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VALVES FOR CONTROLLING GAS STREAMS FLOWING AT VERY LOW FLOW RATES

Filed Dec. 4, 1957 4 Sheets-Sheet 1

Fig. 1

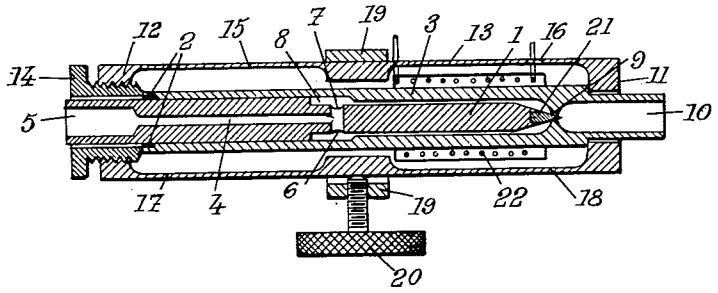


Fig. 2.

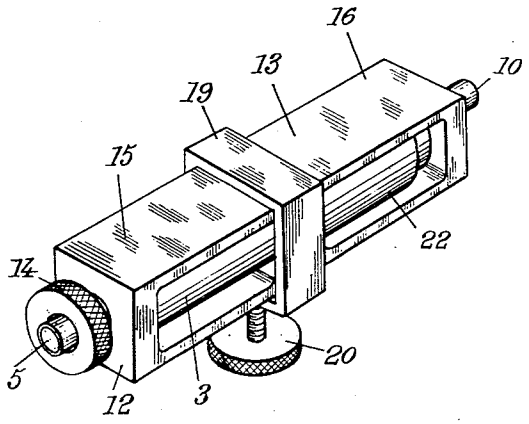
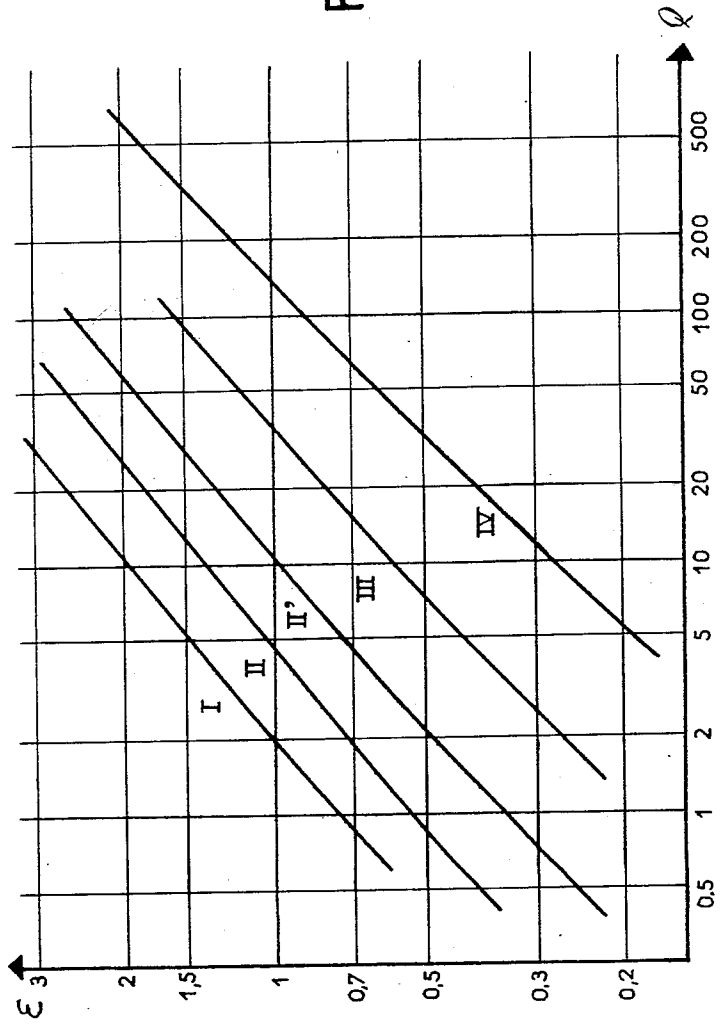


Fig. 3



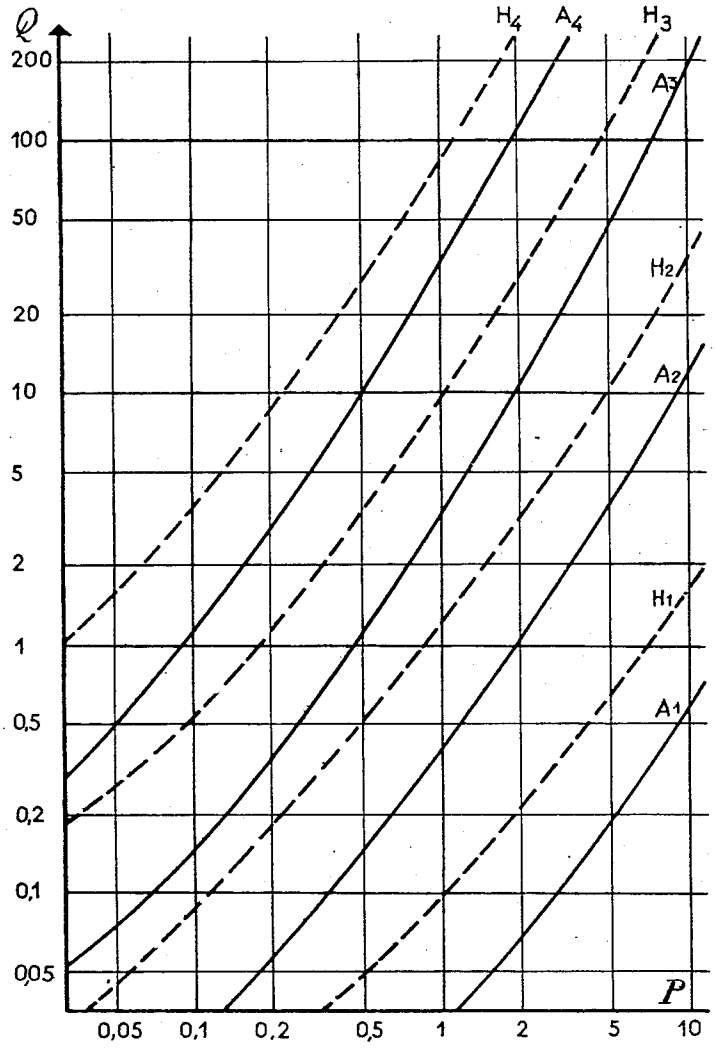

Q
200
100
50
20
10
5
2
1
0,5
0,2
0,1
0,05
H4
A4
H3
A3
H2
A2
H1
A1
0,05
0,1
0,2
0,5
1
2
5
10
P

Fig. 4

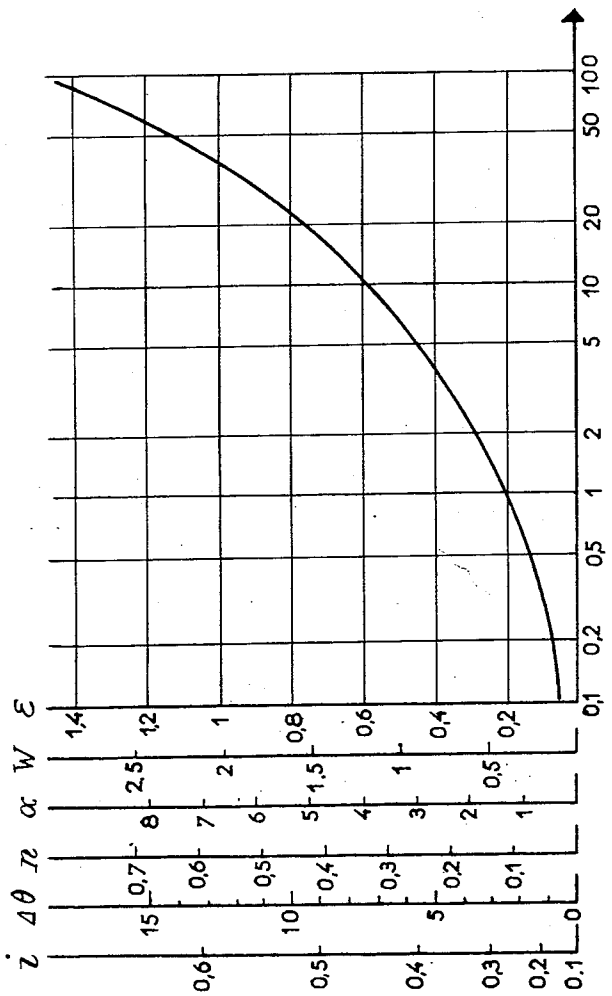

100
50
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5
2
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W
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α
8
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6
5
4
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π
0,7
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0,5
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0,3
0,2
0,1
Δθ
15
10
5
0
i
0,6
0,5
0,4
0,3
0,2
0,1

Fig. 5

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VALVES FOR CONTROLLING GAS STREAMS FLOWING AT VERY LOW FLOW RATES

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The present invention relates to valves for controlling gas streams flowing at very low rates, for instance in order to supply ions sources with the desired amount of gas or to measure the rate of pumping of a molecular vacuum pump.

The chief object of our invention is to provide a valve of this type which is better adapted to meet the requirements of practice than those used at the present time.

According to our invention, such a valve includes an elongated hollow body comprising a transverse partition provided with a hole of circular cross section forming a valve seat, an elongated member mounted in said body, one end of said member having a conical end to form a valve needle adapted to cooperate with said valve seat, the periphery of said member at one end thereof being rigid with said body, the remainder of said member being mounted with a transverse clearance between it and the inner wall of said body, said member being provided with a central longitudinal conduit extending from said second mentioned end of said member and in communication with the clearance space between said member and the inner wall of said body, and mechanical means for adjustably compressing said body in the longitudinal direction thereof whereby the position of said conical end can be adjusted with respect to said hole.

According to a preferred embodiment of our invention, this valve further includes electric means for heating at least a portion of said body in an adjustable manner, whereby the distance between the valve needle and the valve seat can be controlled in a very accurate manner.

Preferred embodiments of our invention will be hereinafter described with reference to the accompanying drawings, which are given merely by way of example, and in which:

FIG. 1 is an axial sectional view of a valve made according to our invention.

FIG. 2 is a perspective view of the same valve.

FIGS. 3 to 5 are curves illustrating the result obtained with our valve.

The valve shown by the drawings includes an elongated member 1 mounted coaxially in a tubular body 3 to which it is welded at 2. These elements are made either both of the same material or respectively of two materials having the same coefficient of thermal expansion, such in particular as metals or alloys which are resiliently deformable and good conductors of heat.

Member 1 is provided with a central longitudinal conduit 4 one end of which forms a nozzle 5. This central conduit 4 communicates through two side conduits 6 and 7 with the inside of body 3.

Body 3 includes a transverse partition or diaphragm provided with a hole of circular cross section forming a valve seat 9. The pointed end 21 of member 1 forms a needle adapted to cooperate with said valve seat 9. The portion of member 1 adjacent to said needle is of smaller cross section than body 3 so that a clearance space is left between member 1 and the inner wall of body 3. Thus, the space 8 into which transverse conduits 6 and 7 open is in permanent communication with the valve seat 9.

Body 3 is caught at its ends between the two end walls

11 and 12 of a kind of cage 13 made of a material having the same coefficient of thermal expansion as the above described elements. This cage 13 is provided at one end with an adjusting screw 14, screwed in the end wall 12 and bearing against the end of body 3.

The side walls of cage 13, which are constituted by two parallel metal plates or strips are relatively thin, as visible at 15, 16, 17 and 18, so as to be easily deformable. Their central portions are surrounded by a kind of belt 19 in which is screwed a screw 20 extending at right angles to body 3 and the free end of which bears against said body.

It will be understood that rotation of screws 14 and 20 (or of one of them) causes a variation of the length of body 3 (made of a sufficiently resilient material). Such a variation of the length of body 3 displaces valve needle 21 with respect to valve seat 9, thus making it possible to control the communication between nozzle 5 and another nozzle 10 provided at the end of body 3 on the other side of valve seat 9 from member 1. When the valve needle is not applied upon its seat, the communication between nozzles 5 and 10 takes place through conduit 4, conduits 6 and 7, space 8 and the hole in valve seat 9.

Screw 14 may serve to obtain a rough positioning of the valve needle and screw 20 a more accurate displacement thereof. One turn of screw 14 imparts for instance to the valve needle a displacement which is several tens of times greater than that resulting from one turn of screw 20.

According to a preferred construction as illustrated by the drawings, there is provided, around body 3, a resistant wire 22 insulated in suitable manner so as to permit of heating said body by passing an electric current through said wire. In order to obtain a better temperature gradient, this winding is located close to the valve seat 9.

It is then possible to modify the position of needle 21 with respect to valve seat 9 by modifying the length of body 3 by thermal expansion thereof. The length of member 1 (which is also made of a material which is a good conductor of heat) is also modified by this heating but as the heating winding 22 is located in the vicinity of valve seat 9, a temperature gradient proportional to the thermal flux is produced in the structure from the part of body 3 surrounded by winding 22 to weld 2 and thence to valve needle 21 so that valve needle 21 is at the lowest temperature.

Member 1 is therefore less expanded than body 3 so that valve 21 is moved away from the valve seat 9, thus opening the valve.

On the contrary, when heating is stopped, the temperature becomes quickly uniform in the whole structure and valve needle 21 is applied on seat 9, thus closing the communication between nozzles 5 and 10.

Care must be taken to prevent valve needle 21 from being applied against valve seat with too great a force which might injure said valve seat. Adjusting screws 14 and 20 may be used to set the apparatus so that this risk is avoided.

According to a preferred embodiment, body 3 and member 1 are made of the same kind of brass. Only the end 21 of member 1 is made of hardened tungsten. This point, which is soldered by means of silver on member 1 serves to shape the valve seat 9 as it will be now explained.

The tungsten point having been rectified, the orifice which is to form valve seat 9 is made manually by rotating member 1 in body 3, in the dry state and under a moderate pressure exerted axially on said member. The operation is observed with a binocular magnifying

glass until the point of **21** is visible on the other side of the transverse partition of body 3. The orifice is then enlarged by rotation of member **1** under very low pressure and with the help of abrasive materials known under the names of "English red" and "chromium green."

The thickness of the partition or diaphragm in which valve seat **9** is provided must be close to 200 microns when the valve elements are made of brass as above mentioned. If the thickness is below 100 microns, the diaphragm is too resilient and moves together with the valve needle. Furthermore, it is then too weak and may be broken under the effect of a shock or of a sudden cooling. If the thickness is above 300 microns, the formation of the hole becomes too difficult and the diaphragm is no longer resilient enough.

The length of the valve is 80 millimeters and its external diameter 8 millimeters. With such dimensions of the valve, the diametral play between the valve seat and the valve needle is at most a fraction of a micron, which makes it difficult to center the needle exactly with respect to the valve seat. Therefore, actually, needle **21** is in contact with seat **9** along a generatrix. The passage through which flows the gas streams is therefore of complex shape, but it may be assumed that the flow rate will be determined by one of the following formulas:

$$Q=K_1 P \epsilon^2 \frac{d}{e}$$

under molecular flow conditions, and:

$$Q=K_2 P^2 \epsilon^3 \frac{d}{e}$$

under laminar flow conditions.

In these formulas:

Q is the flow rate by weight,
P the pressure upstream of the valve seat,
ϵ the diametral play between the seat and the needle,
d the mean diameter of the orifice,
e the thickness of the diaphragm;
K_1 and K_2 being constants.

The curves of FIG. 3 show the influence of the diametral play ϵ (plotted in ordinates in microns with a logarithmic scale) on the flow rate Q (potted in abscissas in cubic centimeters per hour with a logarithmic scale) of air or hydrogen streams flowing through various valves made according to the present invention.

Curve I relates to such a valve subjected to an air pressure of 1 atmosphere, curves II and II' to another valve subjected respectively to an air pressure of 1 atmosphere and a hydrogen pressure of 1 atmosphere, curve III to still another valve subjected to a hydrogen pressure of 2 atmospheres and curve IV to a fourth valve subjected to a hydrogen pressure of 4 atmospheres.

It will be seen that the curves are straight lines having a slope close to 0.5, which indicates a molecular flow.

The curves of FIG. 4 show how the flow rate Q (plotted in ordinates in cubic centimeters per hour with a logarithmic scale) varies as a function of the pressure P (plotted in abscissas in atmospheres with a logarithmic scale) for a given valve and for different values of the diametral clearance ϵ, the curves in dotted lines (H) corresponding to the case where the gas is hydrogen and those in solid lines (A) to the case where said gas is air.

The diametral play ϵ was:

0.125 micron for curves A_1 and H_1,
0.4 micron for curves A_2 and H_2,
1 micron for curves A_3 and H_3, and
2.4 microns for curves A_4 and H_4.

Finally, the scales of FIG. 5, made for a given valve, show how the various adjustment parameters influence the flow rate Q (plotted in abscissas in cubic centimeters per hour with a logarithmic scole). The curve of this figure was made with a valve corresponding to the curve II of FIG. 3 and a hydrogen pressure of 4 atmospheres.

The various parameters that were used were successively (from the left to the right on FIG. 5):

The intensity i of the current flowing through winding **22** in amperes (logarithmic scale);

The temperature difference $\Delta\theta$ between the portion of body 3 close to the valve seat and valve needle **21**, in centigrade degrees;

The number of turns n by which screw **20** was unscrewed;

The angle α of rotation of the adjustment screw **14** in degrees;

The heating power W in watts, with the valve housed in its cage, and

The diametral play ϵ in microns.

In the closed position, the valve practically eliminates any leakage.

The apparatus does not require much force to operate it; in particular it calls only for a low value torque (averaging 200 grams-centimeters applied on screw **20**) and/or a very low electric power of some tenth of a watt (it reaches a value of 3 watts only for a flow rate of 100 cubic centimeters per hour as indicated by FIG. 5).

What we claim is:

1. A valve for controlling the flow of a gas stream which comprises, in combination, a valve housing in form of a stiff straight-walled tube including a transverse partiton provided with a hole of circular cross section forming a valve seat, an elongated valve body inside said tube rigidly joined at one end to the inside wall of said tube, the other end of said body forming a valve needle cooperating with said valve seat, said other end being mounted with a clearance space between it and the inner wall of the tube, said valve body being provided with a central longitudinal conduit communicating with said clearance space and extending therefrom to said first named end, and means actuating the valve body by acting on the valve housing only, said valve actuating means being screw means comprising an annular member coaxial with said tube and directly abutting the outside only of said tube to compress and extend the same in the longitudinal direction, thereby producing indirectly displacement of the valve body and adjustment of the valve opening.

2. The valve as claimed in claim 1 wherein said annular member is rotatable with respect to said tube.

3. A valve for controlling the flow of a gas stream which comprises, in combination, an elongated hollow body composed of a thermal expansive material, said body including a transverse partition provided with a hole of circular cross section forming a valve seat, an elongated member mounted in said body, one end of said member having a conical end to form a valve needle adapted to cooperate with said valve seat, the periphery of said member at the other end thereof being rigid with said body, the remainder of said member being mounted with a transverse clearance between it and the inner wall of said body, said member being provided with a central longitudinal conduit extending from said second mentioned end thereof and in communication with the clearance space between said member and the inner wall of said body, mechanical means for adjustably compressing said body in the longitudinal direction thereof whereby the positon of said conical end can be adjusted with respect to said hole and electric heating means mounted on the outer wall of said body close to said partition.

4. A valve according to claim 1 in which said means for adjustably compressing said tube include a cage mounted on said tube, said cage having two end walls transverse to the longitudinal direction of said tube, a screw parallel to said longitudinal direction screwed in one of said end walls and bearing against one end of said

tube, the other end wall engaging said tube at the other end thereof to prevent displacement of said last mentioned end when said screw is turned to push said tube toward said second mentioned end wall.

5. A valve according to claim 1 in which said means for adjustably compressing said tube include a cage mounted on said tube, said cage having two end walls transverse to the longitudinal direction of said tube, said end walls engaging said tube so as to compress it longitudinally when the distance between them is reduced, said cage further including two opposed longitudinal walls extending between said end walls, a belt transverse to said direction extending around said longitudinal walls and bearing against one of them, and a screw screwed in said belt and having its point applied against the other of said longitudinal walls, whereby rotation of said screw causes said longitudinal walls to be bent toward each other, thus urging said transverse walls toward each other.

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