

March 21, 1967

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3,310,280

DIAPHRAGM VALVE

Filed Nov. 16, 1965

4 Sheets-Sheet 1

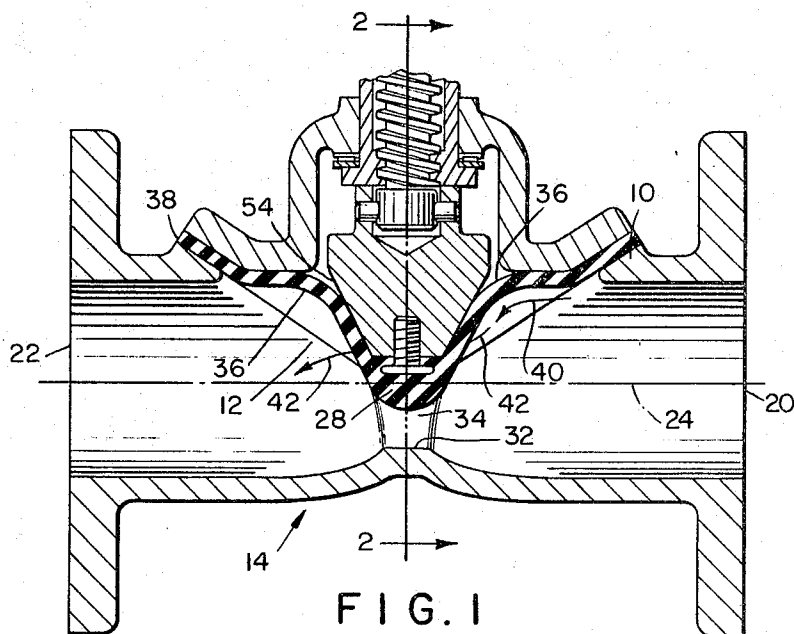
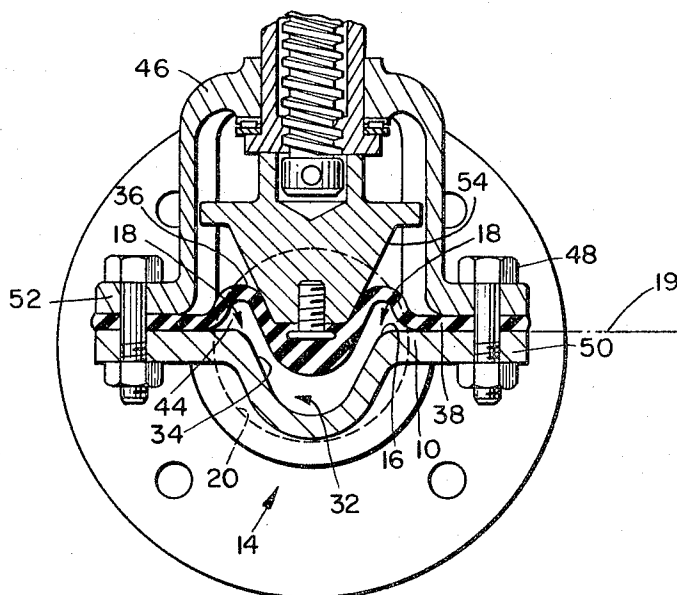


FIG. 2

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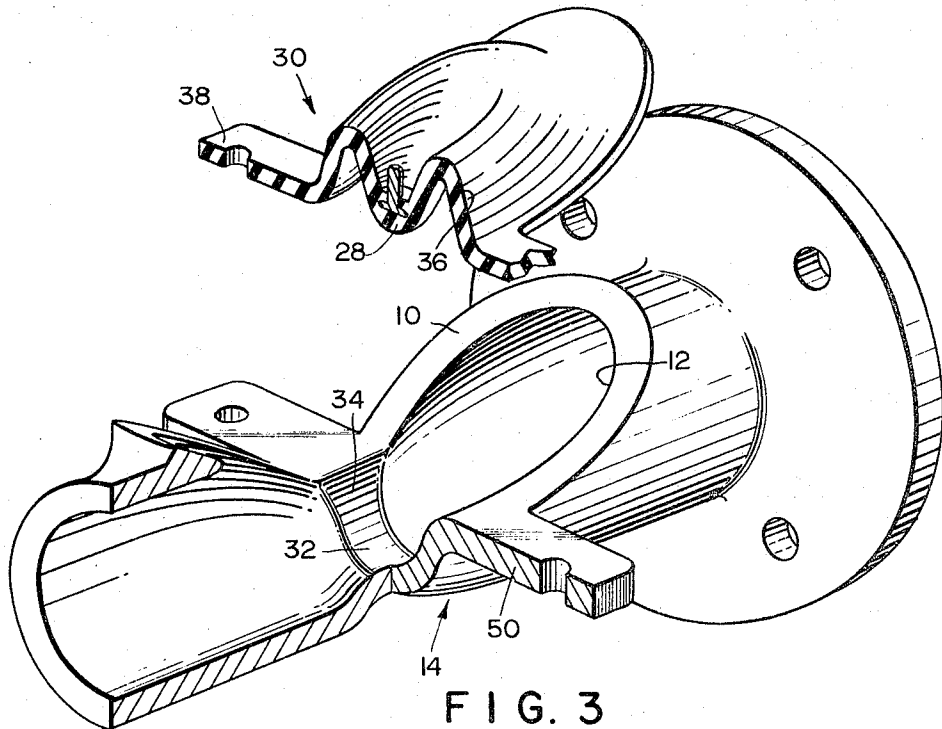
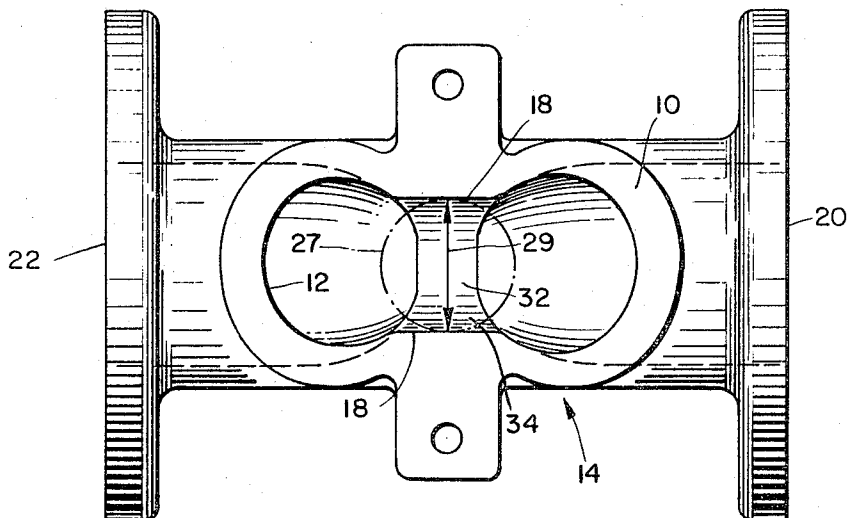
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4 Sheets-Sheet 2



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DIAPHRAGM VALVE

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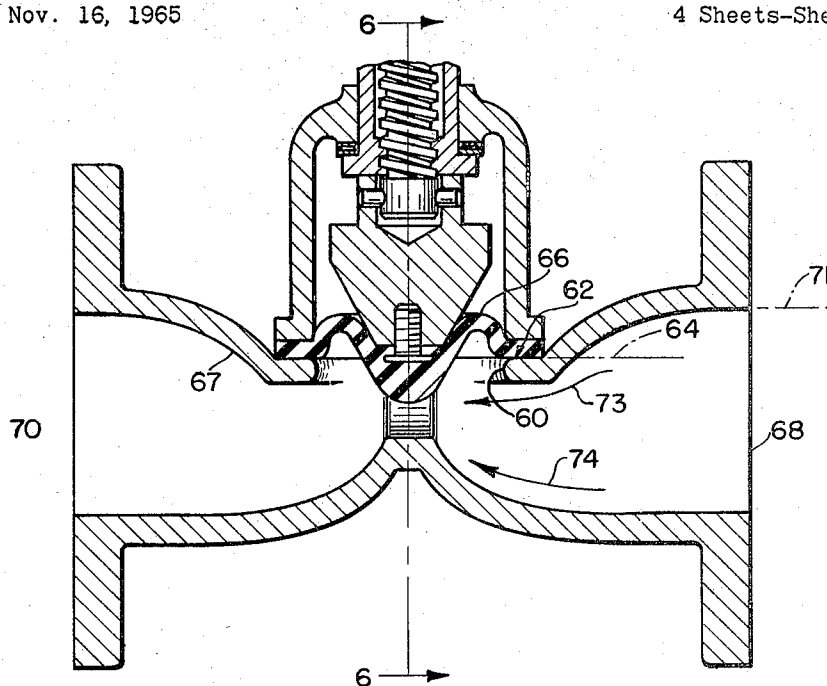


FIG. 5

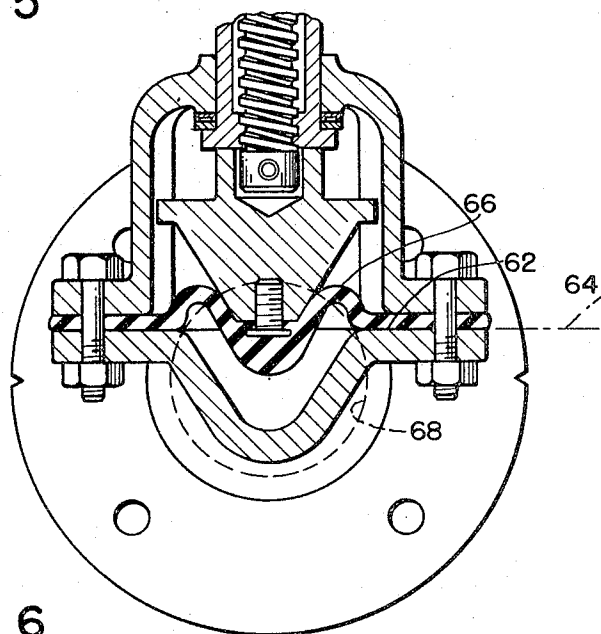


FIG. 6

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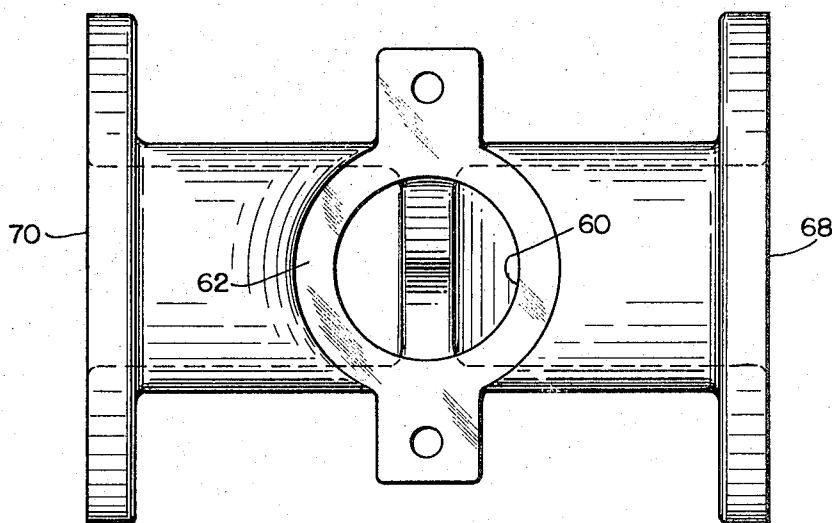


FIG. 7

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3,310,280

DIAPHRAGM VALVE

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10 Claims. (Cl. 251-331)

This application is a continuation-in-part of application Ser. No. 315,817, filed Oct. 14, 1963, and entitled, Diaphragm Valve, now abandoned.

This invention relates to improvements in diaphragm valves. More particularly, it has to do with a diaphragm valve in which there is a sharp reduction in the cross-sectional area of the flow between the inlet end of the passage and the valve seat when the valve is in the open position. With such a construction, and especially with such a construction in which the reduction is located as close as possible to the seat, a characteristic flow curve is achieved which is much more suitable for control valve applications than the prior art diaphragm valves.

A typical diaphragm valve of the kind to which the present invention relates has a body with a flow passage therethrough between its inlet and outlet ends, with a diaphragm opening on one side of said body and communicating with said passage and with a seating on the interior wall surfaces of said body opposite said diaphragm opening. The seating is essentially a narrow concave band with ends merging into the rim of the diaphragm opening at about the level of the axis of the end openings, with steeply sloping end portions extending down into the body from said ends and with a concave center portion. The seating band may have its center portion on a level with the interior walls elsewhere along the body interior or it may be slightly raised above such level. From the seating ends the body opening rim slopes upwardly to opposite points above the axis referred to. A diaphragm having its periphery clamped to this opening rim and having its steeply domed central portion opposite the seating achieves valve closure by being pressed against the seating band and achieves valve opening by being withdrawn from such surface. The diaphragm movements are achieved by a compressor adjacent the back side of the diaphragm and secured to the center thereof. This compressor and other parts of the actuating mechanism are housed in a bonnet which serves to clamp the diaphragm periphery as above described.

To those familiar with this kind of diaphragm valve it is well known that the area of the diaphragm opening in this kind of valve has always been of such shape and size that the cross-sectional area of the flow passageway is greatly increased at the seat.

Stated another way, with a deeply bulged diaphragm having the usual generally circular center portion the area of this portion has always been relatively large, for example, much larger than the area of the flow passage inlet or outlet openings. The reason for this prior art construction is clear. In order to provide as little obstruction to flow as possible the center portion of the seating band has usually had substantially the same curvature as the portions on either side of it, and hence when the side portions of this seating band have sloped sufficiently to permit a rolling action of the domed central diaphragm central portion the body diaphragm opening which has been required for such a diaphragm has had an area much greater than the area of each of the end openings. Consequently the distance across the diaphragm opening between the ends of the seating bands has been so great in the prior art valves of this no-weir or low-weir type that the area of the flow passage at the seating has been far greater than the area of the flow passage at the body end openings. However, this large flow passage area at the

seating when the valve is open has not been regarded as a disadvantage in the prior art valves of this type. On the contrary, the increase in such area at the seating has been welcomed as an aid to free flow, and even where attempts have been made to decrease the size of the body's diaphragm opening in order to make the valve less-expensive the distance between the seating ends (diameter of the body diaphragm opening) has still been greater than the diameters of either of the end openings with the result that the area of the diaphragm opening has been greater than the area of either of the end openings.

Where the prior art has employed a low weir and the concavity of the domed central diaphragm portion has been great the area of the diaphragm opening (still generally circular) has also been much larger than the area of either of the passage ends because of the necessity to provide a slope on the sides of the seating which will permit a rolling action of the domed central diaphragm portion and also because it has been important in this kind of valve to avoid any reduction in the cross-sectional area of the flow passage when the valve is open. Thus, even though there have been efforts to reduce the size of the diaphragm opening in no-weir valves, the diaphragm openings in such valves have still been considerably larger than the inlet or outlet openings in order to avoid any passage area reduction.

The present invention results from my discovery that by sharply reducing the cross-sectional area of the flow passage between the inlet opening and the seat, and preferably by locating this reduction as close as possible to the seat a characteristic curve (flow vs. stem position) results which is much more useful in control work than the characteristic curves of the prior art diaphragm valves.

In by far the most preferred form this invention contemplates a diaphragm valve with a body having an oval diaphragm opening with the short axis across the body and with generally circular end openings and further contemplates that the diameters of these end openings be at least as great as the width of the oval diaphragm opening. It also contemplates a body in which the seating extends along the short axis of the oval opening and has its ends well below the top level of the passage end openings. In this preferred form the area of the flow passage approaching the seating from the inlet (either end opening) is sharply reduced even when the diaphragm is in its fully opened position. Even though the diaphragm is of the kind having a deeply domed portion the required shapes on the sides of the diaphragm dome and body seating result in a maximum flow passage area at the seating which is less than the end opening areas.

The performance of such valves, and others which may also be in accordance with the invention, is particularly useful for control work because the characteristics of such valves more closely approach the exponential form than any prior art diaphragm valves, and such exponential curves permit a given change in stem position to produce the same percentage change in flow anywhere in the range of stem movement.

The importance of such flow control, as distinguished from merely opening and closing a fluid conduit, is best understood by first imagining an ideal valve. As stated, such a valve would be one in which each increment of stem movement produces the same percentage change in flow. This means that when stem movement (abscissa) is plotted against flow (ordinant) the curve rises steeply from the intersection of the axes and then levels off sharply. In the ideal valve the largest value of flow (end of the curve) would seem to be the flow through a straight piece of pipe of the size with which the valve is intended to be used.

There are, however, at least two reasons why it is not practical to have control valves with the same cross-sec-

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tional flow passage area at the seat as in the pipe with which the valve is to be used. One reason is that even though valves can be designed which have equal percent curves right up to such full flow rates the control of the flow in the actual system is not on such an equal percent basis because of the friction losses in the pipe and other accessories. Unless the valve in its wide open position constitutes a substantial part of the total system pressure drop an increment of valve stem movement will have a relatively small effect on total system flow. Accordingly, to assure a suitable degree of control in the valve positions near the wide open position, it is conventional to select a valve which in its wide open position has a cross-sectional passage flow area at the seat substantially smaller than the full pipe cross-sectional area.

Another reason why it is not practical for a control valve to have its flow passage area in the wide open position equal to the pipe cross-sectional area is that to make such a valve have an equal percent curve essentially involves using very large closure members and operating them close enough to their corresponding large seats so that a change in stem position has a significant effect on flow. This has several difficulties, including the extra size of the valve to accommodate the large parts.

Diaphragm valves have been conventionally constructed for on-off service with maximum flow in the wide open position, flow which approaches that of the pipe with which the valve is to be used.

One reason for this development of the diaphragm valve has been the assumption that because of its inherent limitations an "equal percent" cannot be achieved throughout the range of valve movement. More particularly, it has been supposed that the diaphragm quickly loses control of the flow as the open positions are approached. It must be borne in mind here that diaphragm valves conventionally press a closure member (diaphragm) directly down on the seat and have not had the opportunity of progressive seating exemplified by the contoured plug of the plug valve. The result has been that when the diaphragm is moved a relatively small distance away from the seat the effect of further movement on flow becomes sharply less, and in terms of characteristic curves the result is far from exponential and to a great extent is not even linear.

My discovery is that, surprisingly, when the cross-sectional area of the flow passage is reduced sharply between the inlet opening and the diaphragm seat the pressure drop required in control valves is achieved in addition there is a surprising change in the conventional characteristic curve toward the exponential form. A particular advantage of this improved curve is that it approaches the exponential form at the wide open position as well as elsewhere.

It might be supposed that the desirable flow characteristic above described can be achieved by merely limiting the amount of opening movement of the diaphragm in the prior art valves of the kind having a deeply domed diaphragm. This would result in there being a sharp reduction in flow passage area. However, it is not merely the reduction alone, but the shape of the area which is important. If the seating is long, as in the prior art, a small amount of diaphragm lift produces too large a change in flow passage area to achieve an exponential type of curve. The present invention calls for a structural relationship which necessitates a substantial diaphragm lift to produce that same change in flow passage area.

In a preferred form of my invention the above-described desired results are achieved by having a diaphragm opening in the body which is oval and end openings in the body which are substantially circular and by having the areas of each of the end openings at least as great as the area of an imaginary circle which has a diameter equal to the distance between the seating ends. This relationship is achieved in the preferred form by having the rim of the diaphragm opening in the body non-planar,

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by having the ends of the seating lying at a level well below the tops of the end openings, and by having the rim of the oval opening sloping from these seating ends to opposite points above the flow passage.

The area of the imaginary circle is an indication of the distance between the seating ends (which distance is the diameter of this imaginary circle), and the distance between the seating ends determines the area of the actual flow passage at the seating.

The oval shape for the diaphragm opening in the body is preferred because it permits the actual flow passage cross-sectional area to remain as large as possible right up to the seating. This locates the flow control at the seating. A circular diaphragm opening shape may be used, but it would result in unusually steep slopes for the opening rim when the seating ends are maintained at about the level of the end openings axis. This location of the seating ends near the level of this axis is desirable because it enables the flow over the seating to be diverted the least from its direction of movement as the valve is opened. If the rim of the diaphragm opening is located in a flat plane completely on one side of the end openings the result is essentially a weir type valve with a deeper bulge than usual and not within the scope of this invention. However, a diaphragm opening having its rim in a flat plane which is below the level of the tops of the end openings, though not preferred, is within the scope of the present invention.

In diaphragm valves of the kind to which this invention relates non-circular body end openings are not common, and in those non-circular end openings which may be used the maximum dimension is not likely to be very different than the minimum dimension. Accordingly I have found that by having the maximum dimension of the end opening always greater than the distance between the seat ends the desired reduction in flow passage area will obtain as a practical matter.

It is more common to have non-circular passage portions inwardly of the end openings, but here again the maximum and minimum dimensions of such portions are not very different in practice, and as long as the maximum dimension along the passage portion is greater than the distance between the seat ends the reduction in flow passage area can be expected as a practical matter.

Accordingly, it is one object of the present invention to provide a diaphragm valve of the kind having a deeply bulged diaphragm center portion and having seating ends which are below the level of the tops of the end openings in which the flow passage therethrough has its cross-sectional area sharply reduced between the inlet opening and the seat.

Another object is to provide a diaphragm valve of the kind described in which a certain relationship between the diaphragm opening in the body and an end opening in the body provides the desired sharp reduction in flow passage area.

Another object is to provide a diaphragm valve of the kind described in which the area of a body end opening is at least as great as the area of a circle having a diameter equal to the distance between the seating ends.

Another object is to provide a diaphragm valve of the kind described in which the body end openings are circular and the body diaphragm opening is oval with its short axis disposed across the body and with the diameters of its end openings at least as great as the length of this short axis.

Another object is to provide a diaphragm valve of the kind described in which the reduction in the cross-sectional area of the flow takes place closer to the seat than to the inlet opening.

Another object is to provide a diaphragm valve of the kind described in which the greater part of the reduction in cross-sectional area of the flow passage takes place immediately adjacent the seat.

Another object is to provide a diaphragm valve of the

kind first described in which the diaphragm opening is generally circular and has an area not substantially greater than the cross-sectional area of the passage at the inlet opening.

Another object is to provide a diaphragm for which the characteristic curve resulting from a plot of flow against stem position for a constant pressure drop approaches closer to an exponential form than previous diaphragm valves.

Another object is to provide a novel diaphragm valve which is particularly useful as a control valve, but which employs many parts previously used in prior art valves.

Another object is to provide a novel diaphragm valve which is inexpensive to manufacture, efficient in operation and easy to install and service.

Other objects will appear hereinafter.

The best mode in which it has been contemplated applying the principles of the present invention are to be found in the accompanying drawings but these are to be deemed primarily illustrative for it is intended to cover by suitable expression in the appended claims whatever of patentably novelty exists in the invention disclosed.

In the drawings:

FIGURE 1 is a cross-sectional side elevation view of a valve which is one embodiment of the present invention, the valve being shown in the open position;

FIGURE 2 is a cross-sectioned end elevation view taken on line 2—2 of FIG. 1;

FIGURE 3 is a partially sectioned, exploded, perspective view of the body and diaphragm of the valve of FIGS. 1 and 2;

FIGURE 4 is a top plan view of the body alone; and

FIGURES 5, 6 and 7 are views like FIGS. 1, 2 and 4, but showing another embodiment of the invention.

Referring now more particularly to the drawings, the embodiment of FIGS. 1 to 4 shows that the rim 10 around the diaphragm opening 12 in the body 14 is generally saddle shaped, being lower at the sides 16 of the body than in the middle. As a result the weir ends 18 are, of course, located at a level (plane 19) well below the tops of body end openings 20 and 22. Plane 19 is substantially parallel to axis 24 of the circular end openings 20 and 22 and intersects a substantial part of the flow passage. Preferably the plane 19 includes axis 24.

Weirs shaped like the one in this embodiment of FIGS. 1 to 4 have been known in the past, but to my knowledge, they have always been so proportioned relative to the cross-sectional area of the flow passage that there has been either increase in such area at the seating when the valve is opened or, at least, no smaller an area at the seating than anywhere else along the passage. In accordance with the present invention the ends of the diaphragm seating (weir ends 18) are spaced apart by a distance which is sufficiently short with respect to the dimensions of the end openings that during opening of the diaphragm the characteristic flow curve is or approaches the exponential form, or, more particularly, the distance between the seating ends is sufficiently short with respect to the dimensions of the end openings that even when the diaphragm is as wide open as it can be (without any kinds of stops) the area of the flow passage at the seating is nevertheless far smaller with respect to the areas of each of the end openings than in the prior art. Such relationships are satisfied when the area of each of the end openings 20 and 22 is at least as great as the area of a circle 27 having a diameter 29 equal to the distance between the seating ends 18. This is best seen in the end view of FIG. 2 where the circular end opening is indicated by dotted line 20.

Because the seating in this embodiment has such a deep concavity the center 28 of the diaphragm 30 is very thick and has a generally semi-spherical shape which fits the center of the seating 32. The sides 34 of the seating slope steeply upward from this center to the open rim 10. From its center 28 the flexible diaphragm walls 36 extend

to the clamped peripheral portion 38. In FIG. 2 these walls are in a rather sharply rolled configuration in the open position, the rolls being such that the required movement is able to take place to close the valve. In FIG. 1 the rolled configuration is less sharp because the clamped margin in this view while higher up is also farther out. The result is a smooth flow line as indicated by arrow 40. Arrow 42 shows how the flow is smoothly guided through the pockets 44 at the weir and resulting from the rolled configuration.

To simplify securing of the bonnet 46 to the body only two bolt and nut assemblies 48 are used, it being understood, however, that additional such assemblies may be used around the periphery of the diaphragm. The two bolt and nut assemblies pass through cooperating extensions 50, 38 and 52 on the body, diaphragm and bonnet respectively, each having suitable holes. The compressor arrangement is as shown with the compressor underside 54 shaped to conform to the diaphragm in open and closed position. The actuating details of the bonnet and compressor are the same as in the prior art.

One advantage of this kind of opening which dips down at the weir is that it provides a less abrupt change in direction of flow in the open position. Even though this opening is small relative to the end openings it would still provide good passage for a heavy viscous fluid or a fluid with suspended solids.

FIGS. 5, 6 and 7 show another embodiment which is like that of FIGS. 1 to 4 except that the diaphragm opening 60 is circular rather than oval and the rim 62 of the diaphragm opening lies in a flat plane 64, rather than being saddle-shaped. As a consequence the diaphragm 66 is the same in its several elevation view cross-sections, and the upper wall of the body flow passage dips down quite suddenly at 67 as it approaches the diaphragm opening 60 from either of the end openings 68 or 70. As in the embodiment of FIGS. 1 to 4, the flow through the valve when the diaphragm is open produces a diversion of both the upper and lower portions of the flow because the plane 64 is set below the top level (72) of the end openings. Arrows 73 and 74 show this diversion.

FIG. 6 shows particularly well the comparison of flow passage area at the seating with the area of the end opening.

I claim:

1. A diaphragm valve having:

(I) an elongated hollow body having:

(A) walls which:

- (1) define valve body sides,
- (2) terminate in opposite valve body ends,
- (3) have interior surfaces defining a flow passage,

(B) a long dimension measured between said ends,

(C) a diaphragm opening which:

- (1) is located in one of said valve body sides,
- (2) extends through said walls,
- (3) has a rim which:

(a) extends around said diaphragm opening,

(b) has opposite portions lying in a first plane which:

- (i) is parallel to said long dimension,
- (ii) intersects a substantial part of said flow passage,

(4) has a width dimension measured:

- (a) across said opening,
- (b) between said rim portions,
- (c) at right angles to said long dimension,

(D) a diaphragm seat which:

(1) is located:

- (a) on said interior wall surfaces,
- (b) between said valve body ends,
- (c) opposite said diaphragm opening,

- (2) has two separate portions which:
 (a) are sloped steeply with respect to said first plane,
 (b) have their outer ends merging into said diaphragm opening rim portions, 5
 (3) has a center portion connecting said separate portions,
 (E) an end opening which:
 (1) is located at one of said body ends,
 (2) lies in a second plane at substantially right angles to said long dimension, 10
 (3) has an area which is at least as great as the area of an imaginary circle having a diameter equal to said diaphragm opening width dimension, 15
 (II) a flexible diaphragm which:
 (A) has an outer portion in contact with said body rim,
 (B) has a center portion which covers said body diaphragm opening, 20
 (III) means for permanently clamping the diaphragm outer portion against said body opening rim up to said diaphragm opening,
 (IV) means for moving said diaphragm center portion with respect to said diaphragm seat portions to different positions from fully closed to fully open, said diaphragm center portion, 25
 (A) when in fully open position forming with said seat portions a flow opening, measured in a plane parallel to said second plane, which is considerably less in area than said end opening area. 30

2. A diaphragm valve according to claim 1 wherein said end opening is substantially circular.

3. A diaphragm valve according to claim 2 wherein a second end opening is located at the other of said body ends, wherein said second end opening is also substantially circular and wherein said end openings have substantially the same diameter. 35

4. A diaphragm valve according to claim 3 wherein said diaphragm opening in the body is oval with the short 40

axis of the oval disposed at substantially right angles to said long dimension.

5. A diaphragm valve according to claim 4 wherein said diaphragm opening rim portions are located at the ends of the oval short axis wherein said rim has additional opposite portions lying in a third plane which is parallel to said first plane and which lies outside said flow passage, and wherein said rim slopes with respect to said first and third planes as it extends between its said first and second portions.

6. A diaphragm valve according to claim 5 wherein said first plane substantially passes through the axis joining the centers of said circular end openings.

7. A diaphragm valve according to claim 3 wherein said diaphragm opening in said body is substantially circular and wherein the diameter of said circular diaphragm opening is at least as small as the diameter of said end openings.

8. A diaphragm valve according to claim 7 wherein substantially the entire rim of said diaphragm opening in said body lies in said first flat plane. 20

9. A diaphragm valve according to claim 3 wherein said first flat plane passes substantially through the axis joining the centers of said circular end openings.

10. A diaphragm valve according to claim 1 wherein said means for permanently clamping said diaphragm outer portion against said body opening rim comprises a bonnet secured to said body and wherein said means for moving said diaphragm center portion comprises a compressor movably mounted in said bonnet and secured to said diaphragm. 30

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