

[54] **ELECTRO-PNEUMATIC DEVICE**

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[58] Field of Search 251/14, 30, 130, 139, 141; 137/625.64, 625.65

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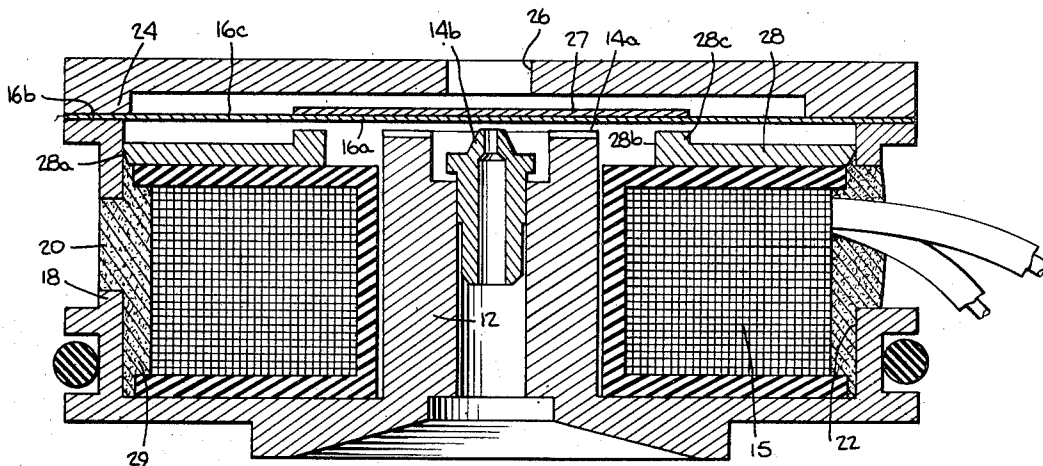
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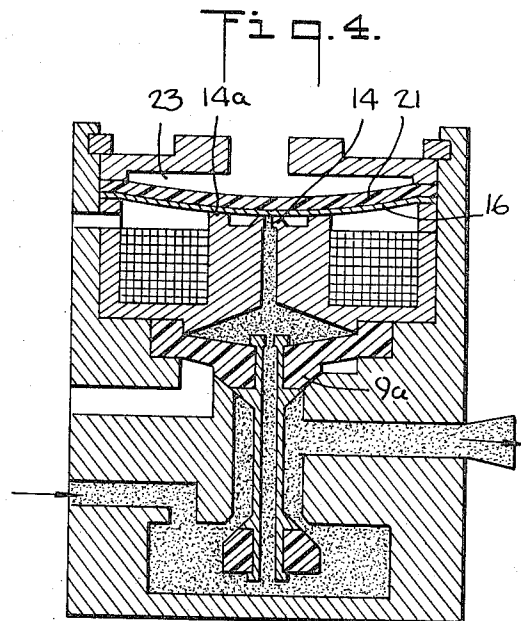
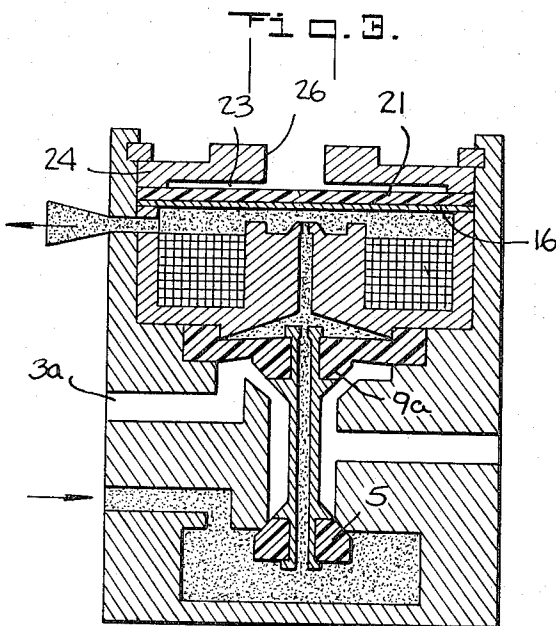
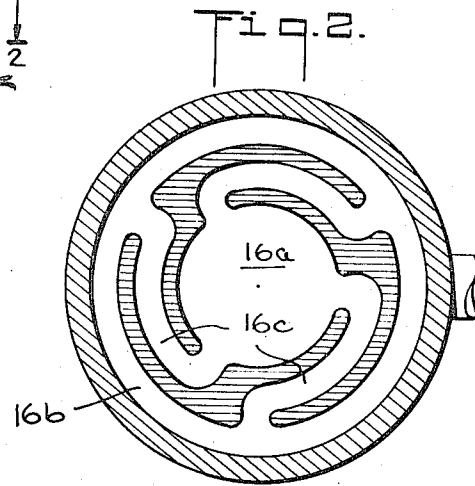
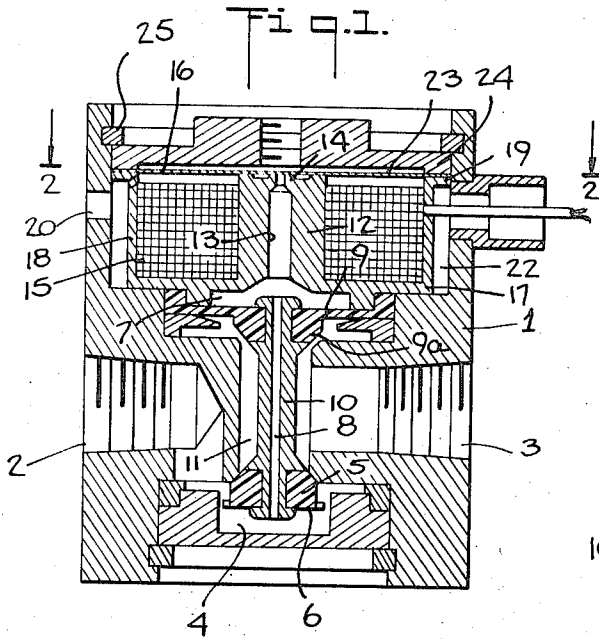
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ABSTRACT

An air valve or other control device actuated by control of escaping air has a magnetizable shell forming a core, a bottom wall and a cylindrical side wall; the core having a passage for the escaping air, terminating with a nozzle and being surrounded by a solenoid. A metal armature disk of great flexibility has a peripheral portion rigidly engaging the end of the shell wall and a portion which is attracted to the core to close the nozzle when the solenoid is energized. Optionally, a non-magnetic diaphragm covers the armature and is enclosed by a chamber having an inlet for signal air under light pressure such as used by fluidic circuitry. Therefore, the device may be actuated by either a fluidic or electrical signal.

11 Claims, 5 Drawing Figures





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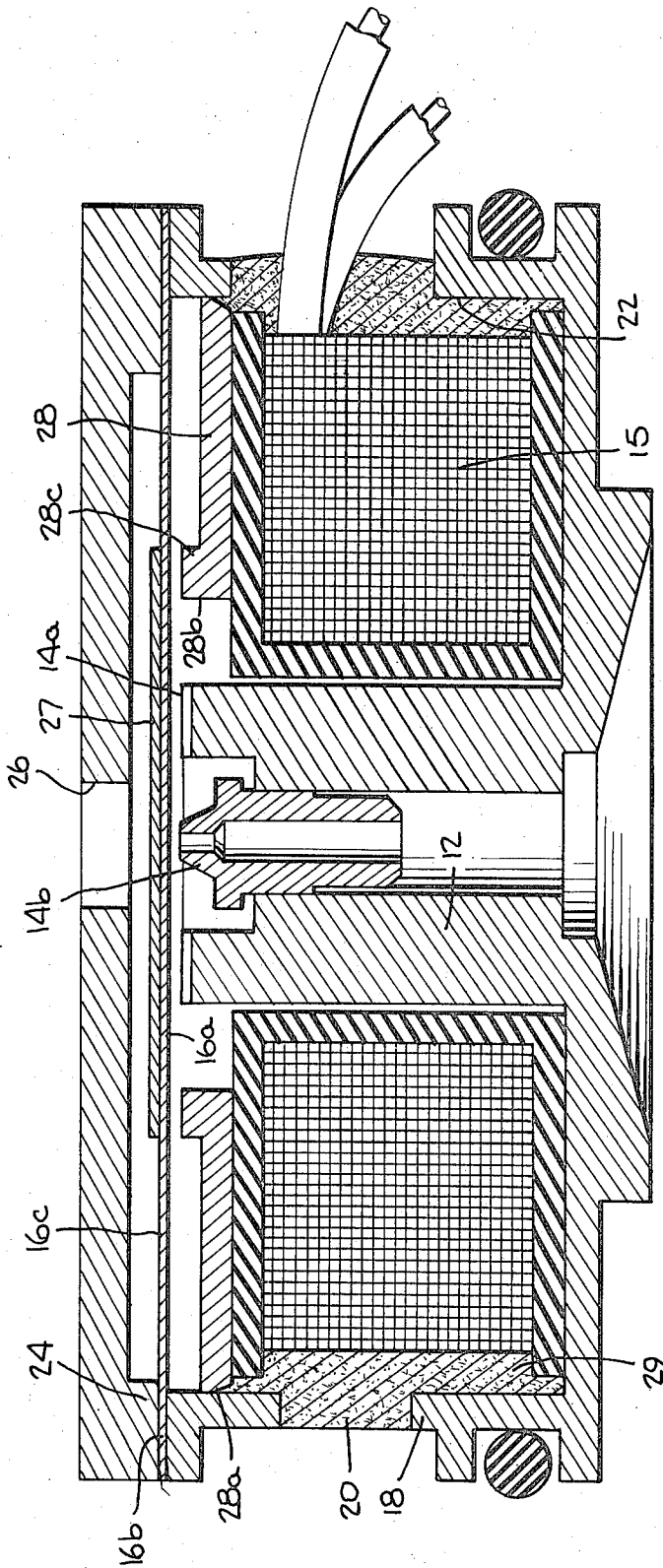
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Fig. 5.



ELECTRO-PNEUMATIC DEVICE

This application is a continuation-in-part of application Ser. No. 186,247, now abandoned, filed Oct. 4, 1971 in the name of the present applicant.

This invention relates to an electro-pneumatic control device which may be actuated by fluidic or electrical signals.

It is particularly concerned with improving air valves of the type actuated by control of escaping, or bleeding, air, one object being to effect this control electrically by using an electrical signal of very small power while obtaining extremely rapid operation and high frequency response of the control operation. Another object is to attain the just stated object while providing for alternate operation of the valve by a pneumatic signal of the nature used by fluidic circuitry.

A specific example of the invention is illustrated by the accompanying drawings in which:

FIG. 1 is a vertical section;

FIG. 2 is a cross section taken on the line 2—2 in FIG. 1;

FIGS. 3 and 4 are schematic representations of the FIG. 1 vertical section illustrating the operational phases; and

FIG. 5 is a vertical section showing a modification.

In this specific example a cylindrical body 1 has an inlet port 2 and an outlet port 3 and contains the valving mechanism.

This mechanism includes a first air chamber 4 with which the inlet 2 connects so that this chamber receives working pressure air introduced to the inlet by any suitable connection. This chamber also connects with the outlet 3 which delivers the working pressure air through a suitable connection for use as exemplified by operating a pneumatic power device. The connection between the first air chamber 4 and the outlet 3 is under the control of a reciprocating poppet valve 5 having a surface 6 receiving the pressure in the first air chamber 4 over a predetermined area fixed by the diameter of the surface 6. The air pressure in the first air chamber 4 acts against this surface 6 to keep the poppet valve 5 normally closed.

The mechanism further includes a second air chamber 7 and a passage means 8 for interconnecting the chambers so that this second chamber receives the air pressure in the first chamber 4. Reciprocating means in the form of a flexible non-metallic diaphragm 9 receives the air pressure in the second chamber 7 over a predetermined area larger than the area provided by the surface 6 of the poppet valve 5 and operates through a stem 10 to open the poppet valve 5. In other words, the diaphragm 9 has a larger piston area than the surface 6 of the poppet valve 5 so that the air pressure in the chamber 7 can force the poppet valve 5 open. The stem 10 has a longitudinal passage forming the previously mentioned means 8. To keep the poppet valve 5 normally closed under the air pressure acting on its surface 6, the chamber 7 is provided with a controllable air escape or bleeding means. While air is escaping from this chamber 7, the pressure in this chamber cannot develop to a degree forcing the poppet valve 5 to open.

This valving mechanism is described briefly because it is a part of the prior art and should be familiar to anyone familiar with such small control valves. The prior

art valves have used both pneumatic and electrical means for controlling the escaping air.

The diaphragm 9 may also actuate a poppet valve 9a which closes when the poppet valve 5 opens and vice versa, permitting the outlet 3 to be connected to an exhaust port 3a when desirable. In FIG. 1 this port 3a is connected with the space 11 surrounding the valve 9a and cannot be seen, but it is represented in schematic FIGS. 3 and 4.

According to the present invention, a magnetizable core 12 has an axial passage 13 connecting at one end with the second chamber 7 and having a magnetizable flow-restrictive nozzle 14 at its other end through which the air escapes from this chamber 7. An electrical solenoid 15 encircles the core 12 and a magnetizable armature disk 16 is positioned substantially in a plane at right angles to the nozzle and core and spaced a small distance therefrom. This armature disk has a central portion for engaging and substantially closing the nozzle against the escape of air therefrom when the solenoid 15 is energized, thus permitting pressure to build in the chamber 7.

The core 12 is formed by a cylindrical magnetizable shell, the core being cylindrical and centrally positioned and at the core's end remote from the armature disk, the shell has a bottom or end wall 17 surrounding the core and a cylindrical side wall 18 extending to an edge 19 contacting the periphery of the armature disk 16 so that when the solenoid 15 is energized a magnetic circuit is formed which is closed when the armature disk portion engages the nozzle 14. The parts 12, 17, 18 and 19 are preferably made integral with each other as is the nozzle 14, and the material used should not permanently retain magnetism when the solenoid is de-energized.

The armature disk 16, as shown by FIG. 2, has a flat central portion 16a for engaging and closing the nozzle 14, a flat peripheral portion 16b for contacting the wall's edge 19, these portions being radially spaced from each other, and flat arms 16c which are all curved to the same radius about the disk's center and interconnect the portions 16a and 16b. The disk is circular and is completely flat with all of the mentioned portions and arms in a single flat plane. The arms 16c are in the form of flat strip-like members. The disk 16 is formed from a single flat piece of extremely thin metal in the order of 0.006 inch thickness. It is not stamped from sheet metal of this thickness because this would interfere with complete flatness and induce strain in the crystalline microstructure. Therefore, magnetizable sheet metal is used in the order of the thickness mentioned and which is initially free from strain, the metal being removed as required to form the portions and arms previously described, by etching away the metal so that the armature disk is correspondingly free from strain with its flatness undistorted. The spacing between the outer end of the nozzle 14 and the armature disk 16 is very small, being in the order of 0.005 inch spacing. Because of the small thickness of the armature disk metal and the long arms 16c the spring rate of the portion 16a is very low. The armature metal should also be incapable of permanently retaining magnetism.

With the solenoid 15 de-energized, the air escapes from the chamber 7 through the nozzle 14 and to the atmosphere by way of porting 20. Because of the shell construction and the almost completely closed magnetic flux path due to the engagement of the armature

disk peripheral portion 16b with the wall's edge 19, this edge actually being a flange, very little electrical power is required to cause the central portion 16a of the armature disk to engage and close the nozzle 14. When this occurs, the air pressure in the chamber 7 builds up extremely rapidly and switches the poppet valve 5 from its closed to its open position, the poppet valve 9a simultaneously closing. A maximum of 0.5 watts of electrical energy is all that is required to actuate the solenoid to effect this switching at the solenoid's rated voltage. The switching time is extremely short because of the very low mass of the moving portions of the armature disk and their very short stroke. High frequency response is obtained; there are no sliding parts and no wear will result from repeated operation. When the solenoid is energized, the very small air gap in the magnet flux circuit is closed so that the holding power requirement on the part of the solenoid is thereafter very small.

To provide for pneumatic operation, a thin non-metallic diaphragm 21 is superimposed on the armature disk 16 on its side opposite to the core 12. FIG. 1 is drawn on an enlarged but closely proportional scale to the actual device and FIGS. 3 and 4 are provided schematically to show the disk 16 and the diaphragm 21, which cannot be accurately represented in FIG. 1. The cylindrical body 1 has a cylindrical recess 22 in which the solenoid and its magnetic structure are located with the circular disk 16 and the diaphragm 21 resting on the flange 19 of the magnetic structure and slidably removable from the recess 22. To retain these two parts in position and to form an air chamber 23, the body has a circular end wall having a peripheral flange 24 which holds the disk and diaphragm in position because this end wall is retained by a snap ring 25 in the end of the body's recess 22. The chamber 23 is extremely small and is provided with an inlet port 26 to which a fluidic signal may be applied to operate the valve as an alternate to electrical operation. Because of the flexible construction of the armature disk and diaphragm, a very sensitive pneumatic operation is possible for the applicable reasons previously explained.

To permit the use of the extremely sensitive armature disk, the core 12 has a raised wall 14a surrounding the nozzle 14, this wall 14a supporting the disk portion 16a and avoiding what would otherwise be a substantially point contact with this portion 16a by the nozzle 14. The wall 14a assists in providing a much better magnetic flux path than would be possible if the nozzle 14a projected from a flat ended core or pole piece. In the latter instance the nozzle would of necessity maintain a space between the armature disk portion 16a and the end of the core or pole piece.

In addition to the exaggerated scale made possible by the schematic representations of FIGS. 3 and 4, they show the two operational phases. In FIG. 3 the valve mechanism is closed to working pressure because the solenoid is de-energized and there is no fluid signal applied to the port 26. In FIG. 4 the armature disk is closing the nozzle 14 because the solenoid is energized or a pneumatic signal is received, the fluid in the chamber 7 from the chamber 4 in this case being received by the diaphragm 9 of larger piston area than that of the surface 6 of the poppet valve 5, the latter accordingly being switched to its open position. Because of the thin non-metallic diaphragm 21 which renders the armature disk impermeable to air, a fluid signal applied to the

port 26 also switches the valving mechanism to open position.

Throughout the foregoing, reference has been made to air because it is usually used in fluidic circuitry and as power to work pneumatic devices. However, any gas can be accommodated by the invention.

It is to be understood that the body 1 and all of the parts referred to herein are cylindrical and positioned concentrically with respect to each other for a balanced operation. This applies to the magnetic structure, the solenoid, the armature disk and diaphragm, and the chamber 23 and its port 26. For convenience of manufacture and appearance, the body 1 is cylindrical as can be seen from FIG. 2; and, of course, the recess 22 is also cylindrical.

In the modification shown by FIG. 5, the diaphragm 21 is eliminated as it would be when pneumatic operation is not desired and the device is to be operated by an electric signal only. In addition, the armature disk nozzle closing portion 16a is thicker than the elastically flexible annular portion formed by the arms 16c. By making this portion 16a thicker, there is a stronger flux path adjacent to the core 12. Such thickening is effected by laminating a magnetizable disk 27 to the nozzle-closing disk portion 16a. This does not interfere with the desired great flexibility because the disk 27 has a diameter substantially the same as the diameter of the flat nozzle-closing portion 16a of the armature disk. This disk 27, therefore, does not extend so as to interfere with the flexibility of the arms 16c.

In addition, in this modification of FIG. 5 a magnetizable annular plate 28 covers the solenoid 15. This plate has an outer periphery 28a contacting the inside of the cylindrical side wall 18 of the magnetizable shell, and an inner periphery 28b adjacent to but radially spaced from the core 12 and which is overlapped by the armature disk's thickened nozzle-closing portion. The plate 28 has a flange 28c forming its inner periphery 28b and which extends upwardly so as to be flush with the raised wall 14a of the core 12, the nozzle 14a having its orifice positioned very slightly above this level as before.

With the above arrangement when the solenoid 15 is energized, a magnetic circuit is formed from the wall 18 through the plate 28, which covers the solenoid, and through this plate's flange 28c and the thickened nozzle-closing portion of the armature disk to the core wall 14a. In other words, the magnetic circuit is largely shunted around the very thin flexible annular portion formed by the disk's curved arms 16c, thus providing a flux path having the capacity for a much higher or greater flux density so that the solenoid 15 requires even less current to hold the armature disk in its closed position. The chance for the armature disk to become magnetically saturated is reduced if not eliminated. The armature disk, of course, carries some of the flux in the same way that it did before in the case of the construction shown by FIG. 1.

The venting port 20 of the construction described before is in this instance not required since there is a flow path through the disk's arms 16c and the port 26, because the diaphragm 21 is not used. The solenoid cover plate 28 may be retained by being press-fitted in the wall 18, the armature disk's periphery being rigidly positioned as described before. If desired, the port 20 and the opening through which the solenoid conductors extend may act as a convenient way to fill the recess 22

with potting compound 29, the recess being upwardly closed by the plate 28.

In this modification the nozzle 14b is shown as an insert in the core 12 so that it may be made of non-magnetic material if desired. This insert concept may be used in the construction shown by FIG. 1.

It can be seen that in all of the constructions shown a substantially closed magnetic circuit is formed when the solenoid 15 is energized. In the construction of FIGS. 1 through 4 the circuit is through the arms 16c of the armature disk; in the form shown by FIG. 5 the flux path is greatly increased by the thick disk 28 and the armature disk thickening obtained by the disk 27 laminated on the nozzle-closing portion 16a of the armature disk.

What is claimed is:

1. An electro-pneumatic control device including a first air chamber having an inlet for air under pressure and an outlet for this air, a reciprocating valve for said outlet, reciprocating means for receiving the pressure in said chamber over a predetermined area for closing said valve by this pressure, a second air chamber, means for interconnecting said chambers so that said second chamber receives the air pressure in said first chamber, reciprocating means for receiving the air pressure in said second chamber over a predetermined area larger than said first area for opening said valve by this pressure, and a controllable air escape means for said second chamber; wherein the improvement comprises said air escape means including a magnetizable core having an axial passage connecting at one end with said second chamber and having a nozzle at its outer end through which the air escapes from this second chamber. an electric solenoid encircling said core, and a magnetizable armature disk positioned substantially in a plane at right angles to said nozzle and core and spaced a small distance therefrom and having a nozzle-restricting portion movable towards said nozzle a distance restricting the escape of air therefrom when said solenoid is energized, said disk having a peripheral portion which is rigidly positioned and an elastically flexible annular portion between this peripheral portion and said nozzle-restricting portion; said core being formed by round magnetizable shell having said core centrally positioned and at the core's end remote from said armature disk having an end wall surrounding the core and a round side wall extending to and contacting said peripheral portion of said armature disk so that when said solenoid is energized a magnetic circuit is formed which is substantially closed when said armature disk nozzle-restricting portion is moved for at least the second said distance towards said nozzle.

2. The device of claim 1 in which the armature disk's said nozzle-restricting portion is thicker than its said annular portion to provide an increase in the magnetic flux adjacent to said core of said magnetic circuit.

3. The device of claim 1 in which a magnetizable annular plate has an outer periphery contacting the shell's said side wall and an inner periphery adjacent to but radially spaced from said core adjacent to said nozzle, said inner periphery being overlapped by the disk's said nozzle-restricting portion, said plate being thicker than said annular portion.

4. The device of claim 1 in which the armature disk's

said nozzle-restricting portion is a flat round central portion, said peripheral portion is flat and contacts said wall's end edge, said portions being radially spaced from each other, and said flexible annular portion is formed by flat arms all curved to the same radius about said disk's center and interconnecting said nozzle-restricting and peripheral portions, said disk being flat.

5. The device of claim 4 in which said disk is formed from a single flat piece of extremely thin metal in the order of 0.006 inch thick with its metal removed by etching to form said portions and arms so that the flatness of the metal is unaffected.

6. The device of claim 4 in which the armature disk's said nozzle-restricting portion is thicker than its said annular portion to provide an increase in the magnetic flux of said magnetic circuit adjacent to said nozzle and core.

7. The device of claim 4 in which a magnetizable annular plate has an outer periphery contacting the shell's said side wall and an inner periphery adjacent to but radially spaced from said core adjacent to said nozzle, said inner periphery being overlapped by the disk's said nozzle-restricting portion, said plate being thicker than said annular portion.

8. An air valve of the type actuated by control of escaping air and comprising a cylindrical body containing valving mechanism and having inlet and outlet air ports, said body containing a cylindrical magnetizable shell concentrically forming a core, an annular flat bottom wall and a cylindrical side wall extending in the direction of the core and the latter concentrically having a passage for the escaping air and terminating with a concentric nozzle, said body having a cylindrical wall extending beyond the end edge of said magnetizable side wall and an end wall having an air inlet, a superimposed non-metallic diaphragm and a thin circular metal armature disk between said body's end wall and the ends of said core and side wall of said shell with said diaphragm on the side facing this shell's said end wall and close thereto and with said disk spaced very close to said nozzle and contacting the end of the side wall of said shell, and an electric solenoid in said shell encircling said core.

9. The device of claim 8 in which said armature disk has a flat round central portion for engaging said nozzle, a flat peripheral portion for contacting said wall's edge, said portion being radially spaced from each other, and flat arms all curved to the same radius about said disk's center and interconnecting said portions, said disk being flat with all of said portions and arms in a single flat plane.

10. The device of claim 9 in which said disk is formed from a single flat piece of extremely thin metal in the order of 0.006 inch thick with its metal removed by etching to form said portions and arms so that the flatness of the metal is unaffected.

11. The device of claim 10 in which said diaphragm and disk have peripheral edges slidably fitting the inside of said body's cylindrical wall and the latter's said end wall is removable and holds said diaphragm and disk by their peripheries against the end edge of said shell's side wall.

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