In some embodiments, the control valve is a normally closed control valve, and the plastically deformed concentric strain hardened region having the concave shape is formed in the second surface of the valve diaphragm.

In one embodiment a valve diaphragm is processed by cold working a small concentric region of one diaphragm surface. In another embodiment the cold working process creates a permanent plastic deformation reducing a diaphragm thickness between 5% and 20%. In another embodiment a radial width of a cold worked region is between 50% and 200% of a diaphragm thickness. In another embodiment a valve diaphragm for use in a normally closed valve has a concentric region of the diaphragm exterior to a valve chamber plastically deformed by a thickness reduction of about 10% of a diaphragm thickness across a radial width of about 100% of the diaphragm thickness. In another embodiment a valve diaphragm for use in a normally open valve has a concentric region of the diaphragm exposed to a valve chamber plastically deformed by a thickness reduction of about 10% of a diaphragm thickness across a radial width of about 100% of the diaphragm thickness. In various embodiments, the diaphragm is formed from a corrosion resistant metallic alloy, such as type 316 stainless steel, Hastelloy® brand nickel-chromium alloys available from Haynes International, Elgiloy® brand cobalt-chromium alloys available from Elgiloy Specialty Metals, etc.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a perspective cross-section of a representative normally closed diaphragm sealed valve;

Fig. 2A is a plan view seen from the actuator side of a diaphragm intended for a normally closed valve;

Fig. 2B is a cross-section through the diaphragm of Fig. 2A intended for a normally closed valve, along the line A-A;

Fig. 3 is a perspective cross-section of a representative normally open diaphragm sealed valve;

Fig. 4A is a plan view seen from the seat side of a diaphragm intended for a normally open valve, along the line B-B;

other side of the diaphragm undergoes tensile stresses. Cold working sufficient to cause permanent plastic deformation of the diaphragm surface will consequently cause compressive forces to become stored within the worked surface and expansive tensile forces to become stored within the opposite surface. The combination of these forces causes the cold worked diaphragm to axisymmetrically bow with the cold worked region being inside the concave side of the resulting cup shape. The cup shape resulting from cold working a region of the diaphragm may be chosen to enhance the performance of a normally closed valve or a normally open valve by selecting which side of the diaphragm to process.

Fig. 2A and Fig. 2B illustrate how cold working a region 75 on the actuator side of a diaphragm 70 will cause the diaphragm to become concave toward the actuator while simultaneously being biased toward the valve seat 20. This arrangement placing the cold worked region 75 on the actuator side exterior to the valve chamber 50 is useful for a normally closed valve design. Fig. 2A is a plan view of the valve housing 60 seen from the actuator side of the sealing diaphragm 70. Fig. 2B is a cross-section through the valve housing 60, after the cold working process, and shows how the resulting unbiased location of the control surface 81 of the control element 80 extends below the previously coplanar bottom 61 of the valve housing 60. Attaching the valve housing 60 to the valve body 90 will cause the control surface 81 of the control element 80 to rest against the valve seat 20 and thus bow the diaphragm 70. The diaphragm 70 is consequently subject to continual elastic compression loading even when the normally closed valve is shut. Applying a lifting force to the control shaft 82, to open the valve for fluid flow, will further deflect the diaphragm 70 and increase the compression within the diaphragm material.

Another representative example of a diaphragm sealed valve for use in a high purity fluid delivery application is illustrated in perspective cross-section by Fig. 3. This typical valve comprises a valve body 390, an inlet conduit 310 and an outlet conduit 314 both of which communicate fluid to or from a valve chamber 350, a valve housing 360 having a valve housing body 362 and including a chamber sealing diaphragm 370, the valve housing 360 being sealed against the valve body 390 by a metallic gasket 365, and a control element 380 moveable by deflection of the diaphragm 370. The manner of controlling fluid flow may be further understood by considering an orifice 312, through which the inlet conduit 310 discharges fluid

into the valve chamber 350, and a seat 320 surrounding said orifice 312, thereby defining a small clearance control gap with respect to the control element 380 which may be changeably positioned by a downward force applied to a control shaft 382, and through which control gap fluid may flow. It should be appreciated the illustration of Fig. 3 shows a normally open valve in an un-actuated open flowing fluid condition and therefore the control gap is at a maximum in the illustrated configuration.

Fig. 4A and Fig. 4B illustrate how cold working a region 375 on the valve chamber side of a diaphragm 370 will cause the diaphragm to become concave toward the valve chamber 350 while simultaneously being biased away the valve seat 320. This arrangement placing the cold worked region 375 on the valve seat side within the valve chamber is useful for a normally open valve design. Fig. 4A is a plan view of the valve housing 360 seen from the valve chamber side of the sealing diaphragm 370. Fig. 4B is a cross-section through the valve housing 360, after the cold working process, and shows how the resulting unbiased location of the control surface 381 of the control element 380 extends above the previously coplanar bottom 361 of the valve housing 360. Attaching the valve housing 360 to the valve body 390 will consequently position the control surface 381 of the control element 380 with a large gap above the valve seat 320. This unbiased gap is larger than intended for an un-actuated fully open flowing fluid condition. A suitable actuator assembly (not shown) may be coupled to the control shaft 382 applying a downward bias force in a manner which reduces the gap between the control surface 381 of the control element 380 and the seat 320 to a desired fully open gap distance. The diaphragm 370 will be consequently subject to continual elastic compression loading for all conditions of the normally open valve. Applying additional downward force to the control shaft 382 of the control element 380, partially closing the valve to reduce fluid flow, will further deflect the diaphragm 370 and increase the compression within the diaphragm material.

Cold working (or alternatively, work hardening or strain hardening) a concentric region of a diaphragm may be done by various processes. A valve housing with associated integral diaphragm formed in a valve housing body may be rotated in a lathe and a burnishing tool applied to the region. Alternatively, a roller burnishing tool may be powered by a machine spindle (e.g. a milling machine) impressed upon the desired region of the diaphragm. Or a form