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3,202,885

ROTARY SOLENOID CONTROL DEVICE

Original Filed Oct. 24, 1957

3 Sheets-Sheet 1

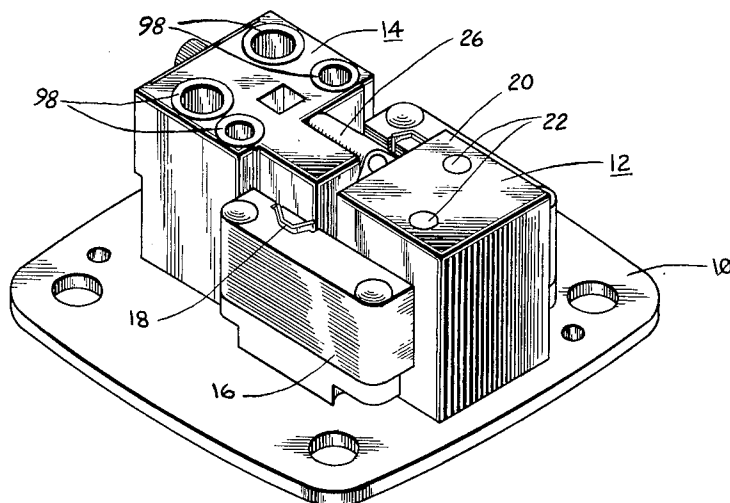


FIG 1

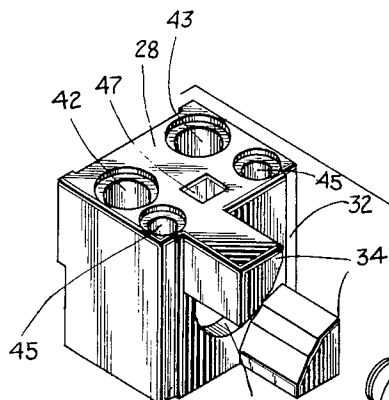


FIG 2

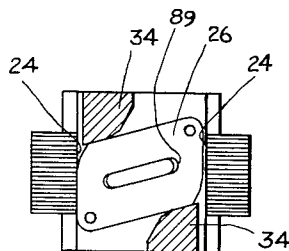


FIG 3

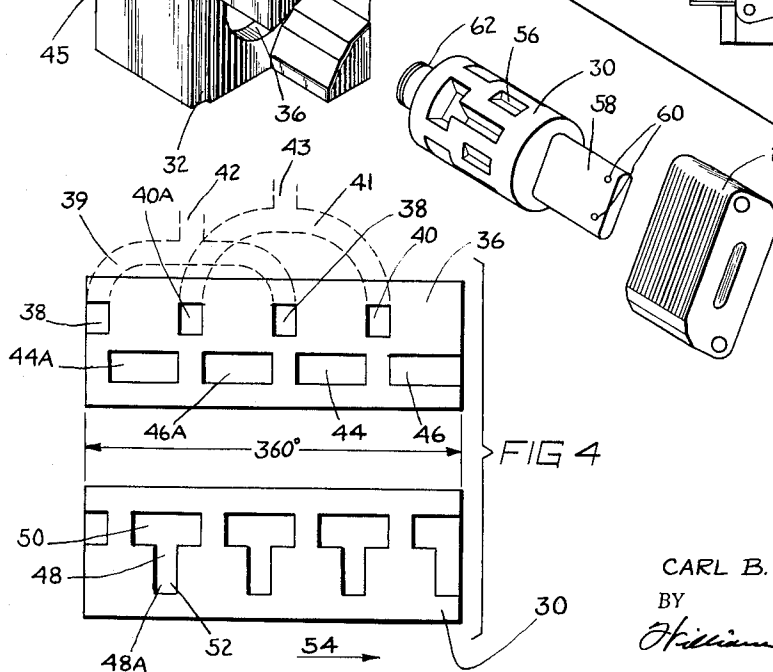


FIG 4

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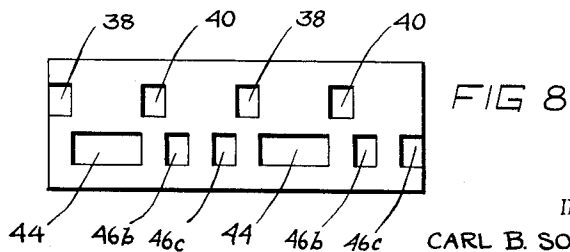
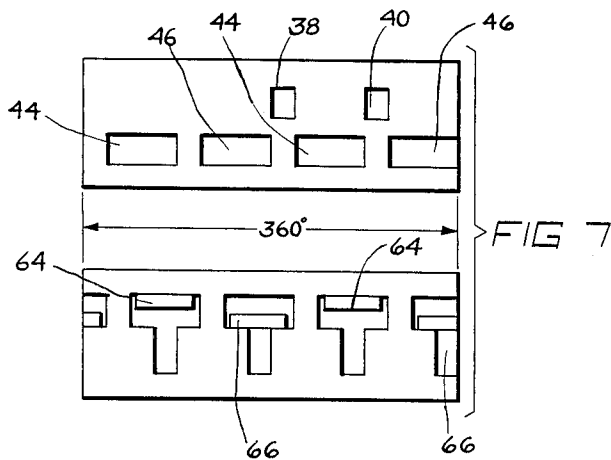
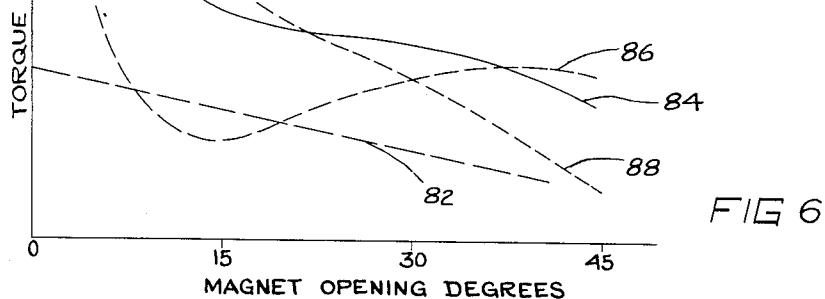
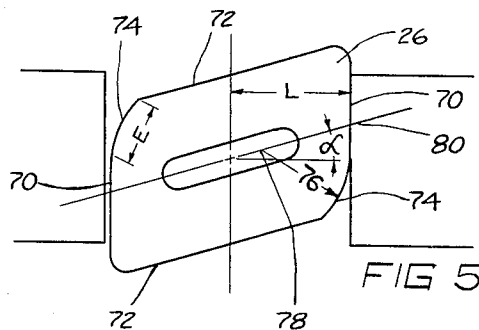
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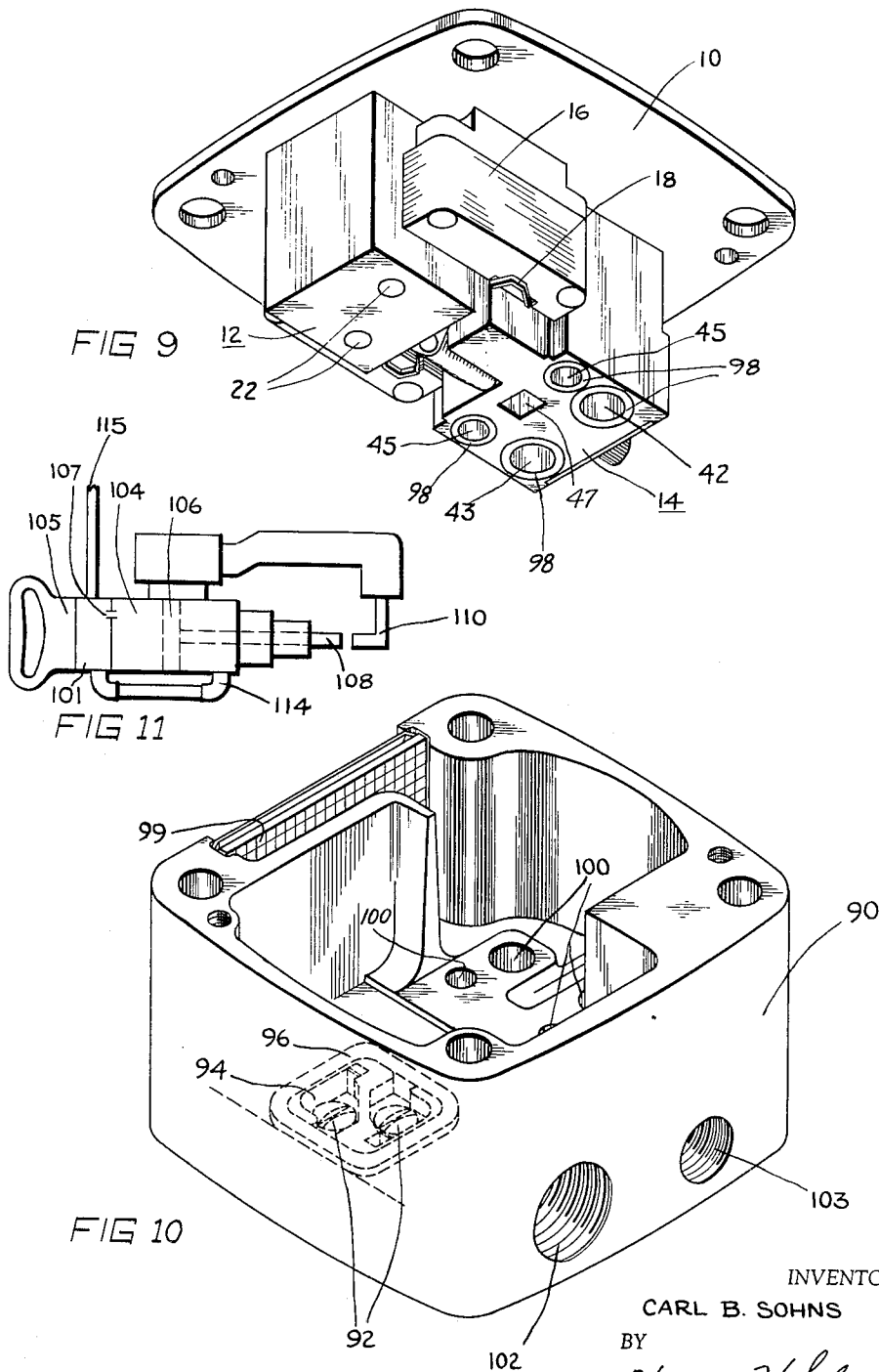
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ROTARY SOLENOID CONTROL DEVICE

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3 Sheets-Sheet 3



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ROTARY SOLENOID CONTROL DEVICE

Carl B. Sohns, Whitefish Bay, Wis., assignor to Square D Company, Park Ridge, Ill., a corporation of Michigan
Original application Oct. 24, 1957, Ser. No. 692,090, now Patent No. 3,023,780, dated Mar. 6, 1962. Divided and this application May 22, 1961, Ser. No. 111,790
6 Claims. (Cl. 317-165)

This invention relates to control devices and is more particularly concerned with the constructional details of a rotary solenoid which may be used with a balanced rotary valve assembly which is especially adapted to be used with pneumatic systems and in general is directed to miniaturized to a high capacity completely balanced, durable and dependable four way valve which may be operated by standard A.C. or D.C. voltages with low power demand and is a divisional application of application Serial Number 692,090, filed October 24, 1957 which has matured into Patent No. 3,023,780.

The rotary valve and solenoid according to the present invention incorporates the above features and is particularly suitable for use on portable devices, such as portable welding guns, wherein the miniature size and weight thereof permits the mounting either on the head or side of the welder. When the control valve is mounted in close proximity to the welder which it is to control, desirable results are obtained. Among the advantages are the saving in compressed air and an increase in speed of operation of the device. This is accomplished by reducing the useless air which is wasted in each cycle by merely filling and emptying the connecting hoses between the valve and the device to be controlled. The valve according to the present invention is pneumatically balanced and will permanently retain its adjustments and is made up of basically four parts which include the body, the rotor, magnet and armature wherein the rotor and armature are rotated as a unit approximately 45°. The enclosure or housing for the valve is also of novel design in that it will permit the connection of the electrical leads to the valve magnet and the connection of the pneumatic passages to the rotary valve when the two parts of the housing are assembled.

It is an object therefore of the present invention to provide a small, high capacity, completely balanced, durable and dependable rotary valve which can be operated by standard voltages with a low power demand.

A further object of the present invention is to provide a rotary solenoid four way rotary valve assembly of miniature size which can be mounted between the cylinder of a pneumatically operated device, such as a portable welding gun, and the handle which is used to transport the device.

Another object of the present invention is to provide a slideable connection between an armature for a rotary solenoid and its support to permit the armature to move into engagement with either of the pole faces of the electromagnet to reduce armature hum when the electromagnet is energized by A.C. current.

A still further object of the present invention is to provide a slideable connection between an armature for a rotary solenoid and its support to permit the armature to move into engagement with either of the pole faces of an electromagnet and to provide stops so the armature will engage only one pole face and be spaced from the other pole face to reduce armature sticking as caused by residual magnetism when the electromagnet is de-energized.

And still another object of the present invention is to provide the rotor of a rotary valve with a projection that is sized so an armature of a rotary solenoid may move thereon and engage either, but not simultaneously, both

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of the pole faces of the electromagnet of the solenoid when the electromagnet is energized.

In carrying out the above object it is another object of the present invention to provide stops which will limit the travel of the armature so the armature will engage only one of the pole faces of the electromagnet while it is spaced from the other pole face whenever the electromagnet is energized.

Another object of the present invention is to provide the bore of a rotary valve with pairs of intake and exhaust ports which are annularly disposed in the bore and cylinder ports which are annularly disposed in the bore relative to each other and axially displaced relative to the intake and exhaust ports so a rotary valve member which has pairs of T-shaped slots therein may interconnect the intake and exhaust ports and provide a pneumatically balanced valve action.

Another object of the present invention is to provide the armature of a rotary magnet with a predetermined configuration so the torque curve for the magnet will complement the shape of the return spring torque curve to provide the maximum moving force when the magnet is energized or de-energized.

A further object is to utilize substantially flat surfaces on the stationary and movable parts of a rotary solenoid which act as pole faces to make the manufacture thereof practical and economical.

Another object of the present invention is to arrange the stops and pole faces of a rotary magnet assembly so the wear on the pole faces will be compensated for by the wear on the stops for the armature.

A further object of the present invention is to form the housing for a magnet actuated rotary valve into two parts wherein one of the parts includes the terminal connectors for the magnet and the passages for the valve and the other part positions the magnet and valve assembly so electrical connectors to the magnet and pneumatic connections to the valve will be completed when the housing parts are assembled.

A further object of the invention is to provide the armature for a rotary magnet with a shape that is non-rectangular and parallelogrammic, wherein the two shorter sides, which provide the pole surfaces, are oriented 75° to 78° from the other sides and the rounded edge which connects the pole surfaces with the other sides has a radius of curvature equal to $3L/4$, where L equals one-half the minimum distance between the pole surfaces.

Further objects and features of the invention will be readily apparent to those skilled in the art from the specification and appended drawings illustrating a preferred embodiment, in which:

FIG. 1 is a perspective view showing one form of the rotary magnetic valve according to the present invention.

FIG. 2 is an exploded view in perspective showing a valve body, a valve rotor and the magnet armature as used in the rotary magnetic valve in FIG. 1.

FIG. 3 is a cross-sectional view showing the relative positions of the magnet armature relative to the magnet poles and armature stops when the electromagnet in FIG. 1 is energized.

FIG. 4 is a developed or imaginary view showing the porting of the valve body and valve rotor as they would appear if the inside and outside surfaces thereof were rolled out in a flat plane.

FIG. 5 is a cross-sectional view of the armature as used in the rotary magnet valve in FIG. 3.

FIG. 6 shows the type of magnet torque curves which may be obtained by varying the dimensions shown in FIG. 5.

FIG. 7 shows a modification of the porting for the valve body and rotor as in FIG. 4.

FIG. 8 shows another modification of the porting of the valve body as in FIG. 4.

FIG. 9 in perspective shows a modification of the rotary magnetic valve as in FIG. 1, wherein the valve is mounted on one of the parts of a valve housing.

FIG. 10 in perspective shows the mating half of the housing for the rotary valve in FIG. 9.

FIG. 11 is a reduced size diagrammatic view showing the rotary magnet valve according to the present invention as mounted on a welding gun.

Referring now to the drawings, in FIG. 1 particularly, wherein the parts of the rotary magnetic valve are clearly shown, the numeral 10 designates a base which may be a part of the housing for the valve, whereon the electromagnet assembly 12 and the valve assembly 14 are secured. The magnet coil of the electromagnet assembly 12 is more or less of conventional construction and includes the laminated iron parts forming the poles 16 which has a shading coil 18 thereon. The coil winding, not specifically shown, and a portion of the laminated iron parts 16, are enclosed within a molded coil covering 20. The lead ends of the coil winding are connected to the contact buttons 22 which are exposed and preferably disposed to be flush with the top surface of the molded material which provides the coil covering 20. The purpose of this flush mounting will become hereinafter apparent. The faces 24 of poles 16, most clearly seen in FIG. 3, are preferably ground to present a substantially flat pole surface to the armature 26 and are arranged to embrace the armature 26 as shown in FIGS. 1 and 3. The valve assembly 14 includes a valve housing 28 and the rotor 30 therefor as clearly shown in FIG. 2. The valve housing 28, preferably formed of molded cored metallic material, has keyways or slots 32 which are located to aid in the positioning of the electromagnet assembly 12 and the valve assembly 14 when the parts are assembled on the base 10. The housing 28 also has extending lugs 34 which are arranged to provide stops for the armature 26 in a manner which will become hereinafter apparent. The rotor 30 is rotatable within the valve bore 36 and is sized to have a minimum tolerance fit therein. The valve housing 28 is provided with ported openings, the disposition of which will now be explained, and is more clearly shown in FIG. 4 of the drawings. For purposes of illustration, FIG. 4 shows the inner curved surface of the valve bore 36 developed as if it were a flat surface. It will be readily seen that all of the porting in the bore 36 is symmetrical, that is, the pair of cylinder ports 38, as can be seen in the drawing, are located on opposite sides of the bore 36 and are 180° apart. Similarly, the cylinder 40 ports are located on opposite sides of the bore 36 and 180° from one another and 90° from the adjacent ports 38. The ports 38 and 40 are respectively interconnected and manifolded by passages 39 and 41 which are formed in the material of the valve housing 28. The passages 39 and 41 respectively connect with passages 42 and 43 which terminate externally of the valve body 28, as in FIG. 2. If desired, the passages 42 and 43 may be utilized to direct air or any other suitable fluid to opposite sides of a piston to be actuated. The inlet and exhaust ports represented by numerals 44 and 46 respectively, are arranged as shown and spaced between the ports 38 and 40. The inlet ports 44 are disposed on opposite sides of the bore 36 between the ports 38 and 40 while the exhaust ports 46 which are disposed 90° from the inlet ports 44 and diametrically on opposite sides of the bore 36, are disposed between the ports 40 and 38. In this connection it is to be noted that the ports 44 and 46 are axially spaced in the cylinder walls relative to ports 38 and 40 and are respectively manifolded through cored passages in the valve housing 28 to openings 45 and the single opening 47. The porting for the rotor 30 is most clearly seen in FIG. 4 of the drawings. The rotor 30 is provided with four equidistantly spaced T-shaped slots 48 arranged so that the arms 50 of the slots 48 will always be in register with one of the

cylinder ports 38 or 40. The valving which is accomplished by the rotor 30 occurs at leg 52 of the T-shaped slot. The valving action of the rotor 30 may be explained by following the movement of one of the slots 48, which is designated as 48A. When the slot designated as 48A is in the position shown, the arms 50 will be continuously in register with the port 40A. When the rotor 30 is rotated 45° in the direction indicated by arrow 54, the bottom portion 52 will move from its initial register with the inlet port 44A to register with the exhaust port 46A to accomplish the valving action. The rotor 30 as shown in FIG. 2 is also provided with notches 56 which are equidistantly disposed between the adjacent slots 48. The notches 56 are provided to reduce the frictional contact of the rotor with the bore 36. Extending from the rotor is a projection 58 on which the armature 26 is slidably mounted and held there against longitudinal movement by suitable means, not shown, such as a wire which is bent to extend through holes 60. Extending from the opposite end of the rotor 30 is a projection 62 which will permit the anchoring of one end of a torsion return spring, not shown, which has its other end attached to the valve body in some suitable fashion as well known to those skilled in the art.

In FIGS. 7 and 8 of the drawings, alternative designs for the porting for the rotor and valve body are shown. In the embodiment shown in FIG. 7, it is to be noted that the ports 44 and 46 are disposed as previously described for FIG. 4. However, only single cylinder ports 38 and 40 are shown instead of the pair of ports described. When this arrangement is employed the T-shaped slots 48 on opposite sides of the rotor 30 are interconnected by means of passages 64 and 66 so that the pneumatic pressure on opposite sides of the rotor will be equal to provide a pneumatically balanced rotor within the valve body 28. In FIG. 8 of the drawings, the cylinder ports 38 and 40 are arranged as described in the embodiment shown in FIG. 4. In this embodiment, the exhaust ports 46 are divided and provided with a space therebetween so that a separate exhaust port 46b and 46c will be provided for each cylinder port 40 and 38. When this arrangement is employed it is possible to vary the operating speed of the piston, not shown, in either direction if an adjustable restriction is utilized in the exhaust line or if the size of ports 46b and 46c is varied.

The shape of the armature 26 as used with the electromagnet assembly 12 is most clearly shown in FIG. 5 of the drawings. First of all it is to be noted that in cross section the armature has a non-rectangular parallelogrammic shape wherein the two shorter sides 70 which provide the pole surfaces for the armature are at an angle of approximately 75° to 78° relative to the longer sides 72. Further it is to be noted that the rounded leading edges 74 which are disposed between the sides 70 and 72 and extend over the distance E on the drawings, have a radius indicated by the arrow 76 which is approximately $3L/4$, where L equals one-half of the shortest distance between the sides 70. The locus 78 for radius 76 is located on the center line 80 of the armature and is arranged so that the rounded leading edge 74 will be tangent to the flat surface of side 70 at their intersection. The center line 80 of the armature is disposed at an angle α which is 12° to 15° relative to the perpendicular of side 70. It has been found that the angle α and the curvature of the rounded leading edges 74 are important to the success of the present invention for a 45° rotation of the armature 26 relative to the pole faces 24. This can be clearly seen in FIG. 6 wherein the magnet opening degrees is plotted against the torque exerted by the electromagnet. In FIG. 6, the line 82 indicates the torsion curve for the return spring which constantly urges the magnet in a counter clockwise direction, as in FIGS. 3 and 5. The curve 84 represents the torque characteristics which are obtained when the angle α is equal to 15° and the radius 76 is equal to $3L/4$. The curve 86 represents the torque characteristics,

obtained when the angle α is less than 12° and/or the radius of curvature 76 is less than $3L/4$. The curve 88 represents the characteristics obtained when the angle α is greater than 15° and/or the radius of curvature 76 is less than $3L/4$. From the curves it is quite apparent that an electromagnet having the torque characteristics of curve 84 is the most desirable in that curve 84 is practically parallel to the torque curve 82 of the torsion spring which it opposes. This will provide the most advantageous net moving force through both magnet opening and closing strokes. Further it is seen that it is possible by varying the contour of the leading edge 74 to obtain the reversed curve if desired or an almost flat curve through 30° as represented by curve 84.

The armature 26, shown in FIG. 3, is provided with a central opening 89 which is sized to provide a sliding fit between the armature 26 and the projection 58 whereon the armature 26 is carried. Thus when the coil winding of the electromagnet is energized, the balanced torque will be induced in the armature throughout its stroke, causing it to rotate to the position shown in FIG. 3 and thereby loading the return spring, not shown, for the rotation in the counter clockwise direction. At the end of the stroke, the armature 26 will slide on the projection 58 so that one of the flat pole surfaces 70 will seal against one of the flat pole surfaces 24 of the magnet. This arrangement will permit the shading coil 18 to act as though there were no air gap present to eliminate magnetic hum if the device is used on A.C. current. When the armature is in engagement with one of the flat pole surfaces 24, an air gap will be present between the opposite flat surface 70 and the other flat pole surface 24. This air gap will prevent sticking of the armature due to residual magnetism when the electromagnet is de-energized. As heretofore stated, the projections 34 are provided on the valve body 28. These projections are arranged to act as stops and limit the armature to exactly 45° travel and permit the armature 26 to slide on projection 58. Another advantage of these projections is that as wear occurs on the flat surfaces 24 or 70, the stops will also wear at the same rate so that the magnet pole gap will remain constant in spite of the wear which is encountered during service.

In FIG. 9 of the drawings, the electromagnet assembly 12 and the valve assembly 14 are shown as mounted on one part 10 of the valve housing. The other part 90 of the valve housing is provided with suitably located spring biased terminals 92 which are located in a recess 94 which is surrounded by a sealing gasket 96 which is preferably made of some elastomeric material, such as rubber. The terminals 92 are positioned to engage contact buttons 22 when the housing part 10 is assembled with the housing part 90. Positioned around each one of the openings 42, 43, and 45 are annular sealing gaskets 98 which are arranged to form a fluid tight connection with the openings 100 in the housing part 90. The openings 100 are arranged through suitable cored passages in the housing part 90 to connect with external openings 102 and 103 to provide connections with the fluid hoses to the air supply and cylinders respectively. In this connection it is to be noted that the opening 47 which represents the exhaust passage is not sealed against the housing part 90 so that the air may pass through the muffler 99 located in one of the walls of housing part 90.

In FIG. 11 of the drawings the rotary valve assembly 101 according to the present invention is shown as mounted between a handle 105 and the cylinder 104 of a welding gun. The valve assembly when so used replaces the conventional head of the cylinder which has a piston 106 movable therein to move the welding electrode 108 relative to electrode 110. The piston 106 is actuated to the right when air enters through port opening 107 which may be one of the openings 100 shown in FIG. 10, which is connected to one of the cylinder passages 42 or 43. Simultaneously, the air from the right side of the piston 106 will escape through the tube 114 to enter opening 103

where it is connected through one of the openings 43 or 42. The exhaust air from these openings is directed by the valve rotor 30 to escape through opening 47 and muffler 99. The air supply through tube 115 enters the valve body through opening 102 and is controlled by the rotation of rotor 30 to alternately direct air to opposite sides of the piston 106 while providing for the escape thereof through muffler 99 as is clearly apparent from the foregoing description.

From the foregoing it is apparent that the rotary valve assembly according to the present invention is ideally suited for use in connection with a portable welding apparatus and that the magnet assembly as used to actuate the valve is suited to actuate mechanisms other than valves. It has been found that the rotary valve according to the present invention possesses several advantages not realized in valves heretofore known. Among these advantages are that it will operate very rapidly. The speed of operation, of course, is the result of the low moment of inertia about the axis of a rotation and the short radial dimensions of the moving parts of the rotor and armature combination. This will permit a more rapid angular acceleration than could be achieved if the linearly movable solenoids were employed to actuate the valve. Another feature which is believed to be important is the low moment of inertia of the parts also reduces the force required to stop the parts at the end of each operation to reduce the shock and extend the life of the device. A still further feature which makes the valve assembly ideally suited for portable devices, is the fact that its operation is unaffected by its position. This is because all of the moving parts are balanced about the axis of rotation so that the position thereof does not influence their operation.

While certain preferred embodiments of the invention have been specifically disclosed, it is understood that the invention is not limited thereto, as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims.

What is claimed is:

1. A rotary solenoid assembly comprising; a U-shaped laminated core providing a pair of spaced arms, a magnet coil embracing the base of the U-shaped core, substantially flat surfaces on the inner surfaces of the arms of the U-shaped core, an armature having a substantially parallelogram shape and a means for rotatably mounting the armature between the arms of the core, said mounting means being arranged to permit the armature to engage either one of the flat surfaces of the core while being spaced from the other flat surface of the core when the magnet coil is energized by an electric current.

2. A rotary solenoid assembly, comprising; a U-shaped laminated magnetic core having a pair of spaced parallel arms interconnected by a web portion, an exciting coil winding surrounding the web, substantially flat surfaces on the opposed surfaces of the arms, an armature having a non-rectangular parallelogram shape and means for mounting the armature between the arms of the core, said mounting means being arranged to permit the armature to engage one of the flat surfaces while being spaced a predetermined distance from the other flat surface to increase the holding effect of the magnet when the coil is energized and to reduce the effect of residual magnetism after the coil is de-energized.

3. A rotary solenoid assembly, comprising; a magnet core having a pair of parallel spaced arms and a portion interconnecting the arms, a magnet coil carried by the interconnecting portion, a substantially flat surface on the opposed surfaces of the parallel arms, an armature arranged to rotate approximately 45° between the arms, said armature having a generally non-rectangular parallelogram cross-sectional shape with two shorter sides providing pole surfaces for the armature, said armature having a pair of opposed internal angles of 75° to 78° and a rounded leading edge which is rotated past the

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flat surfaces of the arms having a radius of curvature approximately equal to $3L/4$, where L equals one-half the shortest distance between the shortest sides.

4. The combination as set forth in claim 3 wherein a support for the armature is arranged to permit the pole surfaces of the armature to engage either of the flat surfaces of the core arms and stops are provided which will permit the pole surfaces to engage only one of the flat surfaces at any one instant.

5. A rotary solenoid assembly, comprising; a magnet core having a pair of parallel spaced arms and a portion interconnecting the arms, a magnet coil carried by the interconnecting portion, a substantially flat surface on the opposed surfaces of the parallel arms, an armature arranged to rotate between the arms, said armature having a generally non-rectangular parallelogrammatic cross-sectional shape with two shorter sides providing pole surfaces for the armature, said armature having a pair of opposed internal angles of 75° to 78° between the shorter and longer sides of the armature.

6. A rotary solenoid assembly, comprising; a magnet core having a pair of parallel spaced arms and a portion interconnecting the arms, a magnet coil carried by the

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interconnecting portion, a substantially flat surface on the opposed surfaces of the parallel arms, an armature arranged to rotate between the arms, said armature having a generally non-rectangular parallelogrammatic cross-sectional shape with two shorter sides providing pole surfaces for the armature, and a rounded leading edge on the shorter sides which is rotated past the flat surfaces of the arms having a radius of curvature approximately equal to $3L/4$, where L equals one-half the shortest distance between the shortest sides.

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