

[54] **SOLENOID ACTUATOR FOR HIGH PRESSURE VALVE**

[75] Inventor: **Slawomir Kowalski**, Rockaway, N.J.

[73] Assignee: **Marotta Scientific Controls, Inc.**,
Boonton, N.J.

[22] Filed: **Sept. 25, 1974**

[21] Appl. No.: **509,048**

[52] U.S. Cl. **335/255; 251/141; 335/262**

[51] Int. Cl.² **H01F 7/08**

[58] Field of Search **335/255, 262, 227, 240;**
251/129, 141

[56] **References Cited**

UNITED STATES PATENTS

2,207,082 7/1940 Wetzel 335/262

FOREIGN PATENTS OR APPLICATIONS

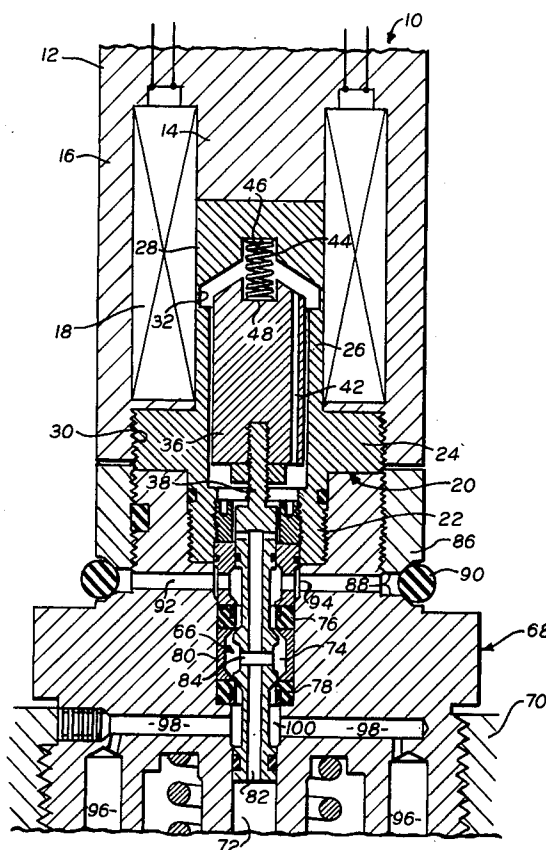
1,070,958 1954 France 251/141
632,670 12/1961 Canada 251/141

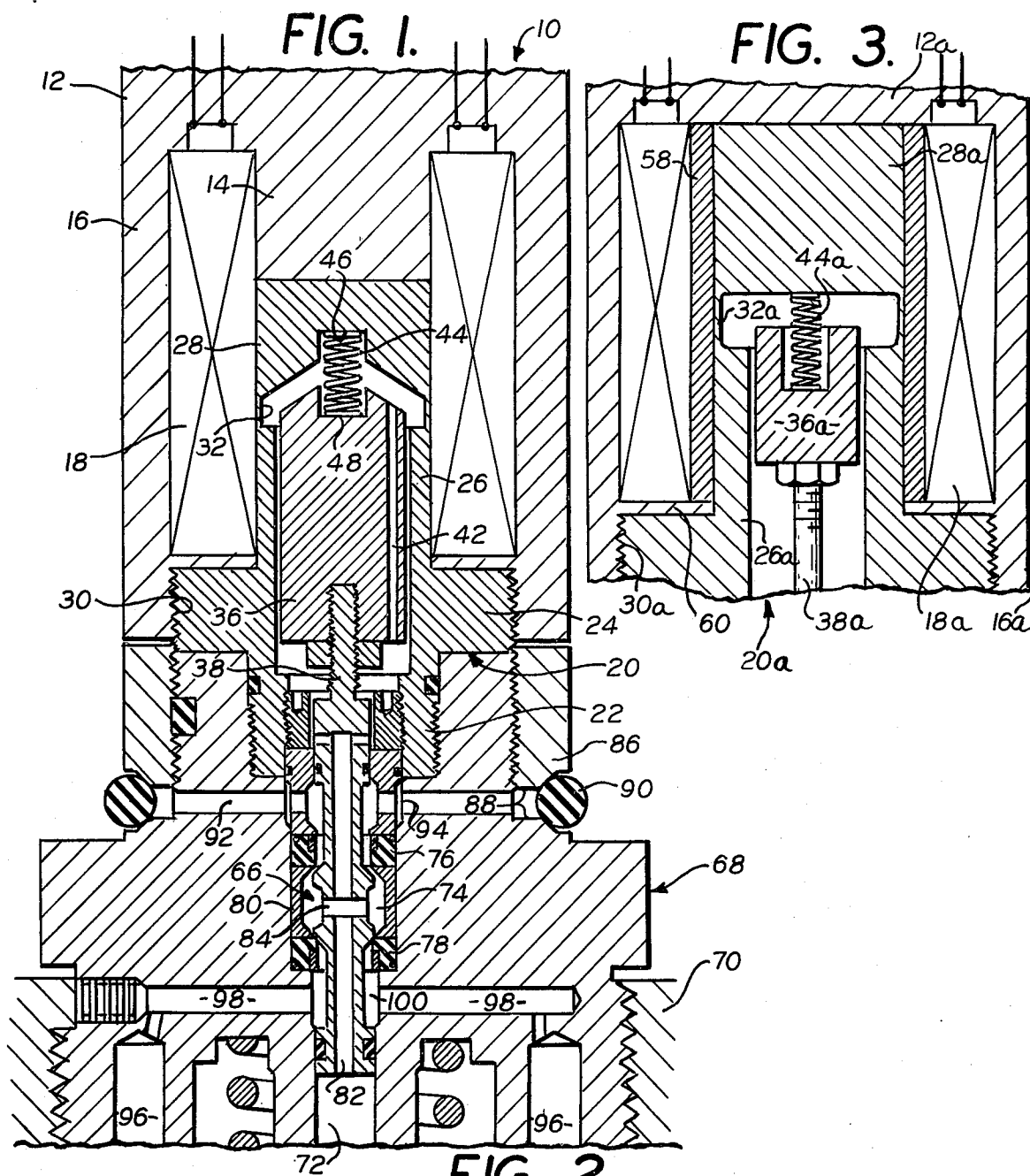
Primary Examiner—Harold Broome
Attorney, Agent, or Firm—Sandoe, Hopgood &
Calimafde

[57] **ABSTRACT**

Some solenoid operated valves have their plungers and plunger guides exposed to the fluid medium that the valve controls. Such solenoids are commonly referred to as "wet solenoids", though the medium controlled may be either liquid or dry gas. When the medium control is at high pressure, of the order of 6,000 pounds per square inch or higher, the plunger guide must be constructed with hoop strength sufficient to withstand this pressure. This invention provides a valve construction with the plunger guide of thin wall section for a portion of its length, so that it becomes magnetically saturated to concentrate flux in the plunger, and with special provisions for preventing the high pressure fluid from breaking the thin wall. The plunger guide, when there is no fluid pressure in the valve, is mechanically loaded by a force exerted in a direction opposite to the main thrust of the high pressure medium.

12 Claims, 3 Drawing Figures





SOLENOID ACTUATOR FOR HIGH PRESSURE VALVE

BACKGROUND AND SUMMARY OF THE INVENTION

The guide in which the solenoid plunger slides is part of the magnetic circuit of the solenoid, and is closed at the top to prevent the controlled fluid from travelling any further than the plunger and plunger guide. In order to have more of the magnetic flux concentrated in the plunger, the plunger guide is made with a portion of its length of thin wall section which saturates quickly so that the remaining flux of the solenoid is concentrated in the plunger.

This reduced thickness of the plunger guide can be made much thinner if provision is made to counteract the high fluid pressure that tends to stretch or to permanently deform or break the plunger guide. This invention constructs the solenoid so that the plunger guide can be prestressed in a direction opposite to the longitudinal thrust of the high pressure fluid that enters the guide. In the preferred construction, the means for prestressing the guide includes parts connected together by screw threads and adjustable to control the amount of prestress imposed upon the thin wall section of the plunger guide.

The solenoid has a core at the upper end of the stroke of the plunger and this core, or at least a part of it, is preferably integral with the plunger guide and of one-piece construction with the plunger guide. The threaded connecting parts are preferably part of the solenoid magnetic circuit, such as the lower flange at one end of the solenoid coil and the magnetizable cladding around the outside of the coil.

Provision is also made to provide for the hoop stresses exerted by the high pressure fluid on the thin wall section of the solenoid plunger guide. One expedient is to make the thin wall section of very limited longitudinal extent and to have thick wall sections of the guide at both ends of the thin wall section for providing reinforcement of the thin wall section against failure resulting from the hoop stress imparted by the high pressure fluid. Another expedient is to use a reinforcing sleeve around the outside of the thin wall section with the sleeve of non-magnetic material so that it does not divert any flux away from the plunger. This reinforcing sleeve need not be of non-corrosive metal since it is not exposed to the high pressure fluid.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

BRIEF DESCRIPTION OF DRAWING

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIG. 1 is a vertical sectional view through a solenoid made in accordance with this invention and showing the solenoid connected with valve mechanism which exposes the solenoid plunger and plunger guide to the full high pressure of the fluid being controlled by the valve;

FIG. 2 is a fragmentary, sectional view showing a modified construction of the plunger and the upper end of the plunger guide; and

FIG. 3 shows a modification of the solenoid of FIG. 1 with a sleeve around the plunger guide for reinforcing the reduced wall section against hoop stress failure.

DESCRIPTION OF PREFERRED EMBODIMENT

FIG. 1 shows a solenoid 10 comprising an outer magnetizable metal housing 12 which includes an upper core section 14 and an outer magnetizable cladding 16.

There is space within the housing 12 for a magnetic coil 18 and this coil encloses a space which is filled at its upper end by the core section 14.

A lower end portion 20 of the housing 10 includes a sleeve 22, a flange 24 that extends across the lower end of the coil 18 to hold the coil 18 in the housing 12, and the lower end 20 also includes a plunger guide 26 extending upwardly from the flange 24 and into the space surrounded by the coil 18.

At the upper end of the plunger guide 26 there is another core portion 28 which is an integral part of the plunger guide 26, and preferably of one-piece construction with the plunger guide 26. The core section 14 contacts with the upper end of the core section 28.

The circumference of the flange 24 is threaded and screws into complementary threads on the inside of the lower end of the cladding 16.

The housing 12 and the lower end portion 20 of the housing may have flat surfaces or other conventional means by which the housing and lower end portion can be held by tools to screw the lower end portion 20 into the threads 30 of the cladding 16. After the confronting faces of the core sections 14 and 28 come in contact with each other, further force supplied to the end portion 20, to screw it into the cladding 16, imposes a greater force of the sections 14 and 28 against one another and this tends to stretch the cladding 16 and to impose progressively greater compression on the cross sections 14 and 28.

There is a groove 32 in the inside surface of the plunger guide 26; and this groove substantially reduces the thickness of the plunger guide at the region, near the upper end of the guide 26, so that the wall thickness of the plunger guide is reduced for a short portion of its length. Because of the limited cross section of the wall of the plunger guide at the groove 32, the metal of the plunger guide becomes magnetically saturated at this thin section, and this forces more of the magnetic flux of the solenoid to enter the plunger 36.

Because of the reduced cross section of metal in the plunger 36 at the groove 32, compression of the cross section 28 and plunger guide 26 concentrates compressive force in the thin wall section of the plunger guide. Because of this prestressing, in compression, of the thin wall section, a substantial fluid pressure within the plunger guide 26 can occur before there is any tension stress on the thin wall section.

The lower end portion 20 of the solenoid housing is screwed into the cladding 16 with a substantial force that is limited so as to avoid compressing the thin wall section at the groove 32 beyond the elastic limit of the metal. The compressive force can be controlled and determined by using torque wrenches to screw the end portion 20 into the cladding 16.

As fluid under pressure enters the plunger guide 26, the fluid pressure, exerted upward against the cross section 28 at the top of the plunger guide, provides a force counter to compression force at the groove 32. This reduces the compressive stress at the groove 32 until there is no longer any compressive stress on the

metal at the groove. Further increase in the high pressure in the plunger guide 26 imposes a tension stress on the metal at the thin wall section at the groove 32. This stress is quite substantial because of the large area of the cross section 28, but the total ultimate tension stress is reduced by the amount of compressive stress originally imposed on the metal at the groove 32 by the prestressing of the metal at the groove when the cladding 16 is screwed down on the threads 30, as already described. None of the high pressure fluid enters the space in which the coil 18 is located and the housing 10, including the threads 30, is made of ample strength to withstand any stresses imposed on the solenoid by the high pressure fluid with which the solenoid and its valve are intended to be used.

The plunger 36 slides in the plunger guide 26. There are motion-transmitting means, such as a connecting rod 38, secured at one end to the plunger 36 and at the other end to valve structure which is operated by the plunger 36.

If the plunger 36 is a free fit in the plunger guide 26, high pressure fluid can flow through the clearance between the plunger guide 26 and the plunger 36. In the preferred construction, however, there is a longitudinal passage 42 opening through the faces at both the upper and lower ends of the plunger 36 for the purpose of permitting free flow of high pressure fluid through the plunger 36. Thus the plunger is balanced and is not influenced by the degree of pressure to which it is exposed in the plunger guide 26. In the construction illustrated, the plunger is pulled toward the cross section 28 by the magnetic pull of the solenoid; and when the energizing current to the coil 28 is shut off, the plunger 36 is moved away from the cross section 28 by a spring 44 located in concentric sockets 46 and 48 in the faces of the cross section 28 and plunger 36, respectively. This is a compression spring.

FIG. 2 shows a modification of the construction shown in FIG. 1. Corresponding parts are indicated by the same reference character as in FIG. 1 but with a prime appended. Instead of the conical top surface of the plunger 36, the plunger 36' has a flat top surface with the recess 8' for holding the coil string 44'. The core portion 28' has a substantially flat face confronting the upper end of the plunger 36' instead of the conical face of the structure shown in FIG. 1.

There are small bosses 52 extending upwardly from the flat top face of the plunger 36'. These bosses 52 are rigidly connected with the plunger 36' but are preferably made of non-magnetizable material and they serve as spacers to prevent the plunger 36' from ever coming into actual contact with the core portion 28'. This makes the pull of the solenoid on the plunger 36' somewhat less at the top of the stroke and permits the plunger 36' to be pushed downwardly by a spring 44' which is much weaker than the spring 44 of FIG. 1.

FIG. 3 shows another modified construction. Parts in FIG. 3 corresponding to those of FIGS. 1 and 2 are indicated by the same reference character with a letter *a* appended. While there are some differences in the dimensions and the shapes of the parts, the important difference between FIG. 3 and the other figures is that a sleeve 58 is placed around the outside of the plunger guide 26a. This sleeve 58 is made of non-magnetizable material and is of substantial tensile strength so that it provides a reinforcing behind the thin wall at the groove 32a.

Since the sleeve 58 is of material through which no magnetic flux will flow, it does not change the low saturation feature of the thin wall at the groove 32a; but it does provide a substantial increase in the ability of the thin wall to resist hoop stress forces. The thin wall cannot bend radially outward without bending the sleeve 58 and the sleeve 58 is made strong enough so that it will not bend sufficiently to acquire any permanent set or to permit the thin wall of the plunger guide 26 to acquire a permanent set as the result of hoop stress force applied by the fluid within the plunger guide 26a.

FIG. 3 shows the sleeve 58 extending for the full length of the side wall of the plunger guide 26a. This is a convenient way to construct the solenoid, but it will be understood that the function of the sleeve 58 in reinforcing the thin wall section, can be formed by a sleeve of less longitudinal length. The important part of the sleeve 58 is a part which is radially outward of the thin wall section at the groove 32a.

The construction shown in FIG. 3 has the same type of screw connection 30a between the flange 24a and the cladding 16a as in FIG. 1. Thus the thin wall section of the plunger guide 26a can be stressed in the same way as with FIG. 1 or FIG. 2. In all constructions, some clearance 60 is provided at the end of the coil 18a so that the full prestress loading is applied to the plunger guide without applying any longitudinal stress to the coil 18a.

In order to make the solenoid of this invention suitable for use with corrosive fluid, the plunger guide and the plunger, and the spring between the top of the plunger and the lower end of the core portion are made of non-corrosive material. This material must be magnetizable however, and in the preferred construction stainless steel of the 300 series is used as the material for the plunger and the plunger guide in its associated core portion at the upper end of the guide.

Referring again to FIG. 1, the sleeve 22 is preferably threaded so that it can be secured into the upper portion of a housing 64 which contains a valve 66 that opens and closes to control the flow of the high pressure fluid. This valve 66 is a pilot valve in the construction shown, but it does control flow and contact with the full pressure of the high pressure fluid that is controlled by a main valve in a housing 68 that threads into a pod 70 of sub-sea control apparatus of a well head of an offshore oil well.

The valve 66 controls flow of high pressure fluid to and from a passage 72. The valve 66 is in a valve chamber 74 formed by an upper valve seat 76, a lower valve seat 78 and a spacer 80 that holds the valve seats at a predetermined distance from one another. An axial bore 82 has its lower end in communication with the passage 72. This bore 82 communicates with the valve chamber 74 through a cross drilling 84 in the valve 66; and the portion of the bore 82 above the cross drilling 84 is for pressure balancing purposes only.

There is a ring 86 threaded over the outside of the housing 68; and the lower end of this ring 86 cooperates with a shoulder on the housing 68 to provide a circumferential groove 88 in which a ring 90 is held. This ring 90 is made of elastomeric material. Angularly spaced, radially extending passages 92 put the groove 88 in communication with an exhaust chamber 94; and this exhaust chamber 94 opens into the valve chamber 74 when the valve 66 is in open position and spaced from the upper seat 76 as shown in FIG. 1.

Exhaust fluid flowing from the passage 72 flows through the bore 82 and cross drilling 84 into the chamber 74. With the valve 66 in open position, as shown in FIG. 1, the exhaust fluid travels past the valve seat 76 into the chamber 94 and through the passages 92 to the groove 88 in which the ring 90 is located. Pressure of this exhaust fluid behind the ring 90 stretches the ring and permits the exhaust fluid to flow around the ring 90 and to discharge into the sea water that surrounds the valve housing 68 above the pod 70. When the exhaust pressure drops to a value less than the pressure of the sea water, the sea water pressure pushes the ring 90 back into the groove 88. Thus the ring 90 acts as a check valve to prevent sea water from entering the valve housing 68 when the pressure of fluid in the valve housing is lower than the pressure of the sea water.

The valve 66 is shown closed against the lower valve seat 78 and it is normally held in this position by pressure of the spring 44 exerted against the upper end of the plunger 36. When the coil 18 of the solenoid is energized, the plunger 36 moves upward and closes the valve 66 against the upper seat 76 and moves the valve into open position spaced from the lower seat 78. Working fluid under high pressure is supplied from passages 96 to a cross drilling 98 in the valve housing 68. This cross drilling 98 communicates with a fluid inlet chamber 100 located immediately below the lower valve seat 78. When the valve 66 is at the upper end of its stroke and closed against the valve seat 76, and spaced from the valve seat 78, high pressure fluid flows from the passages 96, through the cross drilling 98, into the chamber 100 and through the opening in the valve seat 78 into the chamber 74. The high pressure fluid enters the cross drilling 84 and flows downward through the axial bore 82 into the passage 72.

The preferred embodiments of the invention have been illustrated and described, but changes and modifications can be made and some features can be used in different combinations without departing from the invention as defined in the claims.

What is claimed is:

1. A solenoid for controlling high pressure fluid including a coil, a core in the coil, a plunger that moves longitudinally toward and from the core, a tubular plunger guide of magnetizable material surrounding the plunger, the interior of the plunger guide and the plunger within the guide being in position for contact with the high pressure fluid in a closed system when the solenoid is in use, and means for compressing the core and the plunger guide longitudinally with a prestressing force on said core and said plunger guide in a direction counter to the direction of tension stress imposed on the plunger guide by entrance of the high pressure fluid into the plunger guide whereby the prestressing force offsets some of said tension stress.

2. The solenoid described in claim 1 characterized by a reinforcing sleeve of non-magnetizable material surrounding the plunger guide and located between the outside of the plunger guide and the inside surface of the coil for imparting added hoop strength to the plunger guide for resisting radial force against the plunger guide by said high pressure fluid that enters into the plunger guide.

3. A solenoid including in combination a coil that surrounds a center space, a relatively fixed core of magnetizable material at the upper end of the center space, a plunger of magnetizable material in the space

below said relatively fixed core and movable toward and from the core through a stroke, a magnetizable guide in the space and surrounding the plunger and in which the plunger slides, during its stroke, the upper end of the plunger guide being closed so that fluid pressure in the guide exerts an upward thrust against the closed upper end of the guide, a side wall of the guide extending downwardly from the closed upper end and comprising a guide bearing in which the plunger slides, a part of the length of the side wall being of thin section that undergoes magnetic saturation when the coil is energized so as to concentrate more flux in the cross section of the plunger, and means for protecting the thin wall section from permanent deformation by fluid pressure in the guide, said means including connected parts compressing the plunger guide longitudinally to prestress the thin wall section in a direction opposite to that in which the thin wall section is stressed by pressure of the fluid in the guide acting against the closed upper end of said guide.

4. The solenoid described in claim 3 characterized by the plunger guide having thicker wall sections close together and limiting the longitudinal extent of the thin wall section and holding said thin wall section against radial deformation by the pressure in the plunger guide.

5. The solenoid described in claim 3 characterized by said connecting parts including also a flange at the lower end of the plunger guide extending radially outward under the lower end of the coil, and a housing of magnetizable material extending across the closed upper end of the plunger and down the outside of the coil to provide a flux path around the outside of the coil, said flange and housing being securely connected together and exerting longitudinal pressure on the plunger guide.

6. The solenoid described in claim 5 characterized by the flange and housing being connected with one another by screw threads and being movable longitudinally when rotated with respect to one another to screw them along the threads to adjust the compression imparted to the thin wall section of the plunger.

7. The solenoid described in claim 6 characterized by the threads being of sufficient strength and low enough pitch to compress the thin wall section to a stress in compression to offset a substantial part of the force of the fluid pressure against the closed end of the plunger and the tension effect that said fluid pressure in the plunger guide imparts to the thin wall section of the plunger guide.

8. The solenoid described in claim 3 characterized by the solenoid being a part of control means for regulating the flow of a high pressure fluid, and the guiding surfaces of the plunger guide being exposed to contact with the fluid that the solenoid controls and being subject to the pressure of that fluid, the metal of the plunger guide being one that is non-corrosive from contact with said fluid.

9. The solenoid described in claim 8 characterized by the plunger guide being stainless steel of the 300 series.

10. The solenoid described in claim 8 characterized by the plunger guide and other parts of the solenoid being of a strength to operate with fluid pressure in the plunger guide as high as 6000 pounds per square inch.

11. The solenoid described in claim 3 characterized by a sleeve of non-magnetizable material around the outside of the plunger guide and reinforcing the plunger guide against deformation by excessive hoop stresses by pressure fluid within the plunger guide and

7

exerted against the thin wall section.

12. The solenoid described in claim 3 characterized by the relatively fixed core at the upper end of the coil having a cylindrical portion that extends downward into the space surrounded by the coil, the closed upper end of the plunger guide contacting with the upper end of said cylindrical portion and constituting a functional

8

part of the core of the solenoid, and a compression spring between the plunger and the closed upper end of the plunger guide, said spring being held at one end in a recess in one of the confronting faces of the plunger and the closed upper end of the plunger guide.

* * * * *

10

15

20

25

30

35

40

45

50

55

60

65