Jan. 16, 1962 R. A. LEMBERGER 3,017,156

STEPPED-OPENING SOLENOID VALVES

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FIG. 1

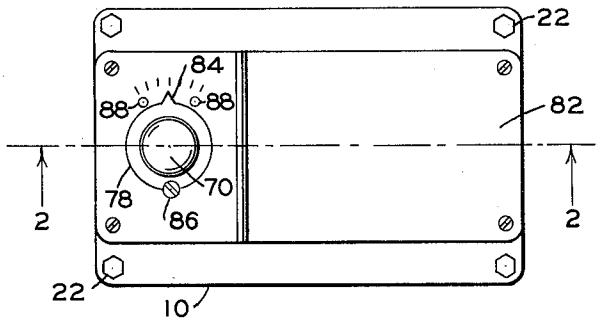


FIG. 3

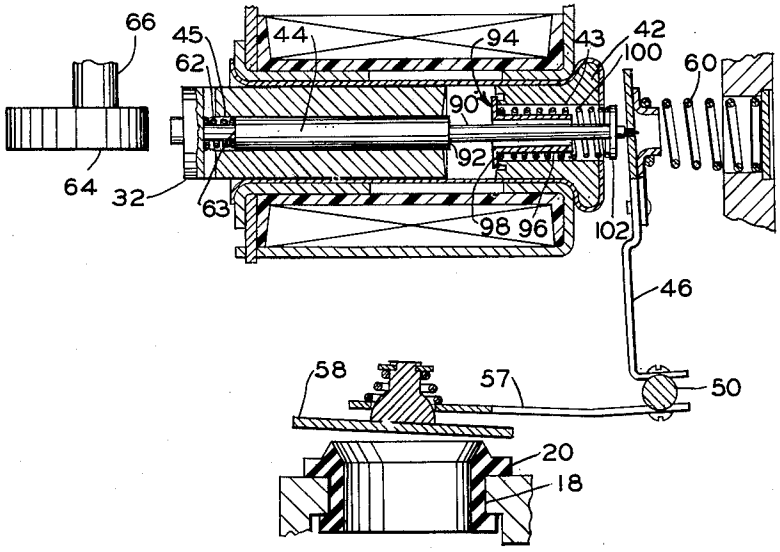


FIG. 4

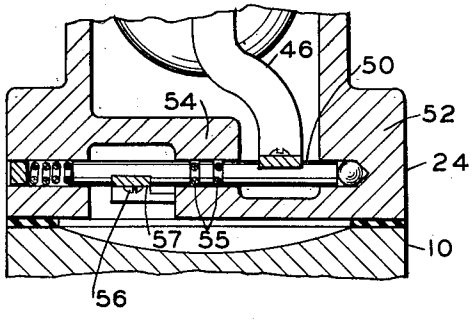
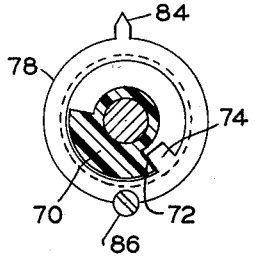


FIG. 5



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FIG. 2

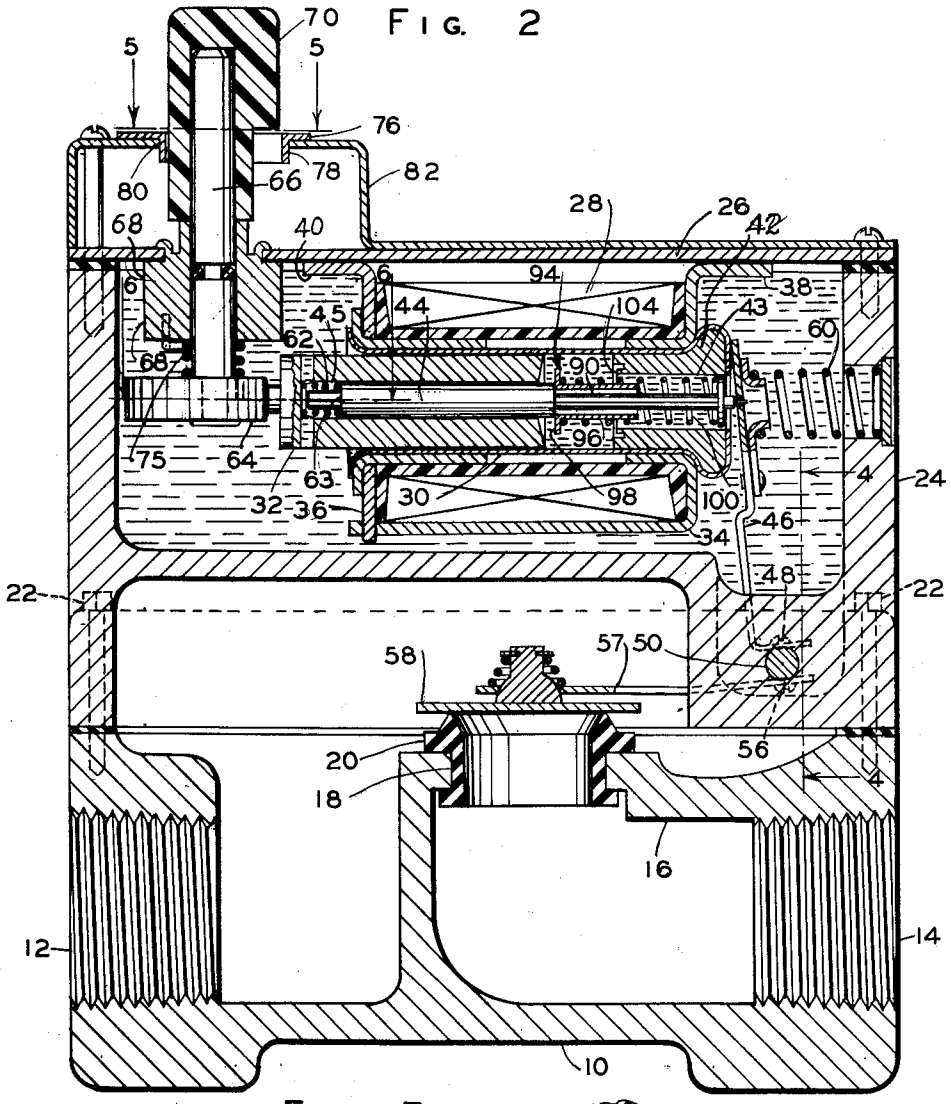


FIG. 6

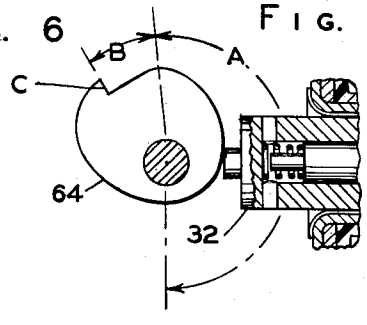
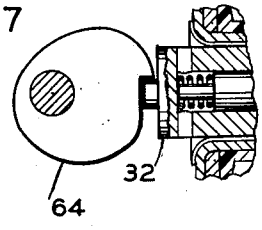


FIG. 7



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STEPPED-OPENING SOLENOID VALVES

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3 Claims. (Cl. 251—54)

This invention relates to solenoid operated valves for controlling the flow of fuel to gas-fired heating furnaces, and particularly to such valves which, when energized, are arranged to move openward a predetermined initial amount at a relatively rapid rate and then complete their opening movement at a relatively slow rate, thereby to supply an immediate limited amount of fuel to establish an initial limited combustion in the furnace and to then increase the flow of fuel slowly to a full amount at a rate which permits the development of sufficient air draft through the furnace to support full combustion.

An object of the present invention is the provision of novel means in a normally closed, solenoid operated valve for effecting a "stepped-opening" operation thereof wherein the valve moves openward an initial predetermined amount at a relatively rapid rate when energized and then continues to move openward to a fully open position at a relatively slow rate.

A further object of the invention is to include means in a solenoid valve of the above character for selectively varying that initial portion of its full opening movement, wherein the valve moves openward at a relatively rapid rate.

Further objects and advantages will become apparent from the following description when read in connection with the accompanying drawings.

In the drawings:

FIG. 1 is a top plan view of a solenoid valve constructed in accordance with the present invention;

FIG. 2 is an enlarged, longitudinal, cross-sectional view of the valve shown in FIG. 1, taken on line 2—2 of FIG. 1;

FIG. 3 is a part sectional view showing the valve in a different operative position;

FIG. 4 is a partial, transverse, cross-sectional view of the valve taken on line 4—4 of FIG. 2;

FIG. 5 is a part sectional view taken on line 5—5 of FIG. 2, showing the manual operating and adjustment knob in a returned position against the adjustable member;

FIG. 6 is a part sectional view taken on line 6—6 of FIG. 2, showing the solenoid plunger in a de-energized position bearing against the cam member; and

FIG. 7 is a similar part sectional view showing the cam member rotated to a position wherein the solenoid plunger is moved thereby to a valve open position and latched in a valve open position.

Referring to the drawings in more detail, numeral 10 indicates the valve body having an inlet 12, an outlet 14, and a partition 16. The partition 16 has a port 18 therein fitted with a resilient valve seat 20. Mounted on the valve body 10 and attached thereto by screws 22 is an upper casing 24 which houses a solenoid actuator. The casing 24 is filled with a viscous liquid and is provided with a sealing top cover 26 of magnetic material from which the solenoid actuator is suspended. The solenoid actuator comprises a winding 28, a central plunger guide sleeve 30 of non-magnetic material, and a plunger 32 of magnetic material slidably arranged in guide sleeve 30. The solenoid winding 28 is enclosed in a supporting frame of magnetic material consisting of members 34 and 36, each having a formed leg 38 and 40, respectively, attached to the underside of cover 26 in any suitable manner as by welding. A plunger stop member 42 of magnetic material fixed in the right end of the guide sleeve 30 forms a closure at that end of the sleeve and limits the travel of plunger 32 toward the right when winding 28 is energized and further serves to complete, with members 34 and 36 and cover 26, a low reluctance path for the magnetic field generated by winding 28. The stop member 42 is provided with a central bore 43 which is considerably smaller in diameter than the diameter of the plunger and plunger guide sleeve 30.

A push rod 44 slidably fitted in a longitudinal bore 45 in plunger 32 projects from the right end of the plunger and extends through the bore 43 in stop member 42 and engages at its projecting right end the free end of an arm 46. The arm 46 is attached at its other end by a screw 48 to the interiorly extending portion of a rocker shaft 50, which rocker shaft is journalled in opposite walls 52 and 54 of casing 24 and extends externally through the casing wall 54, see FIG. 4. In order to provide a seal against leakage of the liquid from the casing 24 through the rocker shaft journal in wall 54 a pair of rubber O rings 55 are fitted in suitable annular grooves in the shaft 50. Attached at one end to the exteriorly extending portion of shaft 50 by a screw 56 is a second arm 57 which carries at its free end a valve 58 which cooperates with the valve seat 20 to control the flow through valve body 10.

A compression spring 60 acting through arms 46 and 57 biases valve 58 in a closed position on valve seat 20. The spring 60 also acts through the push rod 44 to move the solenoid plunger 32 leftward toward a returned position when the solenoid winding 28 is de-energized. The action of spring 60 through push rod 44 in returning solenoid plunger 32 is limited, however, when the free end of arm 46 engages the outer end of magnetic stop member 42, as shown in FIG. 2. A relatively weaker compression spring 62 interposed between the bottom of the solenoid plunger bore 45 and a shoulder 63 formed at the inner end of push rod 44 urges the solenoid plunger further leftward until it engages an adjustable stop cam 64, so that the inner end of push rod 44 is spaced somewhat from the bottom of the plunger bore 45 when the adjustable stop cam 64 is so adjusted as to permit this further travel of the plunger. This spacing between the inner end of push rod 44 and the bottom of bore 45 permits a free movement of the plunger with respect to valve 58 for a purpose to be described.

The cam 64 is rigidly mounted on a shaft 66, which shaft is journalled in a bushing 68 fixed in the casing cover 26. The cam shaft 66 extends exteriorly of the casing 24 and is provided at its exterior end with a hand knob 70 of general cylindrical form. The lower end of knob 70 is cut away to provide thereon a radially extending abutment 72 which is arranged to engage a stop 74, see FIG. 5, to limit the counterclockwise rotation of knob 70 and therefore the shaft 66 and cam 64. A spring 75 connected at one end to cam 64 and at its other end to the fixed bushing 68 biases the knob 70 in a counterclockwise direction against stop 74. The stop 74 is angularly adjustable within limits and is formed as an integral projection extending radially inward from the flange portion 76 of a ring member 78. The ring member 78 surrounds the knob 70 and is mounted for rotatable adjustment in a circular aperture 80 formed in a stamped cover member 82, which cover member overlays and is fixed to the casing cover 26. The ring member 78 is further provided with a pointer element 84 to indicate the angular position of stop 74 with reference to indicia on the stamped cover 82, see FIG. 1. The ring member is fixed in any angularly adjusted position by a clamping screw 86, and the range of adjustment of the ring member 78 is

limited by a pair of spaced stops 88 on the stamped cover 82 arranged to be engaged by the pointer element 84.

Referring to FIG. 6 of the drawings, it will be seen that the cam 64 has a gradual rise "A" progressing in a counterclockwise direction so that if the ring 78, see FIG. 5, is angularly adjusted from the position shown therein so as to move the stop 74 counterclockwise, the leftward movement which plunger 32 is permitted to travel will be increased and the space between the end of push rod 44 and the bottom of the plunger bore 45 will consequently be increased. Adjustment of the ring member 78 in a clockwise direction from the position shown will reduce the space between the end of push rod 44 and the bottom of bore 45, and thereby reduce the free travel of plunger 32 with respect to the valve 58 when the solenoid is energized.

The cam 64 also has a flat tangential surface "B" at a height from the cam center slightly less than that of the high point of the cam surface "A." The flat surface "B" is terminated by a shoulder "C." When in the absence of electrical power for energizing the solenoid it is desired to open the valve 58 manually, the knob 70 is rotated clockwise until the reduced end of plunger 32 is bearing on the flat surface portion "B" of the cam 64, as shown in FIG. 7. In this position the cam 64 is detained from returning under the force of its return spring 75, when the hand knob 70 is released, because of the force applied axially along the plunger by the relatively strong spring 60, so that the valve remains latched in an open position. The shoulder "C" merely forms a stop against further unnecessary rotation of the knob. The rise of cam surface "A" is, however, made slightly less than that which would be required to move plunger 32 against plunger stop 42 and the valve 58 to the full open position to which it is moved when the winding 28 is energized. This provision is made so that when the plunger 32 has been manually moved to and latched in this somewhat less than full valve-open position, the subsequent restoration of the electrical power source will effect a further movement of plunger 32 toward the right and thereby release the latch-up of plunger 32 and cam 64 and permit the cam to return under spring 75. The operation of valve 58 is thereby automatically transferred from manual to electrical operation.

The push rod 44 has a reduced diameter portion 90, which extends through the bore 43 of the plunger stop member 42, and a shoulder 92 formed at the left end of this reduced diameter portion. A check valve member generally indicated at 94, having a sleeve portion 96 and a flange portion 98 at one end thereof, is loosely fitted over the reduced diameter portion 90 of the push rod with its flanged end normally bearing against the shoulder 92 and its sleeve portion 96 extending to some extent under all conditions into bore 43. The check valve 94 is biased against the shoulder 92 by a light spring 100 bearing at one end against a retaining washer 102 fixed on the right end of the push rod 44 and bearing at its other end against the flange 98 of the check valve. A valve seat 104 is formed at the inner end of bore 43 with which the flange portion 98 of the check valve cooperates to control the flow of liquid through bore 43.

It is to be understood that the viscous liquid filling the chamber 24 enters and fills all open cavities and passages in the solenoid actuator immersed therein, and that the liquid flows to and fro through the bore 43 as the chamber formed between the right end of plunger 32 and the stop member 42 is expanded and contracted by reciprocation of the plunger. The check valve sleeve portion 96, being entered into the bore 43, forms a restriction to flow therethrough so that, when the plunger moves toward the right and discharges liquid through passage 43, the check valve is moved through a long stroke toward its seat 104 against its light return spring 100, and when the plunger moves toward the left, the check valve is immediately moved from its seat.

The check valve 94 differs in its operation from that of conventional check valves in that the distance it travels from its full returned postion to its closed position is considerably greater and in that the force which moves it this greater distance is relatively constant. From the point at which check valve 94, in closing, has approached sufficiently close to its seat 104 to effect an appreciable restriction between its flange portion 98 and the seat, it is operated to a completely closed position much in the same manner as a conventional check valve; that is, by an extremely rapid increase in force which completes this last slight movement very rapidly. When the flow through bore 43 is reversed, the check valve 94 leaves its seat instantly in the same manner as a conventional check valve. While it is true, of course, that as the check valve 94 moves toward its closed position the increasing entry of its sleeve portion 94 into bore 43 increases the restriction to flow, and therefore to some extent increases the force applied to closing the valve, this force increase with relation to valve movement is, however, considerably less than occurs in the operation of conventional check valves.

In view of the long travel of check valve 94 through which it is operated by relatively constant flow, it will be seen that considerable movement of the plunger 32 is required to effect the movement of the check valve 94 from its full open position to closed position and that a predetermined relationship of movement of the plunger and check valve may be achieved by varying one or more of several controlling factors. For example, at constant plunger velocity and liquid viscosity, the speed or movement of the check valve would be increased relative to that of the plunger by increasing the restrictive effect of the check valve, but if the velocity of the liquid stream in which the check valve is disposed is no greater than that of the plunger, the greatest velocity which the check valve could attain would be that of the plunger. By providing the restrictive passage 43 so as to speed up the flow and by arranging the check valve 94 so that its sleeve portion is entered into the passage 43, the velocity of the check valve is increased over that of the plunger even when using a lower viscosity liquid and a less restrictive check valve. It is important that the viscosity of the liquid and restrictive effect of the check valve (when open) be limited to values which will permit a predetermined, minimum-required, return speed of the plunger when the solenoid is de-energized, which will effect the closing of valve 58 at a sufficient speed to preclude flash back at the gas burner.

Operation

The device is shown in FIG. 2 in a de-energized position with the valve 58 fully closed and with the ring member 78 adjustably positioned intermediately of its adjustment range, which places cam 64 in the position shown in FIG. 6 and results in an intermediate spacing of the left end of push rod 44 from the bottom of plunger bore 45. When under these conditions the solenoid winding 28 is energized, the plunger 32 starts to move toward the right, and as it does, it forces liquid through the bore 43. The relationship of the net cross-sectional area of the bore 43 to that of plunger guide sleeve 30, the relationship of the cross-sectional area of the sleeve portion 96 of the check valve to the net cross-sectional area of the bore 43, the strength of spring 100, and the viscosity of the liquid are such that the check valve 94 is moved from its full open to full closed position by a rightward movement of plunger 43 which is equal to twice the space between the end of push rod 44 and the bottom of plunger bore 45, shown in FIG. 2. During that initial half of the total rightward movement of the plunger required to

close check valve **94**, in which the space between the end of push rod **44** and the bottom of plunger bore **45** is taken up, the valve **58** is not moved, but during the last half of this total required plunger movement, the valve **58** is moved openward a predetermined amount at a relatively rapid rate. When the plunger has moved the total distance required to close the check valve **94**, further rightward movement of the plunger and the opening movement of valve **58** to its full open position will proceed at a relatively slow rate, due to the considerable restriction to flow caused by the seating of the check valve.

When the check valve **94** is seated, the flow of liquid displaced by the plunger **32** is limited to the annular orifice defined by the inner wall of the check valve sleeve portion **96** and the reduced portion **90** of the push rod. The positions of the plunger 32, the check valve 94, and the valve 58 at the instant the check valve **94** closes are shown in FIG. 3 of the drawings.

When the ring member **78** is rotated to its counterclockwise limit wherein the pointer 84 bears against the left-hand stop pin 88, see FIG. 1, the space between the end of push rod **44** and the bottom of plunger bore **45** will be maximum, or twice that space shown in FIG. 2. Under these conditions the free travel of plunger **32**, before it picks up the valve **58**, is sufficient to seat the check valve **94** so that the entire opening movement of valve **58** will be relatively slow and at a substantially constant speed. When the ring member **78** is rotated to its clockwise limit wherein the pointer bears against the right-hand stop **88**, no space will exist at the left end of push rod **44**. Under these conditions the plunger **32** is operatively connected to valve **58** through the full plunger stroke, and the plunger and valve **58** will move through a maximum, initial, rapid-opening step which is equal to the total amount of plunger travel required to seat the check valve **94**.

As an alternative arrangement, the check valve seat **104** could be formed at the right end of bore **43**, with reference to FIG. 2, and the check valve could be formed as a simple perforated disc entered into the bore and slidably mounted on a reduced portion of the push rod **44** and having such diameter as to respond in the required manner to the flow through bore **43**. In this arrangement, the closing force acting on the check valve would be substantially constant, for a constant flow, throughout its stroke until it closely approached its seat. However, the arrangement shown provides a better means, in the elongated sleeve portion, for maintaining alignment of the valve with a relatively loose fit on the push rod. Moreover, in the arrangement shown, the increase in restriction occasioned by progressing entry of the sleeve portion **94**, resulting in increased closing force, offsets the build-up of return spring **100**, and when the solenoid is de-energized, the restrictive effect of the check valve decreases as it approaches its open position, thereby reducing resistance to the return movement of the plunger as the valve **58** approaches its closed position. This is a particular advantage because the more rapidly the latter portion of the closing movement of valve **58** can be effected, the less likelihood there will be of burner flash back.

The foregoing description and accompanying drawings are intended to be illustrative and not limiting, the scope of the invention being set forth in the appended claims.

I claim:

1. In a solenoid valve assembly, a valve, a strong spring means biasing said valve in a closed position, a solenoid including a plunger guide sleeve, a winding surrounding said sleeve, and a plunger slidably fitted in said guide sleeve and arranged to engage said valve and to move it open when said plunger is attracted in one direction upon energization of said winding, light compression spring means between said valve and said plunger for effecting an overtravel of said plunger in an opposite direction beyond the point to which it is moved by said valve closing spring when said winding is de-energized, whereby an amount of free plunger travel with respect to said valve occurs when said winding is energized, means forming a closure at one end of said guide sleeve, a chamber, a liquid in said chamber, a passage connecting said chamber and the interior of said guide sleeve at its closed end whereby liquid is caused to flow to and fro through said passage as said plunger is reciprocated in said sleeve, a flow responsive member movable axially in said passage between lesser and greater flow restricting positions therein, resilient means biasing said member in its less restricting position, and said member being arranged to move from its lesser to greater restricting position in response to a predetermined flow through said passage resulting from a predetermined initial movement of said plunger in a valve opening direction upon energization of said winding, whereby said plunger moves relatively rapidly a predetermined initial amount when energized until said member has reached its greater restricting position, and adjustable stop means arranged to be engaged by said plunger when de-energized for variably limiting the overtravel of said plunger to an amount equal to or less than the predetermined initial movement of the plunger required to move said member to its greater restrictive position, whereby that portion of the initial rapid opening movement of said plunger which is effective in moving said valve openward is varied.

2. In a solenoid valve assembly, a main valve to be operated including a valve operating member movable with said valve, strong spring means biasing said valve in a closed position, a solenoid for operating said valve including a plunger guide sleeve, a winding surrounding said guide sleeve and a plunger slidably fitted in said guide sleeve and arranged to engage said valve operating member and to move said valve open when said plunger is attracted in one direction upon energization of said winding, relatively light spring means acting between said valve operating member and said plunger for effecting an overtravel of said plunger in an opposite direction beyond the point to which said plunger is moved by said valve closing spring when said winding is de-energized, thereby to provide an initial amount of free plunger travel with respect to said valve when said winding is susebquently energized, means forming a closure at one end of said guide sleeve, a chamber, a fluid in said chamber, a passage connecting the interior of said guide sleeve at its closed end with said chamber, whereby said fluid flows to and fro through said passage when said plunger is reciprocated, a valve seat at one end of said passage, a flow responsive check valve having a portion movable axially in said passage in response to fluid flow therethrough and having a portion exterior of said passage adapted to engage said valve seat when said check valve is moved a predetermined distance in one direction, thereby to restrict the flow through said passage, bypass means permitting reduced flow through said passageway when said check valve is seated, stop means for limiting the movement of said check valve in an opposite direction, means biasing said check valve against said stop means, said flow responsive portion of said check valve being responsive to a predetermined flow through said passage for a predetermined interval in a direction resulting from a predetermined movement of said plunger in a main valve opening direction to move said check valve from a position against said stop means to a seating position on said valve seat, whereby said plunger moves relatively rapidly an initial amount in a valve opening direction upon energization of said winding, and adjustable stop means arranged to be engaged by said plunger when de-energized for variably limiting its overtravel and consequently its free travel relative to said main valve, whereby that portion of the initial rapid movement of said plunger upon energization, during which it is operatively connected to said valve, is

varied, thereby varying the rapid opening step of said main valve.

3. A solenoid valve assembly as set forth in claim 1 in which said adjustable stop means comprises a spring-returned manual operator having a cam surface movable therewith and arranged to be engaged by said plunger as it returns to its de-energized position, and adjustable stop means for variably limiting the return of said manual operator, thereby to variably limit the overtravel of said plunger, and said manual operator being operable,

through engagement of said cam surface, to move said plunger sufficiently toward its energized position to effect the substantial opening of said valve.

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