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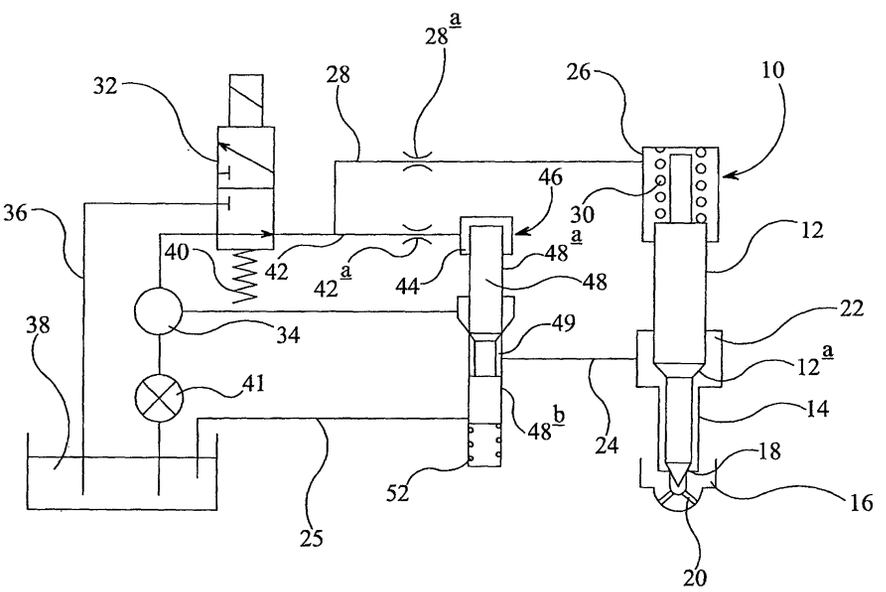
(54) Fuel system

(57) A fuel system comprising a fuel injector (10) having a delivery chamber (22) which is arranged to receive fuel from a source (34) of high pressure fuel and from which fuel is delivered to a combustion space upon initiation of injection, comprising first and second control chambers (26, 44) for receiving a control fluid, a three way control valve arrangement (32) which is operable to control fluid pressure within the first control chamber (26) so as to control fuel injection timing, and to control fluid pressure within the second chamber (44), and a shut-off valve arrangement (46) operable in response to fluid pressure variations within the second control chamber (44) so as to control the flow of fuel between the source (34) of high pressure fuel and the delivery chamber (22) of the injector. The three way control valve arrangement (32) is actuable between a first position in which the first control chamber (26) communicates with a source (34; 61) of control fluid at relatively high pressure and a second position in which the first control chamber (26) communicates with a low pressure control fluid reservoir (38; 60).

The invention provides the advantage that leakage of fuel into the engine cylinder or other combustion space of the associated engine is reduced as the flow of high pressure fuel into the delivery chamber (22) is terminated between successive injections of fuel.

FIG 1



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Description

[0001] The invention relates to a fuel system for use in delivering fuel to an internal combustion engine. In particular, the invention relates to a common rail fuel system comprising a common rail arranged to supply fuel under high pressure to a plurality of fuel injectors.

[0002] In a common rail fuel system, a common rail is charged with fuel at high pressure by means of a high pressure fuel pump, and is arranged to supply fuel to a plurality of fuel injectors for delivering fuel to the associated engine. In order to control the timing of fuel injection, it is known to use a two way control valve in the fuel system to control the pressure of fuel within a fuel injector control chamber. A surface associated with a valve needle of the injector is exposed to fuel pressure within the control chamber, the pressure of fuel within the control chamber applying a force to the valve needle which serves to urge the valve needle against a valve needle seating. When the valve needle is seated, fuel injection does not occur. When it is desired to commence injection, the control valve is actuated so as to cause a reduction in fuel pressure within the control chamber such that the valve needle is caused to lift away from its seating, permitting fuel within a delivery chamber to flow past the valve needle seating into the engine cylinder or other combustion space.

[0003] The control chamber communicates with the common rail through a restricted flow passage. The control valve controls communication between the control chamber and a low pressure fuel reservoir such that, when the control valve is closed a high pressure is established within the control chamber and when the control valve is open, fuel within the control chamber is able to drain to the low pressure fuel reservoir. During injection, fuel is able to flow at a restricted rate to the control chamber and from the control chamber to the low pressure reservoir. The system is inefficient, however, due to the presence of the fuel flow path between the source of high pressure fuel and the low pressure drain. By way of example, DE 4142739 describes a fuel system of the aforementioned type.

[0004] In known systems, high pressure fuel is often supplied continuously to the delivery chamber of the injector between successive injections. Thus, there is a hazard of leakage of fuel past the valve needle seating into the engine as a result of, for example, seat wear, seat damage due to debris, seizure of the valve needle in the open position or fracture of the nozzle body. The risk of engine damage is therefore increased and engine performance is impaired. Any such leakage of fuel into the engine cylinder between injections is a particular problem in larger engines for which the period between successive injections is relatively long.

[0005] Efficiency of the fuel system may be improved by replacing the two way control valve with a three way control valve arranged such that the control chamber communicates either with the source of fuel under pressure or with the low pressure fuel reservoir. Direct communication between the source of high pressure fuel and the low pressure fuel reservoir is therefore prevented, or restricted to the periods during which the control valve is being switched. However, the aforementioned hazard of fuel leakage past the valve needle seating into the engine cylinder is not avoided.

[0006] It is an object of the present invention to provide a fuel system in which at least one of the aforementioned disadvantages is removed or alleviated.

[0007] According to the present invention there is provided a fuel system comprising a fuel injector having a valve needle which is engageable with a valve needle seating to control fuel delivery from the injector and a delivery chamber which is arranged to receive fuel from a source of high pressure fuel and from which fuel is delivered to a combustion space upon initiation of injection, the fuel system comprising

first and second control chambers for receiving a control fluid, wherein a surface of the valve needle or a component carried thereby is exposed to fluid pressure within the first control chamber,

a three way control valve arrangement which is operable to control fluid pressure within the first control chamber so as to control fuel injection timing, and to control fluid pressure within the second chamber, and

a shut-off valve arrangement operable in response to fluid pressure variations within the second control chamber so as to control the flow of fuel between the source of high pressure fuel and the delivery chamber of the injector,

wherein the three way control valve arrangement is actuable between

a first position in which the first control chamber communicates with a source of control fluid at relatively high pressure and a second position in which communication between the source of control fluid and the first control chamber is broken and the first control chamber communicates with a low pressure control fluid drain or reservoir.

[0008] Movement of the valve needle away from the valve needle seating to initiate fuel injection is controlled directly by means of the three way valve arrangement, by operating the three way valve to control fuel pressure within the first control chamber at the back of the needle.

[0009] Preferably, the shut-off valve arrangement is arranged such that, when the control valve arrangement is in the second position, the shut-off valve arrangement is caused to move into an open position to permit fuel flow between the source of high pressure fuel and the delivery chamber.

[0010] The control fluid may, but need not, take the form of fuel to be injected by the injector.

[0011] The invention provides the advantage that, between successive injections of fuel, the shut-off valve arrangement terminates the flow of fuel into the delivery chamber of the injector. Thus, the risk of fuel leaking into the combustion space between injections is substantial-

ly eliminated.

[0012] The shut-off valve arrangement preferably includes a shut-off valve member exposed to fluid pressure within the second control chamber, wherein the shut off valve member is engageable with a seating to control delivery of fuel under high pressure to the delivery chamber, wherein the shut-off valve member is biased away from the seating by a force due to bias means, for example a spring, and whereby the flow of fuel from the source of fuel at high pressure to the delivery chamber is prevented when the shut-off valve member is seated against the seating.

[0013] Alternatively, the shut-off valve member may be biased into engagement with a seating by a force due to the bias means, the flow of fuel from the source of fuel at high pressure to the delivery chamber being prevented when the shut-off valve member is seated against the seating.

[0014] The system may be arranged such that the first control chamber selectively communicates with the source of control fluid at relatively high pressure through a first flow path provided with a first restriction.

[0015] The system may also be arranged such that the second control chamber selectively communicates with the source of control fluid at relatively high pressure through a second flow path provided with a second restriction.

[0016] The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a fuel system in accordance with a first embodiment of the present invention, and

Figure 2 is a schematic diagram of a fuel system in accordance with a second embodiment of the invention.

[0017] Referring to Figure 1, the fuel system includes a fuel injector, referred to generally as 10, comprising a valve needle 12 which is slidable within a bore 14 provided in a fuel injector nozzle body 16 (only a part of which is shown).

[0018] The bore 14 is shaped to define a valve needle seating 18 with which the valve needle 12 is engageable to control fuel delivery through a set of outlet openings 20 provided in the nozzle body 16. In practice, the valve needle 12 and the bore 14 within which the valve needle 12 moves are shaped such that movement of the valve needle 12 is guided by co-operation between a region of the valve needle 12 and an adjacent region of the bore 14.

[0019] The bore 14 is shaped to define a delivery chamber 22 for receiving high pressure fuel through a first supply passage 24. In use, when fuel under high pressure is delivered through the first supply passage 24 to the delivery chamber 22, a force is applied to a thrust surface 12a of the valve needle 12 which serves to urge the valve needle 12 away from the valve needle seating 18. At the end of the valve needle 12 remote from the outlet openings 20 of the injector, a surface of the valve needle 12, or a component carried by the valve needle 12, is exposed to fuel pressure within a first control chamber 26 housing a first spring 30, wherein the first control chamber 26 is in communication with a further supply passage 28. A force due to fuel pressure within the first control chamber 26 acts in combination with a force due to the first spring 30 to oppose the force applied to the thrust surface 12a of the valve needle 12 due to fuel pressure within the delivery chamber 22. By controlling fuel pressure within the control chamber 26, movement of the valve needle 12 towards and away from the valve needle seating 18 can be controlled so as to control the timing of initiation and termination of fuel injection.

[0020] Fuel pressure within the first control chamber 26 is controlled by means of a control valve arrangement 32 in the form of a three way control valve. The three way control valve 32 includes a second spring 40 which acts on a valve member (not shown) of the arrangement 32 to urge the three way control valve 32 into a first position (as shown in Figure 1). When in the first position, the three way control valve 32 is arranged such that fuel from a source 34 of fuel at high pressure is able to flow through the three way control valve 32, into the further supply passage 28 and through a first restriction 28a into the first control chamber 26. When the three way control valve 32 is moved to a second position, communication between the source 34 and the first control chamber 26 is broken and the further supply passage 28 is brought into communication with a flow path 36 to a low pressure drain or fuel reservoir 38. The provision of the first restriction 28a serves to limit the rate at which high pressure fuel can flow into the first control chamber 26 when the three way control valve 32 is in the first position, and the rate at which fuel is able to escape from the first control chamber 26 to the low pressure drain 38 when the three way control valve 32 is moved to the second position.

[0021] Typically, the three way control valve 32 may be an electromagnetically operated valve arrangement in which an armature is coupled to a control valve member, energisation and de-energisation of a winding causing movement of the armature and, hence, movement of the control valve member. It will be appreciated, however, that the control valve arrangement may be actuated by alternative means. The source 34 may take the form of a common rail supplied with fuel under high pressure by means of a high pressure fuel pump 41.

[0022] Not only does the three way control valve 32 control the flow of fuel into and out of the first control chamber 26, but the three way control valve 32 is also arranged to control the supply of fuel through an additional supply passage 42 to a second control chamber 44 associated with a shut-off valve arrangement, re-

ferred to generally as 46. The additional supply passage 42 is provided with a second restriction 42a which serves to limit the rate at which fuel is able to flow from the source 34 of fuel at high pressure to the second control chamber 44 when the control valve arrangement is in the first position, and the rate at which fuel is able to escape from the second control chamber 44 to the low pressure drain 38 when the three way control valve 32 is in the second position.

[0023] The shut-off valve arrangement 46 is arranged to control the supply of fuel from the source 34 to the first supply passage 24 and, hence, to the delivery chamber 22 of the fuel injector. The shut-off valve arrangement 46 includes a shut-off valve member 48 which is slidable within a further bore 49 defined in a shut-off valve housing. The further bore 49 is shaped to define a further seating 50 with which the shut-off valve member 48 is engageable. When the shut-off valve member 48 is seated against the further seating 50, fuel is unable to flow from the source 34, past the further seating 50, into the supply passage 24 and into the delivery chamber 22. When the shut-off valve member 48 is moved away from the further seating 50, fuel is able to flow from the source 34, through the shut-off valve arrangement 46 and into the supply passage 24 for delivery to the delivery chamber 22. The shut-off valve arrangement 46 includes a third spring 52 which biases the shut-off valve member 48 into an open position. In use, when it is desired to terminate the flow of fuel into the delivery chamber 22, fuel pressure within the second control chamber 44 is increased such that a force is applied to an end surface of the shut-off valve member 48 which serves to overcome the force due to the third spring 52, thereby urging the shut-off valve member 48 into engagement with the further seating 50.

[0024] In use, starting from circumstances in which the three way control valve 32 is in the first position, such that fuel under high pressure is supplied through the further supply passage 28 to the first control chamber 26 and through the additional supply passage 42 to the second control chamber 44, the valve needle 12 will be urged against the valve needle seating 18 due to the force of the spring 30 acting in combination with the force due to fuel under high pressure within the first control chamber 26. Additionally, the shut-off valve member 48 will be urged against the further seating 50 due to high fuel pressure within the second control chamber 44. High pressure fuel from the source 34 cannot therefore flow past the further seating 50, into the supply passage 24 and into the delivery chamber 22. As the valve needle 12 is seated against its seating 18, fuel injection does not take place.

[0025] In order to initiate injection, the three way control valve 32 is moved to the second position, thereby breaking communication between the source 34 of fuel at high pressure and the first and second control chambers 26, 44. Fuel within the first control chamber 26 is able to flow through the three way control valve 32 into the low pressure reservoir 38 such that fuel pressure within the first control chamber 26 is reduced. Movement of the three way control valve 32 into its second position also provides the effect of causing fuel pressure within the second control chamber 44 to be reduced as fuel is able to flow from the second control chamber 44 to the low pressure drain 38. As a reduced force acts on the end of the shut-off valve member 48 due to reduced fuel pressure within the second control chamber 44, the shut-off valve member 48 is urged away from the further seating 50 due to the force of the third spring 52, thereby causing fuel under high pressure to flow from the source 34, through the shut-off valve arrangement 46 and into the delivery chamber 22. The force applied to the thrust surface 12a of the valve needle 12 is therefore increased and a point will be reached at which the increased force applied to the thrust surface 12a is sufficient to overcome the reduced force applied to the surface of the valve needle 12 by fuel within the first control chamber 26 such that the valve needle 12 moves away from the valve needle seating 18. Fuel within the delivery chamber 22 is therefore able to flow past the valve needle seating 18 and through the outlet openings 20 into the engine cylinder or other combustion space.

[0026] When it is desired to terminate injection, the three way control valve 32 is moved into its first position such that communication between the first control chamber 26 and the low pressure drain 38 is broken and, in addition, communication between the second control chamber 44 and the low pressure drain 38 is broken. High pressure fuel from the source 34 is therefore able to flow through the three way control valve 32 into both the further supply passage 2, and hence into the first control chamber 26, and also through the additional supply passage 42 into the second control chamber 44. Increased fuel pressure within the second control chamber 44 serves to urge the shut-off valve member 48 against the further seating 50 to break communication between the source 34 and the delivery chamber 22. Additionally, increased fuel pressure within the first control chamber 26 acts in combination with the force due to the first spring 30 to overcome the reduced force applied to the thrust surface 12a of the valve needle 12 such that the valve needle 12 is urged against the valve needle seating 18 to terminate fuel injection.

The three way control valve 32 provides a common means for controlling both movement of the valve needle 12, by controlling fuel pressure within the first chamber 26, and for controlling movement of the valve member 48 of the shut off valve arrangement 46 by controlling fuel pressure within the second chamber 44. The three way control valve 32 has two states of operation, a first in which fuel pressure within the first chamber 26 is caused to be increased and fuel pressure within the second chamber 44 is caused to be reduced, and a second in which fuel pressure within the first chamber 26 is caused to be reduced and fuel pressure within the second chamber 44 is caused to be reduced. The system

is relatively simple in that only two valves 32, 46 are required (in addition to the valve needle of the injector) to control fuel injection, with operation of the shut off valve arrangement 46 and the valve needle 12 being controlled by a common control means in the form of the three way valve arrangement 32.

[0027] The present invention provides the further advantage that, between subsequent injections of fuel, the flow of high pressure fuel into the delivery chamber 22 is prevented by means of the shut-off valve arrangement 46. Any leakage of fuel into the engine cylinder between successive injections is therefore substantially eliminated. This provides a particular advantage in heavy duty systems where the period between successive injections of fuel is relatively long. The system is also advantageous in that, due to the provision of the three way valve 32 to control communication between the chambers 26, 44, the low pressure drain 38 and the source 34, the flow of high pressure fuel to the low pressure drain 38 is restricted to periods during which the control valve member 32 is being switched. Leakage of fuel to low pressure during fuel injection is therefore reduced and fuel consumption is improved.

[0028] The provision of the first spring 30 within the first control chamber 26 ensures the valve needle 12 is urged against the valve needle seating 18 when the engine is not operational. It will be appreciated, however, that alternative bias means may be provided, if required. The arrangement of the first spring 30 within the first control chamber 26 substantially eliminates an additional leakage path to the low pressure drain 38, thereby reducing the parasitic loss of fuel to the low pressure reservoir.

[0029] In an alternative embodiment of the invention, the third spring 52 forming part of the shut-off valve arrangement 46 may be arranged within the second control chamber 44 to urge the shut-off valve member 48 against the further seating 50. By appropriate shaping of the shut-off valve member 48 to include an upper region 48a of enlarged diameter and a lower region 48b of reduced diameter, the system can still be operated as described previously as a sufficient force will be applied to the angled surfaces of the shut-off valve member 48 to urge the shut-off valve member 48 away from the further seating 50 when fuel pressure within the second control chamber 44 is reduced.

[0030] In a further alternative embodiment, the shut off valve arrangement 46 may be configured such that fuel pressure is increased within the chamber housing the spring 52 at the end of the valve member 48 remote from the chamber 44. Conveniently, this embodiment of the invention may include an outwardly opening valve needle, but it will be appreciated that an alternative arrangement of flow lines may be provided to enable this embodiment to be operated with an inwardly opening needle (as in Figure 1).

[0031] A further advantage of the present invention is that the valve needle 12 is urged against the valve needle seating 18 to terminate injection more rapidly due to high pressure fuel within the first control chamber 26 acting in combination with the force due to the first spring 30 and reduced fuel pressure within the delivery chamber 22. It will be appreciated that, when the three way control valve 32 is moved to the first position, the time at which the shut-off valve member 48 moves towards the further seating 50 relative to movement of the valve needle 12 towards the seating 18 can be optimised by careful selection of the dimensions of the first and second restrictions 28a, 42a provided in the further and additional supply passages 28, 42 respectively.

[0032] Figure 2 shows an alternative embodiment of the invention in which a separate control fluid is used to control the shut-off valve arrangement 46 and the fuel injector 10, rather than fuel from the source 34. Again, the three way valve 32 is operable to control fuel pressure in both the first chamber 26 and the second chamber 44 so as to control movement of both the valve needle 12 and the shut off valve member 48. A second pump 61 is arranged to draw the control fluid from a reservoir 60, the delivery of the control fluid to the further supply passage 28 and the additional supply passage 42 being controlled by means of the three way control valve 32. Fuel to be delivered through the first supply passage 24 to the delivery chamber 22 of the injector is supplied from the source 34, as described previously with reference to Figure 1.

[0033] Operation of the embodiment in Figure 2 is substantially the same as that for the embodiment shown in Figure 1. Thus, when the three way control valve 32 is in its first position, control fluid is able to flow into the further supply passage 28, and therefore into the first control chamber 26, and into the additional supply passage 42, and therefore into the second control chamber 44. In such circumstances, the shut-off valve member 48 is in engagement with the further seating 50 such that fuel under high pressure is not supplied from the source 34 to the first supply passage 24. Control fluid at relatively high pressure within the first control chamber 26 also serves to urge the valve needle 12 of the injector 10 against its seating 18.

[0034] When it is desired to commence injection, the three way control valve 32 is moved to its second position such that control fluid is unable to flow into the first and second control chambers 26, 44. Control fluid within the first control chamber 26 is able to flow through the three way control valve 32 into the reservoir 60 such that fluid pressure within the first control chamber 26 is reduced. Additionally, control fluid within the second control chamber 44 is able to flow through the three way control valve 32 to the reservoir 60 such that a reduced force acts on the end of the shut-off valve member 48 due to reduced fluid pressure within the second control chamber 44, the shut-off valve member 48 thereby being urged away from the further seating 50 to enable fuel from the fuel source 34 to flow into the first supply passage 24 for delivery to the delivery chamber 22. In such

circumstances, fuel injection takes place through the outlet openings 20, as described previously.

[0035] The embodiment of the invention shown in Figure 2 is particularly suitable for use in heavy duty engines, for example in marine engines, where the fuel to be injected into the engine combustion space has fluid properties, such as viscosity, which make it unsuitable for use as a control fluid. Typically, the control fluid may take the form of engine lubricating oil.

Claims

1. A fuel system comprising a fuel injector (10) having a valve needle (12) which is engageable with a valve needle seating (18) to control fuel delivery from the injector and a delivery chamber (22) which is arranged to receive fuel from a source (34) of high pressure fuel and from which fuel is delivered to a combustion space upon initiation of injection, the fuel system further comprising;
   first and second control chambers (26, 44) for receiving a control fluid, wherein a surface of the valve needle (12) or a component carried thereby is exposed to fluid pressure within the first control chamber (26),
   a three way control valve arrangement (32) which is operable to control fluid pressure within the first control chamber (26) so as to control fuel injection timing, and to control fluid pressure within the second chamber (44), and
   a shut-off valve arrangement (46) operable in response to fluid pressure variations within the second control chamber (44) so as to control the flow of fuel between the source (34) of high pressure fuel and the delivery chamber (22) of the injector,
   wherein the three way control valve arrangement (32) is actuable between
   a first position in which the first control chamber (26) communicates with a source (34; 61) of control fluid at relatively high pressure and a second position in which communication between the first control chamber (26) and the source (34, 61) of high pressure fuel is broken and the first control chamber (26) communicates with a low pressure control fluid reservoir (38; 60).

2. A fuel system as claimed in Claim 1, wherein the shut-off valve arrangement (46) is arranged such that, when the three way control valve arrangement (32) is in the second position, the shut-off valve arrangement (46) is moved into an open position to permit communication between the source (34) of high pressure fuel and the delivery chamber (22).

3. A fuel system as claimed in Claim 2, wherein the shut-off valve arrangement includes a shut-off valve member (48) exposed to fluid pressure within the second control chamber (44) and engageable with a seating (50) to control delivery of fuel under high pressure to the delivery chamber (22), wherein the shut-off valve member (48) is biased away from the seating by a force due to bias means (52), and whereby the flow of fuel from the source (34) of fuel at high pressure to the delivery chamber (22) is prevented when the shut-off valve member (48) is seated against the seating (50).

4. A fuel system as claimed in Claim 2, wherein the shut-off valve arrangement includes a shut-off valve member (48) exposed to fluid pressure within the second control chamber (44) and engageable with a seating (50) to control delivery of fuel under high pressure to the delivery chamber (22), wherein the shut-off valve member (48) is biased into engagement with the seating (50) by a force due to bias means (52), and whereby the flow of fuel from the source (34) of fuel at high pressure to the delivery chamber (22) is prevented when the shut-off valve member (48) is seated against the seating (50).

5. A fuel system as claimed in Claim 3 or Claim 4, wherein the bias means (52) is arranged within the second control chamber (44).

6. A fuel system as claimed in any of Claims 1 to 5, wherein the first control chamber (26) selectively communicates with the source (34) of control fluid at relatively high pressure through a first flow path (28) provided with a first restriction (28a).

7. A fuel system as claimed in any of Claims 1 to 6 wherein the second control chamber (44) selectively communicates with the source (34; 61) of control fluid at relatively high pressure through a second flow path (42) provided with a second restriction (42a).

8. A fuel system as claimed in an of Claims 1 to 7, wherein the control fluid takes the form of the fuel to be delivered to the combustion space.

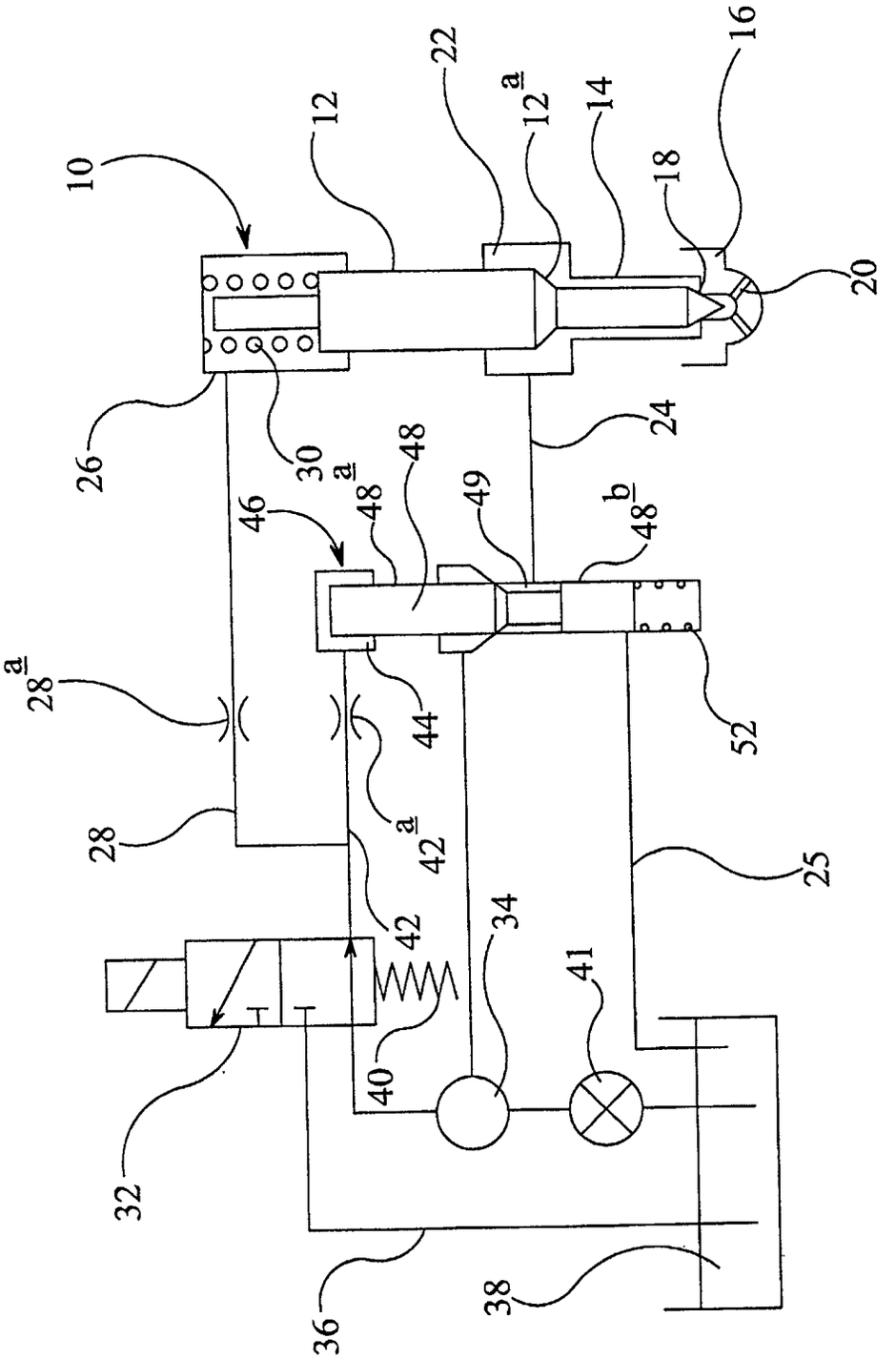
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FIG 1

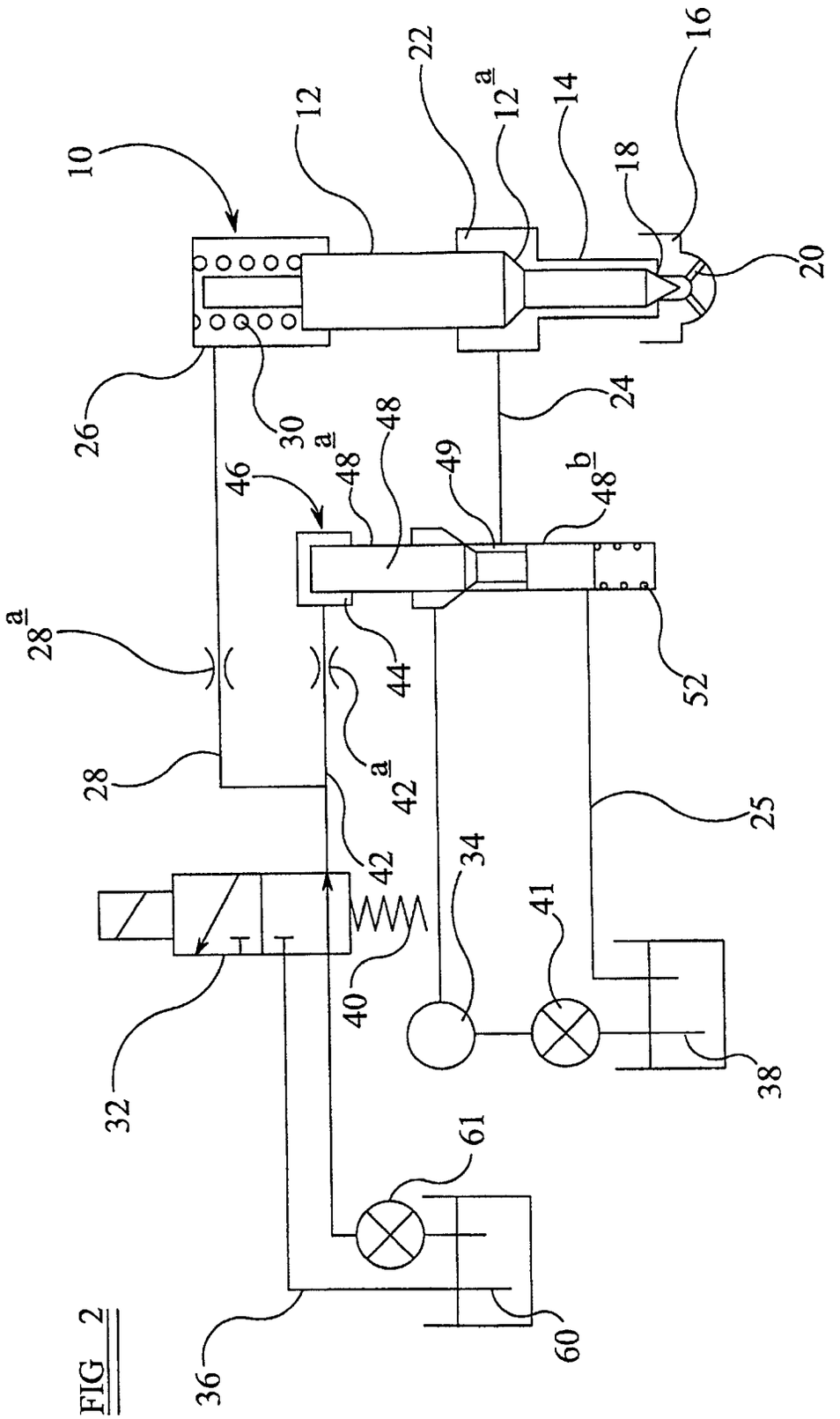
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FIG 2