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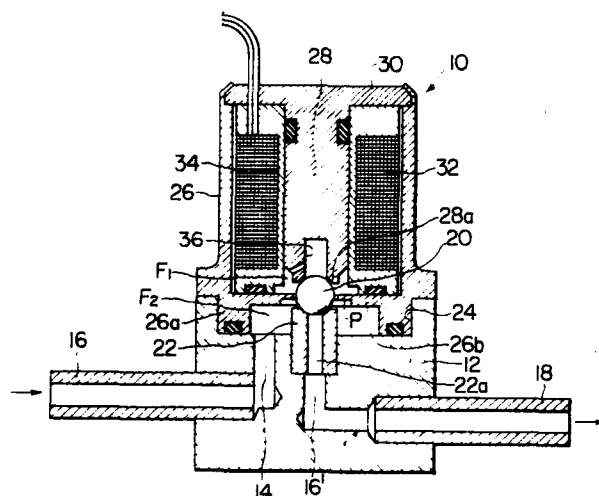
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54 **Electromagnetic valve for fluid flow control.**

57 An electromagnetic valve (10) for controlling fluid flow comprises a magnetic spherical valve member (20) movably disposed in a fluid chamber (F_1 , F_2) to which fluid is admitted, a non-magnetic valve seat member (22) on which the spherical valve member (20) is seatable, a main magnetic pole member (28a) disposed opposite the valve seat member (22) and in close proximity to the spherical valve member (20) to attract the valve member thereto, and a side magnetic pole member (P) disposed around the spherical valve member (20) and in close proximity to the valve member, the side magnetic pole member (P) being spaced from and between the level of the extreme end of the main magnetic pole member (28a) and the level of the extreme end of the valve seat member (22), so that a magnetic field formed between the main and side magnetic pole members (28a, P) effectively acts on the spherical valve member (20) so as to shorten the response time and stability in the action of the electromagnetic valve.



"ELECTROMAGNETIC VALVE FOR FLUID FLOW CONTROL"

This invention relates to an electromagnetic valve for controlling the amount of a fluid flow, and more particularly to an improvement of such an electromagnetic valve for controlling the amount of fuel flow supplied to an internal combustion engine used in automotive vehicle.

5 In connection with an electronically controlled fuel injection system for supplying sprayed fuel into the combustion chambers of an internal combustion engine, it is well known that a fuel injector of the fuel injection system is provided with an electromagnetic valve continuously repeating the opening and closing operation to control the flow amount of the fuel to be injected.

10 Such an electromagnetic valve is composed of a valve member which is elongate in its direction of movement and slidable in an elongate guide member, and requires to

15 be produced by high precision machining, for the purpose of maintaining an adequate fluid seal between the valve member and the guide member.

There has also been proposed an electromagnetic valve of the type wherein a spherical valve member seatable on a valve seat is used to control the flow amount of fuel supplied to an engine. The electromagnetic valve of this type has a significant advantage in that an adequate fluid seal can be maintained even if the valve seat

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is produced by press working. Therefore, such an electromagnetic valve does not require high precision machining and accordingly is advantageous in this regard as compared with the electromagnetic valve of the type
5 using the elongate valve member slidably disposed in the elongate guide member.

However, even such an electromagnetic valve using the spherical valve member encounters the following problems: The magnetic poles are not located such that
10 the magnetic field formed by the magnetic poles effectively acts on the spherical valve member. Consequently, the electromagnetic valve of this type has a defect in that the response time becomes prolonged to reduce the response characteristics. Additionally, the biasing force of a
15 spring biasing the spherical valve member does not always act vertically or in the direction of the valve seat and accordingly the valve member unavoidably moves laterally to cause unstable opening and closing action of the valve member, contributing to the reduction in
20 high precision control of the amount of fuel flow.

The present invention contemplates overcoming problems encountered in conventional and already proposed electromagnetic valves, by locating a side magnetic pole on which the magnetic force of a main magnetic pole is
25 concentrated, in close proximity to a spherical valve member as far as possible within a range in which the spherical valve member never contacts the side magnetic pole even when moved in the direction thereof.

It is a main object of the present invention
30 to provide an improved electromagnetic valve which is high in the response characteristics and stability in opening and closing action as compared with various conventional and already proposed electromagnetic valves, making possible high frequency opening and closing and
35 improving the durability of the electromagnetic valve.

It is another object of the present invention to provide an improved electromagnetic valve the response time of which is considerably shortened by so locating a main magnetic pole and a side magnetic pole that the magnetic field formed between the main and side magnetic poles effectively acts on a magnetic spherical valve member.

It is a still another object of the present invention to provide an improved electromagnetic valve in which a spherical valve member can be firmly seated on a valve seat within a very short period of time when required, because the valve is constructed and arranged to generate force biasing the spherical valve member toward the valve seat.

It is a further object of the present invention to provide an improved electromagnetic valve in which a main magnetic pole and a valve seat are so formed that the lateral movement of a spherical valve member is restricted and the valve member is guided to be correctly seated on the contact surfaces therefor.

It is a still further object of the present invention to provide an improved electromagnetic valve which is suitable for use in an electronically controlled fuel injection system which requires a very short response time and precise control of the amount of fuel flow.

In the accompanying drawings:-

Fig. 1 is a cross-sectional view of a preferred embodiment of an electromagnetic valve in accordance with the present invention;

Fig. 2 is a fragmentary enlarged sectional view of an essential part of the electromagnetic valve of Fig. 1, showing an example of a main magnetic pole;

Fig. 3A is a bottom plan view of another example of the main magnetic pole, as viewed from the direction of a spherical valve member;

Fig. 3B is a cross-sectional view taken in the direction of the arrows substantially along the line II-II; and

Fig. 4 is a cross-sectional view of an essential part of an already proposed electromagnetic valve.

Referring now to Figs. 1 and 2 of the drawings, there is shown a preferred embodiment of an electromagnetic valve 10 in accordance with the present invention, which is usable for controlling the amount of fuel flow supplied to an internal combustion engine for an automotive vehicle, though not shown. The electromagnetic valve 10 is composed of a base member 12 which is formed with a fluid inlet passage 14 into which a fluid is introduced through an inlet pipe 16. The base member 12 is further formed with a fluid outlet passage 16 from which the fluid is discharged out of the valve 10 through an outlet pipe 18.

A spherical valve member 20 made of magnetic material is seatable on a valve seat member 22. The valve seat member 22 is made of non-magnetic material and disposed such that a lower portion (no numeral) thereof is embedded in the base member 12 and an upper portion (no numeral) thereof projects into a recess 24 formed in the top section of the base member 12. The valve seat member 22 is generally cylindrical and formed with a passage 22a which forms part of the fuel outlet passage 16.

A generally cylindrical casing 26 is secured to the base member 12 in such a manner that a bottom section 26a thereof is securely and sealingly disposed in the recess 24. A magnetic core 28 is disposed in the casing 26 and integrally provided with a lid section 30 which closes an opening formed in the top section of the casing 26. An electromagnetic coil 32 is disposed around the outer periphery of the magnetic core 28 through a bobbin 34.

The magnetic core 28 is formed with a tip portion

28a which serves as a main magnetic pole when electric current is supplied to the magnetic coil 32 and the magnetic core 28 is energized. The axis of the magnetic core 28 is aligned with that of the valve seat member 22a.

5 The core 28 is provided at its tip portion 28a with a valve contact surface S_1 which is located opposite to a valve contact surface S_2 of the valve seat member 22. It is to be noted that the valve member 20 is movably located between the contact surfaces S_1 and S_2 and the
10 stroke of the valve member 20 in the upward and downward directions is restricted by the contacting surfaces S_1 and S_2 .

The casing 20 is formed with a radial annular section 26b which surrounds the valve member 20. The inner
15 peripheral portion P of the annular section 26b is spaced from and between the level of the extreme end of the tip portion 28a of the magnetic core 28 and the level of the extreme end of the tip portion of the valve seat member 22. Additionally, the inner peripheral portion P lies
20 as near as possible to the valve member, but never contacts the valve member 20. The radial annular section 26b is so arranged that the axes of the magnetic core 28 and the valve seat member 14 are perpendicular to the flat surface (no numeral) of the radial annular section 26b.
25 It is to be noted that the inner peripheral portion P of the annular section 26b is made of magnetic material and serves as a side magnetic pole, so that magnetic field is formed between the tip portion 28a of the core 28 and the inner peripheral portion P.

30 As clearly shown in Fig. 2, the valve contacting surfaces S_1 and S_2 are frusto-conical or part-spherical. Accordingly, the lateral movement or the movement in the direction of the side magnetic pole P of the valve member is restricted as seen from one indicated in phantom in
35 Fig. 2. Furthermore, by virtue of the shapes of the

contacting surfaces S_1 and S_2 , the valve member 20 can be correctly seated on the contacting surfaces S_1 and S_2 . As clearly seen from Fig. 2, the tip portion 28a of the magnetic core 28 is formed with a hollow 36 and accordingly the tip portion 28a is formed in the cylindrical shape. The hollow 36 communicates through a passage 38 with an upper fuel chamber F_1 which communicates with a lower fuel chamber F_2 through an annular opening (no numeral) defined between the side magnetic pole P and the spherical valve member 20. The lower fuel chamber F_2 is defined between the recessed surface of the base member 12 and the surface of the bottom section 26a of the casing 26. It will be understood that the fuel in the fuel chambers F_1 and F_2 admitted into the fuel outlet passage 16 through the opening 22a of the valve seat member 22 when the valve member 20 separates from the valve contacting surface S_2 of the valve seat member 22.

The operation of the thus arranged electromagnetic valve will be now explained.

When electric current is not passed through the magnetic coil 32 and the magnetic core 28 is not energized, magnetic force does not act on the spherical valve member 20. At this time, the valve member 20 receives the pressure of the fluid introduced into the hollow 36 through the passage 38 in addition to the pressure of the fluid in the fluid chambers F_1 and F_2 . Accordingly, the valve member 20 is pushed downward in the drawing to be firmly seated on the surface S_2 of the valve seat member 22. As a result, the fluid in the fluid chambers F_1 and F_2 cannot flow to the fluid outlet passage 16.

On the contrary, when electric current is passed through the magnetic coil 32 and the magnetic core 28 is energized, a magnetic field is formed between the tip portion 28a (the main magnetic pole) of the magnetic

core 28 and the inner peripheral portion P (the side magnetic pole) of the annular portion 26b. Then, the magnetic force of the main magnetic pole 28a is concentrated on the side magnetic pole P as indicated by the lines a of magnetid force in Fig. 2. It will be understood that the magnetic force generated between the main magnetic pole 28a and the side magnetic pole P can effectively act on the spherical valve member, shortening the response time and improving the stability in the opening and closing actions of the valve.

By the action of thus generated magnetic force, the valve member 20 is moved upward in the drawing to be attracted to the main magnetic pole 28a. Then, the spherical valve member 20 is guided to the frusto-conical or part-spherical surfaces S_1 , and the lateral movement of the valve member 20 is effectively restricted by the co-operation of the surface S_1 and the surface S_2 . Accordingly, the spherical valve member 20 is correctly seated on the surface S_2 of the main magnetic pole 28a, preventing the vibration of the valve member 20 in the lateral direction or the direction of the side magnetic pole P. As a result, the fluid admitted to the fluid chambers F_1 and F_2 flows into the fluid outlet passage 16 through a clearance formed between the surface of the spherical valve member 20 and the contact surface S_2 and the valve seat member 22. The fluid introduced into the outlet passage 16 is supplied through the pipe 18 into a required position though not shown.

It will be understood that the pressure differential is generated between the upstream and downstream sides relative to the valve member 20 since the pressure at the clearance between the valve member 20 and the valve seat member 22 lowers by the fluid flow through the clearance. accordingly, the spherical valve member 20 receives the force to be pulled downward in the drawing due to the

above-mentioned pressure differential whenever the fluid flows.

When the passage of the electric current through the magnetic coil 32 is stopped, the magnetid force of the main magnetic pole 28a collapses. Then, the spherical valve member 20 is forced downward in the drawing by the action of the above-mentioned pressure differential so as to be seated on the contact surface S_2 of the valve seat member 22. At this time, the lateral vibration of the valve member 20 is effectively restricted by the co-operation of the surface S_2 and the surface S_1 , so that the fluid flow from the inlet passage 14 to the outlet passage 16 is stopped. It will be understood that, by virtue of the action to force the valve member downward in the drawing, a spring for forcing the valve member 20 downward can be omitted.

As mentioned above, in this case, the closing action of the valve member 20 can be achieved by the pressure differential generated due to the fluid flow through the clearance between the valve member 20 and the surface S_2 of the valve seat member 22 in addition to the pressure for admitting fluid, although such closing action of the valve member may be achieved by the action of a spring in conventional cases. Therefore, the arrangement described above can effectively prevent unstable behaviour of the spherical valve member 20 due to the inclined location of the valve member 20 and the vibration to the valve member 20, which greatly contributes to the improvement in response time and stability in the opening and closing actions of the spherical valve member 20.

Furthermore, at the opening of the valve member 20, the fluid adjacent the surface of the valve member 20 is easily introduced into the hollow 36 since the latter communicates through the passage 38 with the fluid chamber F_1 . This can effectively prevent a disadvantageous

damping effect on the valve member 20 due to the fluid adjacent the surface of the valve member which damping effect is liable to rise when the valve member 20 is seated on the surface S_1 of the main magnetic pole 28a at the beginning of the opening action of the valve member 20. Additionally, the adhesion of the valve member 20 onto the contact surface S_1 of the main magnetic member 28a is effectively prevented by the fluid supply from the hollow 36 and the passage 38. The sticking of the valve member 20 is liable to occur at the beginning of the closing action of the valve member 20, i.e., at the beginning of the downward movement of the valve member in the drawing. This can improve the response characteristics of the spherical valve member 20, contributing to the omission of a spring for forcing the valve member 20 downward.

Otherwise, as shown in Figs. 3A and 3B, the hollow 36 formed at the main magnetic pole 28a is replaceable with a plurality of grooves 40 formed on the contact surface S_1' of the main magnetic pole 28a. In this case, even when the spherical valve member 20 is firmly seated on the surface S_1' , the fluid is present in the grooves 40 which communicate with the fluid chamber F_1 , though not shown. It will be understood that, also with these grooves 40, the same effect as with the hollow 36 in Figs. 1 and 2 can be obtained.

While, in the embodiment of Figs. 1 and 2, both the contact surfaces S_1 and S_2 have been shown and described as formed frusto-conical or part-spherical, it will be appreciated that the contact surface S_1 of the main magnetic pole 28a may be flat as the distance between the surfaces S_1 and S_2 is within a range that the lateral movement of the spherical valve member 20 is restricted by the frusto-conical or part-spherical surface S_2 of the valve seat member 22. In the case

where the electromagnetic valve mentioned above is used for controlling fuel flow amount in an internal combustion engine, the stroke of the valve member 20 in the axial direction of the main magnetic pole 28 and the valve seat member 22 is preferably about 0.05 to 0.1 mm from the point of view of response characteristics and durability. For example, the stroke of the valve member 20 is about 0.075 mm when the diameter of the valve member 20 is 5 mm; the shortest distance between the side magnetic pole P and the valve member 20 which is correctly seated on the valve seat member is about 0.1 to 0.25 mm; the angle of the contacting surface S_1 (in cross-section in Fig. 2) with respect to a horizontal plane (not shown) is about 45 degrees; and the angle of the contacting surface S_2 (in cross-section in Fig. 2) with respect to the horizontal plane is about 35 to 45 degrees. It will be appreciated that the stroke of the valve member 20 may be so determined that a sufficient opening area can be obtained to attain the amount of fuel flow suitable for use.

Fig. 4 shows a known electromagnetic valve 50, for the purpose of comparing with that in accordance with the present invention. In this electromagnetic valve 50, a spherical valve member 52 disposed in a fluid chamber F_3 is biased by a spring 56 disposed at a central bore (no numeral) of a main magnetic pole 58, so that the valve member 52 can effectively be seated on a valve seat member 54. When the valve member 52 is attracted to the main magnetic pole 58 to be moved upward in the drawing, fluid admitted into a fluid inlet passage 60 flows into a fluid outlet passage 62 through a clearance formed between the surface of the valve member 52 and the valve seat member 54. It is to be noted a side magnetic pole 64 is located spaced from the spherical valve member 52 and beyond the valve seat member 54. Accordingly, a magnetic field formed between the main magnetic pole 58 and the

side magnetic pole 64 cannot effectively act on the spherical valve member 52 since the magnetic force of the main magnetic pole 58 is concentrated on the side magnetic pole 60 as indicated by the lines b of magnetic force in Fig. 4.

As will be appreciated, the electromagnetic valve of this type encounters the problem discussed in Background of the Invention due to the fact that the spherical valve member 52 is biased downward also by the action of the biasing force of the spring 56, in addition to the above-mentioned problem due to the location of the side magnetic pole 64.

However, it will be understood from the foregoing discussion, that such problems encountered in the known electromagnetic valve can be effectively solved by the arrangement in accordance with the present invention.

As seen from the foregoing, according to the present invention, the side magnetic pole P is located in close proximity to the spherical valve member 20 and therefore an effective magnetic field is formed relative to the spherical valve member 20, which improves the response characteristics and the stability in the opening and closing actions of the spherical valve member 20. Besides, since a spring for biasing the valve member 20 toward the valve seat member 22 is not used, inclination of the valve member 20 is prevented to improve the sealing ability by the valve member 20 and the stability of the action of the valve member 20, further improving the response characteristics of the opening action of the valve member 20. Such omission of the spring further contributes to an improvement in the durability of the electromagnetic valve, since the breakage of the spring does not occur. Moreover, since the spherical valve member 20 is not provided with a slidable portion it becomes possible to carry out the opening and closing actions of

the valve member 20 at a very high frequency, greatly contributing to an improvement in the durability of the electromagnetic valve.

5 In the case where the electromagnetic valve according to the present invention is used for controlling the amount of fuel flow in which high response characteristics, accuracy and stability are required from points of view of exhaust emission control and fuel economy, the electro-
10 magnetic valve according to the present invention is advantageous in productivity as compared with a conventional electronically controlled fuel injection system which is provided with an electromagnetic valve using a slidable elongate valve member and operated in response to the amount, intake air due to the fact such an elongate valve
15 member and its guide member require high precision machining in its production.

In this connection, although fuel injection is carried out at the rate of once per one engine revolution in the conventional fuel injection system, the electro-
20 magnetic valve according to the present invention makes it possible to inject fuel at the rate of a plurality of times per engine revolution, improving the mixing of fuel and intake air.

Now, in the case of a so-called single point fuel
25 injection system in which the fuel supplied to all engine cylinders is carried out by only a single fuel injector valve, it is necessary, for example, to inject fuel at least three times per engine revolution in a four cycle and six cylinder engine in which air intake takes place
30 three times per engine revolution. Accordingly, it will be understood that it is necessary that the frequency of the opening and closing actions of the valve be 300 Hz or more even when the maximum engine speed is 6000 rpm, and the amount fuel flow is in proportion to the pulse
35 widths of electric signals supplied to the electromagnetic

valve. It will be appreciated that such requirements
can be satisfied by the electromagnetic valve in
accordance with the present invention and therefore
the electromagnetic valve according to the present
5 invention is advantageous in this respect, as compared
with other electromagnetic valves.

CLAIMS

1. An electromagnetic valve (10), having a fluid chamber (F_1, F_2) into which a fluid is admitted, comprising:
a magnetic spherical valve member (20) disposed and movable within said fluid chamber;

a non-magnetic valve seat member (22) on which said spherical valve member is seatable, the fluid within said fluid chamber being dischargeable out of said electromagnetic valve through a clearance formed between said valve seat member and said spherical valve member;

a main magnetic pole member (28a) disposed opposite said valve seat member and in close proximity to said spherical valve member, said spherical valve member being able to be attracted to said main magnetic pole member; and

a side magnetic pole member (P) disposed around and in close proximity to said spherical valve member, said side magnetic pole being spaced from and between the level of the extreme end of said main magnetic pole member and the level of the extreme end of said valve seat member so that the magnetic field formed between said main and side pole members effectively acts on said spherical valve member.

2. An electromagnetic valve as claimed in claim 1, characterised in that there is provided means for generating a pressure differential between the upstream and downstream sides relative to said spherical valve member, so that said valve member is biased toward said valve seat member when the fluid flow through said clearance between said valve seat member and said spherical valve member.

3. An electromagnetic valve as claimed in claim 2, characterised in that said main magnetic pole member (28a)

and said valve seat member (22) are formed with valve contact surfaces (S_1, S_2) respectively, with which said spherical valve member is contactable, at least the valve contact surface of said valve seat member being concave to firmly receive said spherical valve member.

4. An electromagnetic valve as claimed in claim 3, characterised in that the valve contact surfaces (S_1, S_2) of said magnetic pole member and said valve seat member are concave, respectively.

5. An electromagnetic valve as claimed in claim 4, characterised in that each of the contact surface of said main magnetic pole member and the contact surface of said valve seat member is of frusto-conical shape.

6. An electromagnetic valve as claimed in claim 4, characterised in that each of the contact surface of said main magnetic pole member and the contact surface of said valve seat member is of part-spherical shape.

7. An electromagnetic valve as claimed in claim 3, characterised in that said main magnetic pole member (28a) is formed at its valve contact surface with a hollow (36) which communicates with said fluid chamber through a passage (38) formed through said main magnetic pole member.

8. An electromagnetic valve as claimed in claim 3, characterised in that said main magnetic pole member (28a) is formed at its valve contact surface (S_1') with a plurality of grooves (40) which communicate with said fluid chamber.

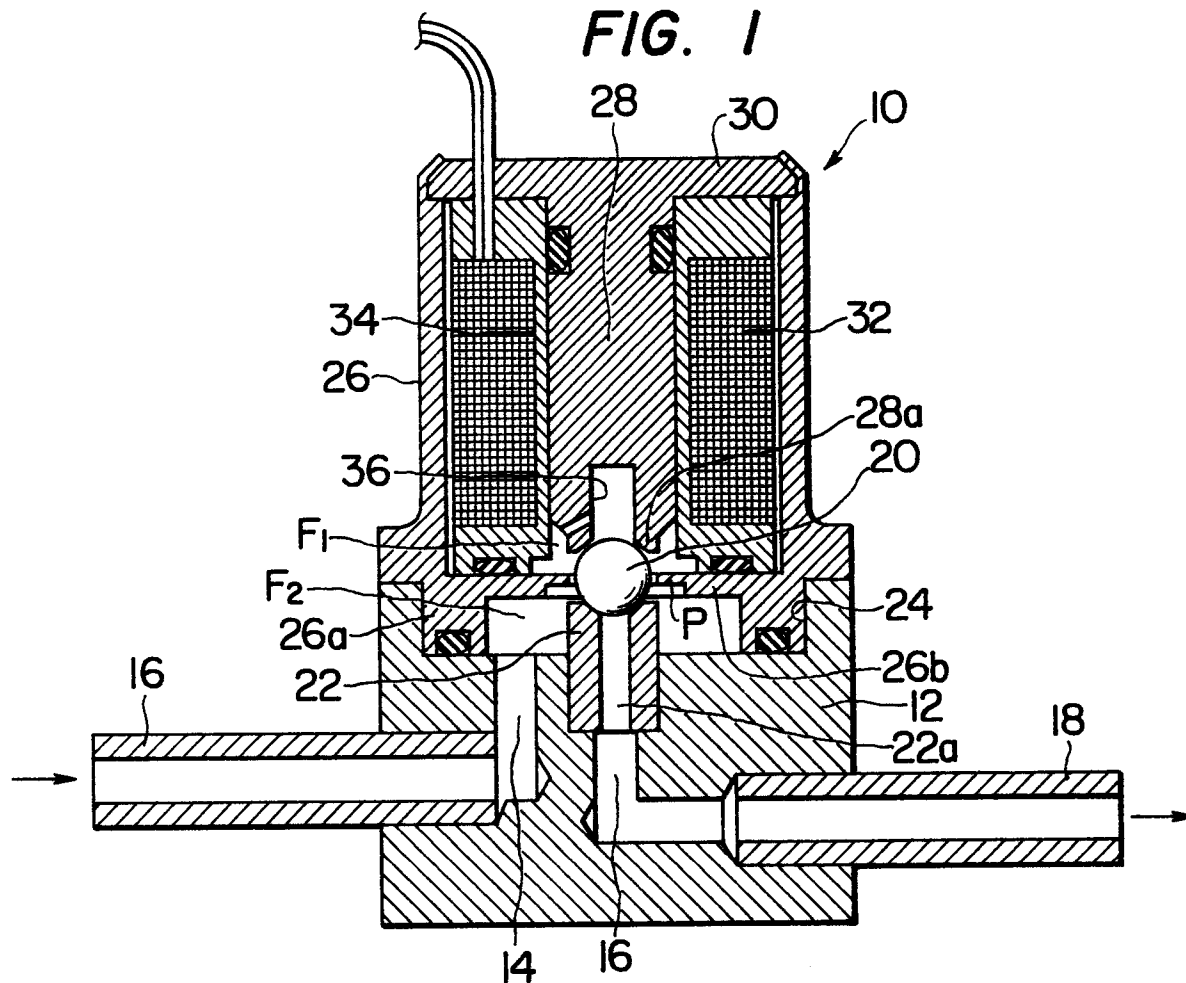
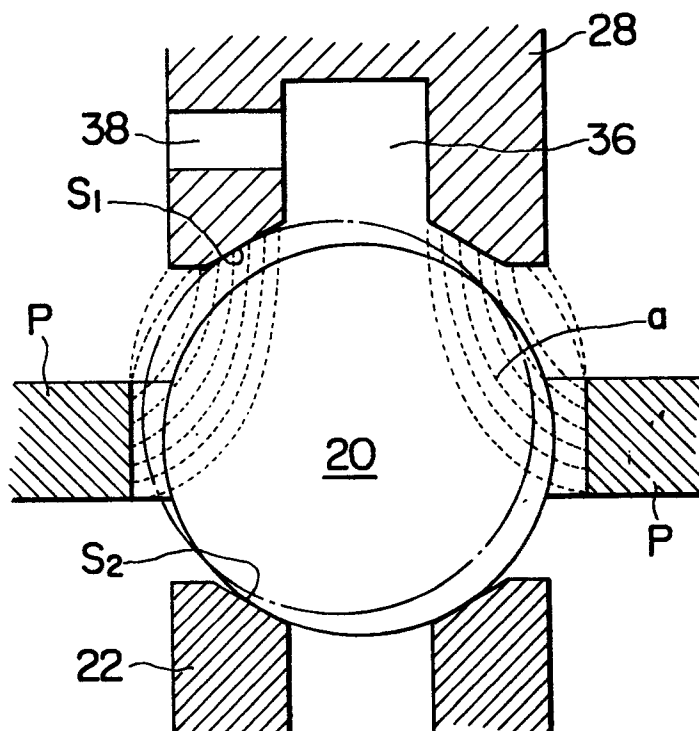
9. An electromagnetic valve as claimed in claim 7, characterised in that said valve seat member (22) is located substantially vertical and provided with an elongate opening (22a) formed along the axis of said valve seat member, the fluid in said fluid chamber being

dischargeable out of said electromagnetic valve through said elongate opening.

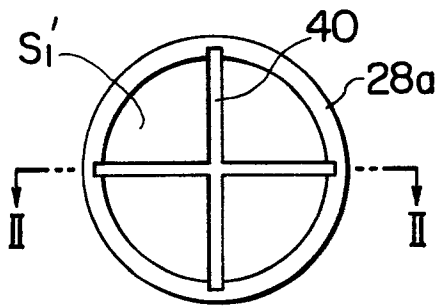
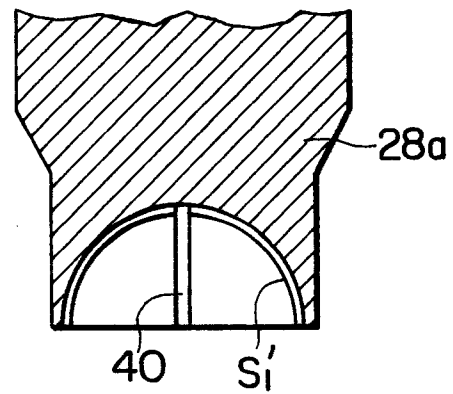
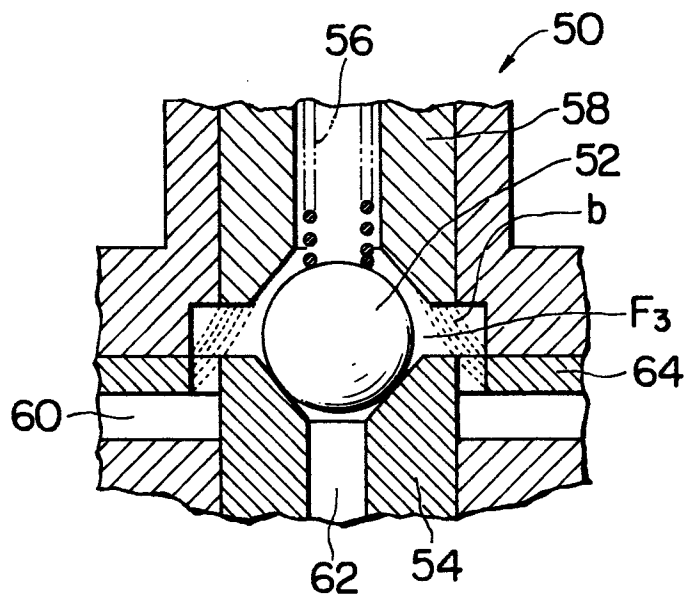
10. An electromagnetic valve as claimed in claim 9, characterised in that said main magnetic pole member (28a) is elongate substantially vertically, the axis of said main magnetic pole member being aligned with that of said valve seat member.

11. An electromagnetic valve as claimed in claim 10, characterised in that said side magnetic pole member is a magnetic radial annular member (P) which is integral with a casing (26) of said electromagnetic valve, said side magnetic pole member being so located that the axes of said main magnetic pole member and said valve seat member are perpendicular to the flat surface of said radial annular member.

12. An electromagnetic valve as claimed in claim 11, characterised in that said main magnetic pole member (28a) and said valve seat member (22) are spaced from each other by a distance such that the lateral movement of said spherical valve member is restricted so that said spherical valve member is prevented from contacting with the inner periphery of said magnetic radial annular member (P).

FIG. 1**FIG. 2**

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FIG. 3A**FIG. 3B****FIG. 4**



European Patent
Office

EUROPEAN SEARCH REPORT

0006769
Application number

EP 79 301 297.2

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	DE - A1 - 2 719 729 (PLESSEY AG) * pages 3 to 7, paragraph 1; page 11; fig., positions 4, 10, 16, 30 *	1-4, 7, 9-12	F 02 M 51/08
	DD - A - 97 026 (PETROL INJECTION LTD et al.) * page 2; fig. 1 *	1	
	DE - A - 2 300 458 (RENAULT et al.) * claim 1; fig. 1 *		TECHNICAL FIELDS SEARCHED (Int. Cl.)
			F 02 M 17/00 F 02 M 37/00 F 02 M 47/00 F 02 M 51/00 F 02 M 61/00 F 02 M 69/00
			CATEGORY OF CITED DOCUMENTS
			X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
			&: member of the same patent family, corresponding document
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
Berlin	27-09-1979	STÖCKLE	