FIGURE 2, and to be actuated to move it to the left-handmost, valve-opening position as shown in FIGURE 1, a gas pressure generating unit 24a, the same as or identical to that of the unit 24, hereinbefore described, may be substituted for the plug 22 and placed in the right-hand end of the valve bore, as shown in FIGURE 3. With this substitution and modification, the valve is actuated by means of the unit 24a in the same manner as hereinbefore described in connection with the actuation of the valve by the unit 24, and the resultant combustion gases generated in the right-hand end of the valve bore act upon the end of the valve element 48 to move the valve spool 45 in a left-hand direction to the position in the left-hand end of the bore 17, shown in FIGURE 1.

An important feature of this valve is its provision for protecting the fluids in the valve at all times from contamination by the products of combustion of the gas pressure generating units. This is accomplished by the presence of the end valve elements 46 and 48 which, subsequent to the actuation of the valve by firing the combustible propellant in the cartridge 25, move from the positions shown in FIGURE 1 to the positions shown in FIGURE 2; at which either and both positions all of the gaseous products of the combustion of the propellant material are retained, sealed off in the ends of the valve bore from communication with the fluid to be or being valved within the valve fluid passages. Similarly, it is to be noted that if the valve spool is initially located as shown in FIGURES 2 and 3, in which position flow of fluid through the valve is cut off, to the position shown in FIGURE 1, in which the fluid to the valve is free to pass through the valve, the valve elements 46 and 48 likewise at all times act as barriers to insure freedom of contamination of the valved fluids by any of the contents of the right-hand or left-hand ends of the bore, such as the products of combustion of the pressure generating materials of cartridge 25a. Freedom from any possible contamination of the fluids in the system in which the valve is connected is thereby at all times insured. This latter feature of the valve is also important in connection with the operation of the valve as described in connection with the apparatus of FIGURE 3.

Referring now principally to FIGURE 3, another important feature of this invention is the fact that propellant units such as shown at 24 and 24a may be initially attached at both ends of the valve bore 17 whereby the valve may be successively, doubly actuated to move the valve spool 45 either from an initial position in which the valve is open to flow of fluid therethrough, to a second position in which the valve is closed to flow of fluid therethrough, followed by a second operation which returns the valve spool 45 from its shut-off position to the open position; or the reverse of these sequential operations may obviously be employed. Thus, the valve is capable of at least two successive operations; namely, from an initially open to a closed condition, or from an initially closed to an open condition, or both of such operations in sequence.

It is to be understood that the foregoing is illustrative only and that the invention is not limited thereby but may include various modifications and changes made by those skilled in the art without distinguishing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. Valve apparatus comprising: a valve body portion having a bore formed therein; closure means for each end of said bore; separate inlet and outlet ducts in said body, each communicating at separate longitudinally spaced-apart locations, with said bore, there being an intermediate, uninterrupted section of said bore extending between such spaced-apart locations; a valve element located coaxially in said bore, said valve element extending closely across said bore and having a peripheral surface portion in slidable sealing engagement with the inside surface of the wall of said bore, said valve body portion and said surface portion being composed of a material having a hardness and rigidity at least approximating that of a metal of the class consisting of aluminum and steel, said peripheral surface having the form of a longitudinally convexly curved zone and said zone having a maximum outside diameter greater than the inside diameter of said bore, whereby said peripheral surface makes an interference press fit within said bore, said valve element being slidable axially within said bore between an axial position in a section of said bore outside of said intermediate section at which said ducts are in communication with each other through said intermediate section, and an axial position within said intermediate section at which said ducts are thereby cut off from communication with each other, while maintaining said fit in said section of said bore; and force means actuatable for moving said valve element axially in said bore between said positions.

2. Valve apparatus comprising: a valve body portion having a bore formed therein; closure means for each end of said bore; separate inlet and outlet ducts in said body, each communicating at separate longitudinally spaced-apart locations, with said bore, there being an intermediate, uninterrupted section of said bore extending between such spaced apart locations; a valve element located coaxially in said bore, said valve element extending closely across said bore and having a peripheral surface portion in slidable sealing engagement with the inside surface of the wall of said bore, said valve body portion and said surface portion being composed of a material having a hardness and rigidity at least approximating that of a metal of the class consisting of aluminum and steel, and said peripheral surface having the form of a longitudinally convexly curved zone and having a maximum outside diameter greater than the inside diameter of said bore, whereby said peripheral surface makes an interference press fit within said bore, said valve element being slidable axially within said bore between an axial position in a section of said bore outside of said intermediate section at which said ducts are in communication with each other through said intermediate section, and an axial position within said intermediate section at which said ducts are thereby cut off from communication with each other, while maintaining said fit in said sections of said bore; and force means contained within an end of said bore actuatable for moving said valve element axially in said bore between said positions.

3. Valve apparatus comprising: a valve body portion having a bore formed therein; closure means for each end of said bore; separate inlet and outlet ducts in said body, each communicating at separate, longitudinally spaced-apart juncture locations, with said bore, there being an intermediate, uninterrupted section of said bore extending between such spaced-apart juncture locations; a valve spool located in said bore, said valve spool being formed with a pair of coaxial, axially spaced-apart annular valve elements interconnected by an intermediate stem portion of reduced outside diameter relative to that of said valve elements, each of said valve elements having a peripheral

7

surface of contact with the inside surface of the wall of said bore having the shape of a longitudinally convexly curved zone and having a maximum outside diameter greater than the inside diameter of said bore, whereby said surface of contact and the inside surface of said bore make an interference fit with one another, said valve body portion and said annular valve elements being composed of a material having a hardness and rigidity at least approximating that of a metal of the class consisting of aluminum and steel, said valve spool being slidable axially within said bore between an axial position at which both said valve elements are in a section of said bore outside said intermediate section and said ducts are in communication with each other through said intermediate section of said bore, and an axial position at which said valve elements are positioned in sections of said bore on opposite sides of one of said spaced-apart juncture locations and said inlet and outlet ducts are thereby cut off from communication with each other by at least one of said valve elements, said fit being maintained in said sections of said bore; and means for moving said valve spool between said locations.

4. Valve apparatus in accordance with claim 3 in which said means for moving said valve spool is contained within an end of said bore.

5. Valve apparatus in accordance with claim 4 in which said means for moving said valve spool comprises combustible gas generating material.

6. Valve apparatus comprising: a valve body portion having a bore formed therein; closure means for each end of said bore; separate inlet and outlet ducts in said body, each communicating with an intermediate portion of said bore at separate, adjacent, longitudinally spaced-apart, juncture locations, a valve spool located in said bore, said valve spool having first, second and third coaxial, axially spaced apart, annular valve elements interconnected by intermediate stem portions of reduced outside diameter relative to that of said valve elements, each of said valve elements having a peripheral surface of contact with the inside surface of the wall of said bore having a shape at least approximating that of a longitudinally convexly curved zone and having a maximum outside diameter greater than the inside diameter of said bore, whereby said surface of contact and the said inside surface of said bore make an interference fit with one another, said valve body portion and said annular valve elements being composed of a material having a hardness and rigidity at least approximating that of a metal of the class consisting of aluminum and steel, said valve spool being slidable axially within said bore between an axial position within said bore at which a first one of said valve elements is adjacent one end portion of said bore and the second and third ones of said valve elements are located in straddling position relative to both said adjacent juncture locations whereby said inlet and outlet ducts are in communication with each other through a portion of said bore intermediate said second and third valve elements, and the end portion of said bore adjacent said first valve element is isolated by said first valve element from both of said ducts, and another position in said bore at which one of said second and third valve elements is adjacent the other end of said bore and one of said second and third valve elements is positioned in said bore intermediate said juncture locations, at which another position said inlet and outlet ducts are thereby cut off from communication with each other, and the other end portion of said bore adjacent said outer one of said second and third valve elements is isolated from both said ducts; and means for applying force to said valve spool to move it axially in said bore between said positions.

7. Valve apparatus comprising: a valve body portion having a bore formed therein; closure means for each end of said bore; separate inlet and outlet ducts in said body, each communicating with an intermediate portion

8

of said bore at separate, adjacent, longitudinally spaced-apart, juncture locations, a valve spool located in said bore and slidable axially therein, said valve spool having first, second and third coaxial, axially spaced-apart, annular valve elements interconnected by intermediate stem portions of reduced outside diameter relative to that of said valve elements, each of said valve elements having a peripheral surface of contact with the inside surface of the wall of said bore having the shape of a longitudinally convexly curved zone and having a maximum outside diameter greater than the inside diameter of said bore, whereby said surface of contact and the inside surface of said bore make an interference fit with one another, said valve body portion and said annular valve elements being composed of a material having a hardness and rigidity at least approximating that of a metal of the class consisting of aluminum and steel, said valve spool being slidable axially within said bore between an axial position at which an outer first one of said valve elements is adjacent an end portion of said bore and the second and third ones of said valve elements are located in straddling position relative to both said adjacent juncture locations whereby said inlet and outlet ducts are in communication with each other through a portion of said bore intermediate said second and third valve elements and the end portion of said bore adjacent said outer first valve element is isolated by said first valve element from both of said ducts, and another position in said bore at which an outer one of said second and third valve elements is adjacent another end of said bore and one of said second and third valve elements is positioned in said bore intermediate said juncture locations, at which another position said inlet and outlet ducts are thereby cut off from communication with each other, and the other end portion of said bore adjacent said outer one of said second and third valve elements is isolated from both said ducts; and means for introducing fluid under pressure to one outer end surface of one of said outer valve elements to move said valve spool axially in said bore between said positions.

8. Valve apparatus comprising: a valve body portion having a bore formed therein; closure means for each end of said bore; separate inlet and outlet ducts in said body, each communicating with an intermediate portion of said bore at separate adjacent longitudinally spaced-apart juncture locations, a valve spool located in said bore and slidable axially therein, said valve spool having first, second and third coaxial, axially spaced-apart, annular valve elements interconnected by intermediate stem portions of reduced outside diameter relative to that of said valve elements, the peripheral surface of contact of each of said valve elements, with the inside surface of the wall of said bore each having a longitudinally convexly curved shape and having a maximum outside diameter greater than the inside diameter of the said surface of said bore, whereby said surface of contact and the inside surface of said bore make an interference fit with one another, said valve body portion and said annular valve elements being composed of a material having a hardness and rigidity at least approximating that of a metal of the class consisting of aluminum and steel, said valve spool being positionable axially within said bore such that a first one of said valve elements is located adjacent an end portion of said bore and the second and third ones of said valve elements are located in bridging positions relative to said adjacent juncture locations whereby said inlet and outlet ducts are initially in communication with each other through a portion of said bore intermediate said second and third valve elements and the end portion of said bore adjacent said first valve element is isolated by said first valve element from said second valve element and from both of said ducts, and positionable axially within said bore such that one of said second and third valve elements is positioned axially within said bore intermediate said juncture locations and said inlet and outlet ducts are thereby cut off from com-

9

munication with each other, and the end portion of said bore adjacent said third valve element is isolated by said third valve element from at least one of said ducts; and means including a quantity of ignitable, combustible gas-generating material in at least one end portion of said bore; and means to ignite said combustible material thereby to apply gas pressure to the outer end surface of one of said valve elements to move said valve spool axially in said bore between said positions.

9. Valve apparatus in accordance with claim 6 and a restricted, pressure equalizing passage extending from one end portion to the opposite end portion of said bore.

10. Valve apparatus in accordance with claim 7 and

10

a restricted, pressure equalizing passage extending from one end portion to the opposite end portion of said bore.

11. Apparatus in accordance with claim 1 in which said material is a rigid metallic material.

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