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(54) **FUEL PUMP**

(75) Inventors: **Pierre Bouchauveau**, Blois; **Dany Guillot**, Huisseau/Cosson; **Claude Leveque**, Mont Pies Chambord, all of (FR)

(73) Assignee: **Delphi Technologies Inc.**, Troy, MI (US)

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(51) **Int. Cl.**^{7} **F02M 41/00**; F02M 37/04
(52) **U.S. Cl.** **123/458**; 123/506; 123/450
(58) **Field of Search** 123/450, 458, 123/506, 511

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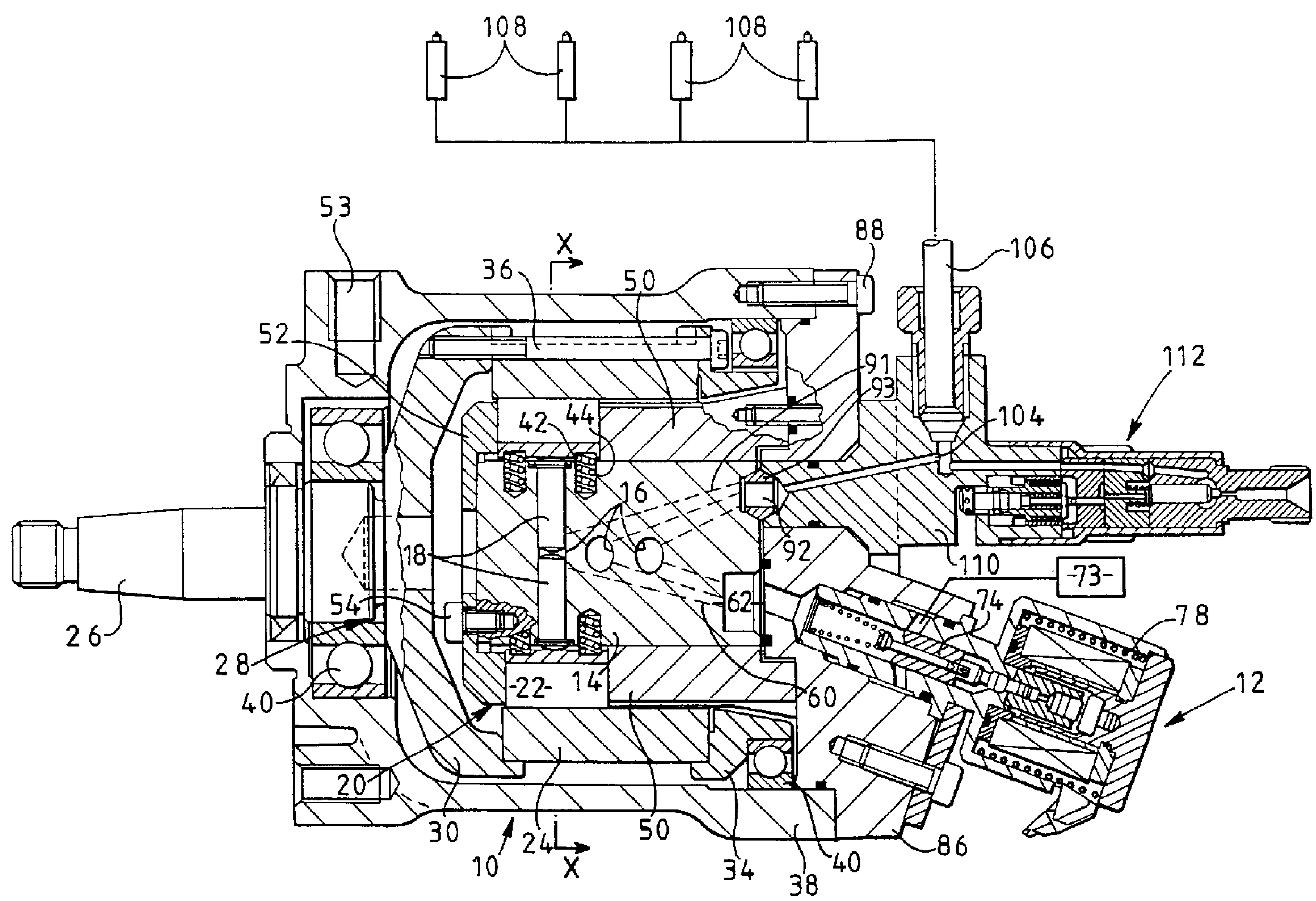
Primary Examiner—Thomas N. Moulis
(74) *Attorney, Agent, or Firm*—Cantor Colburn LLP

(57) **ABSTRACT**

A fuel supply system for supplying fuel to the cylinders of an associated engine is disclosed. The system comprises a fuel pump for supplying high pressure fuel to a delivery line, a plurality of injectors connected to the delivery line and means operable to deliver fuel through the injectors to respective cylinders of an associated engine, and a control valve connected to the delivery line and operable to control the pressure of fuel within the delivery line.

9 Claims, 5 Drawing Sheets



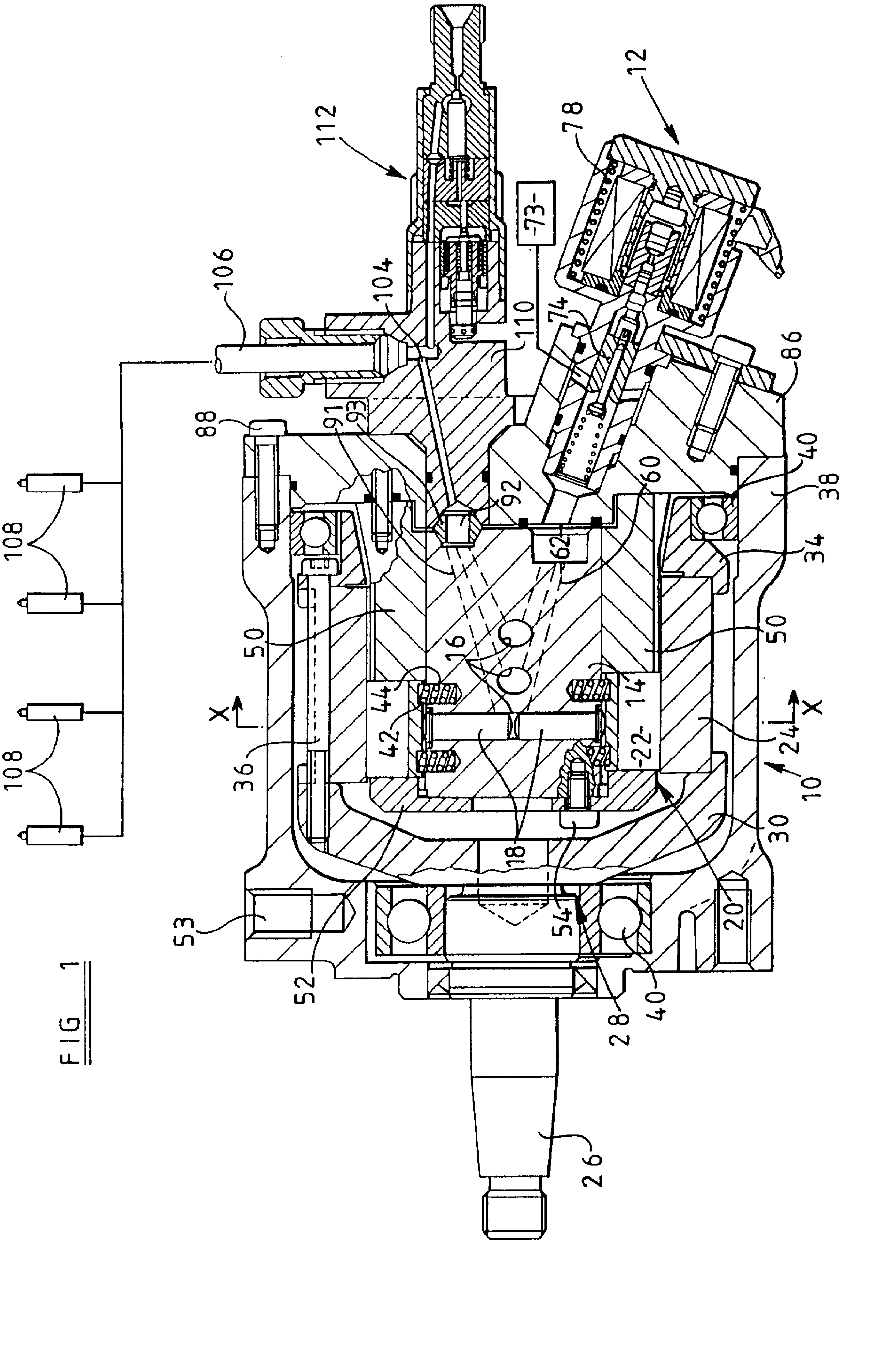

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FIG 1

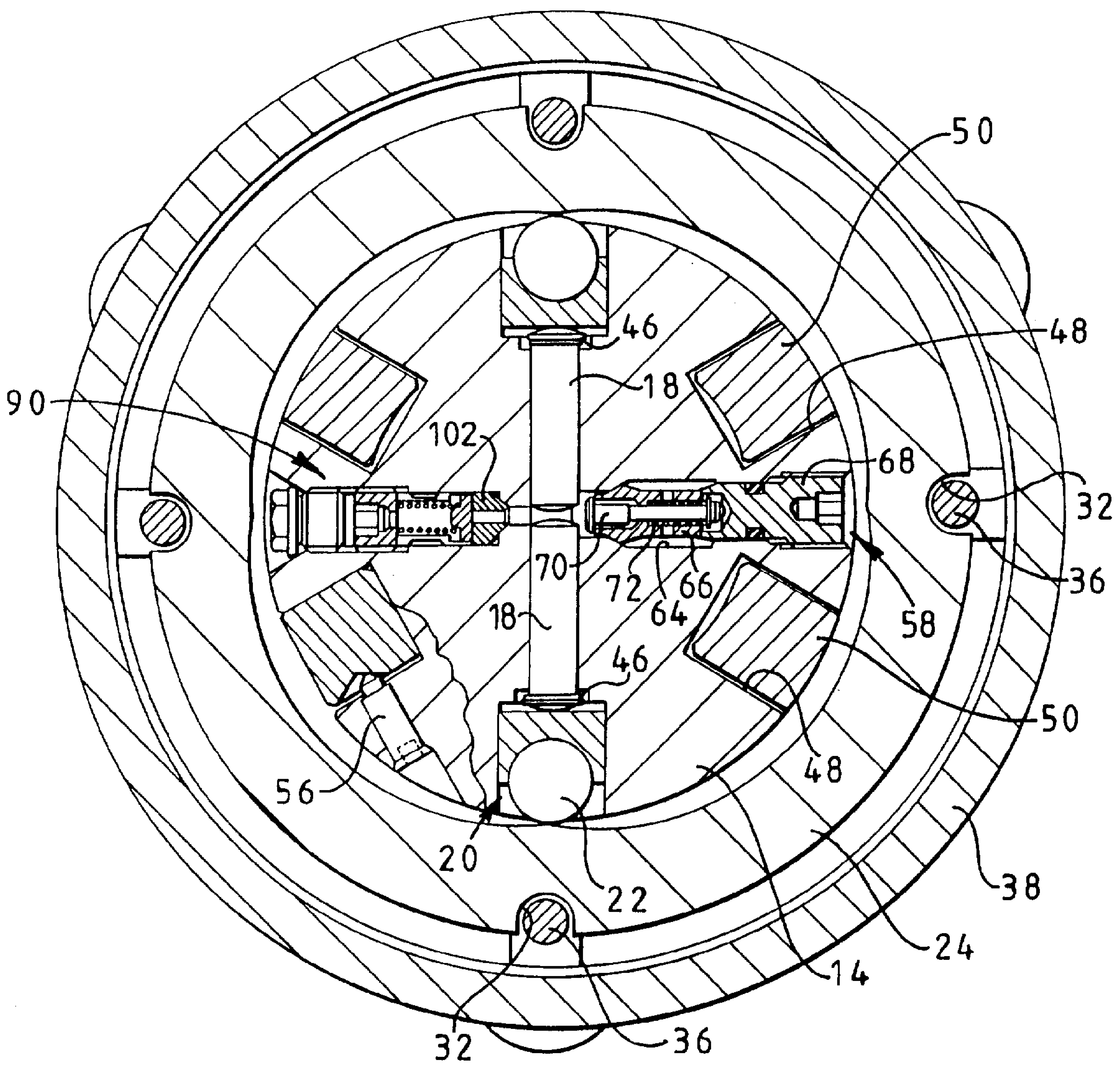
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FIG 2

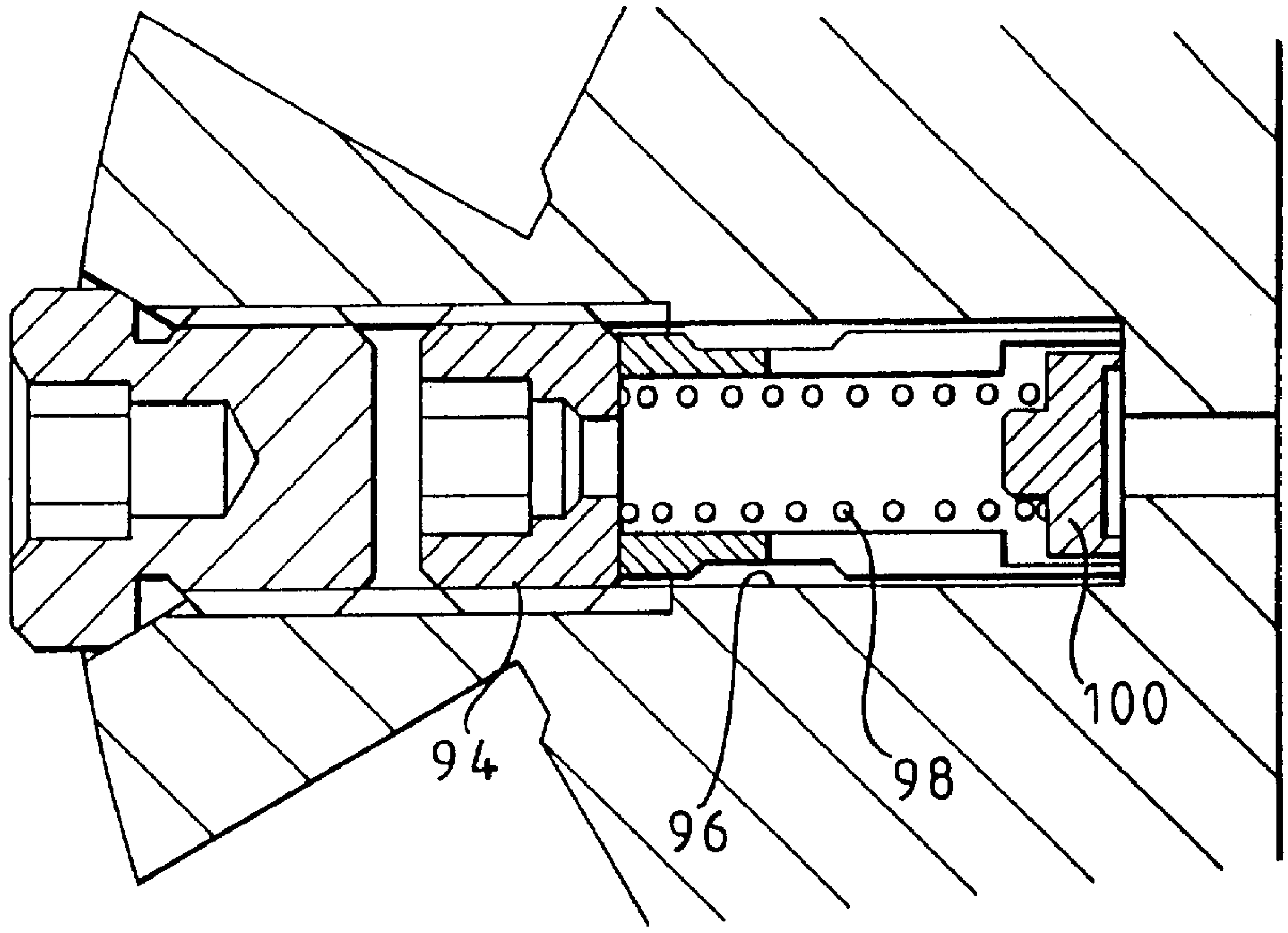

FIG 3

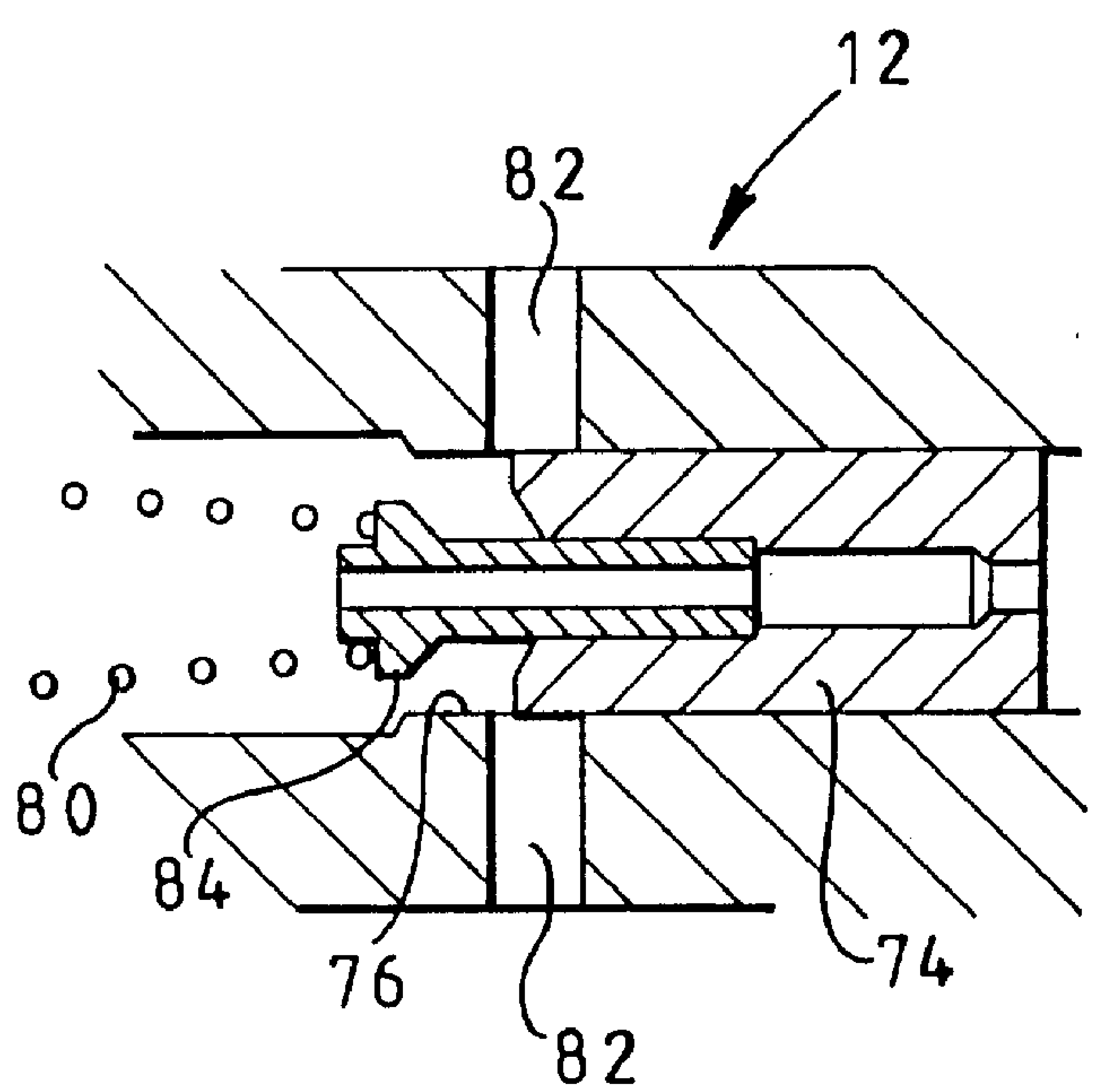

FIG 5

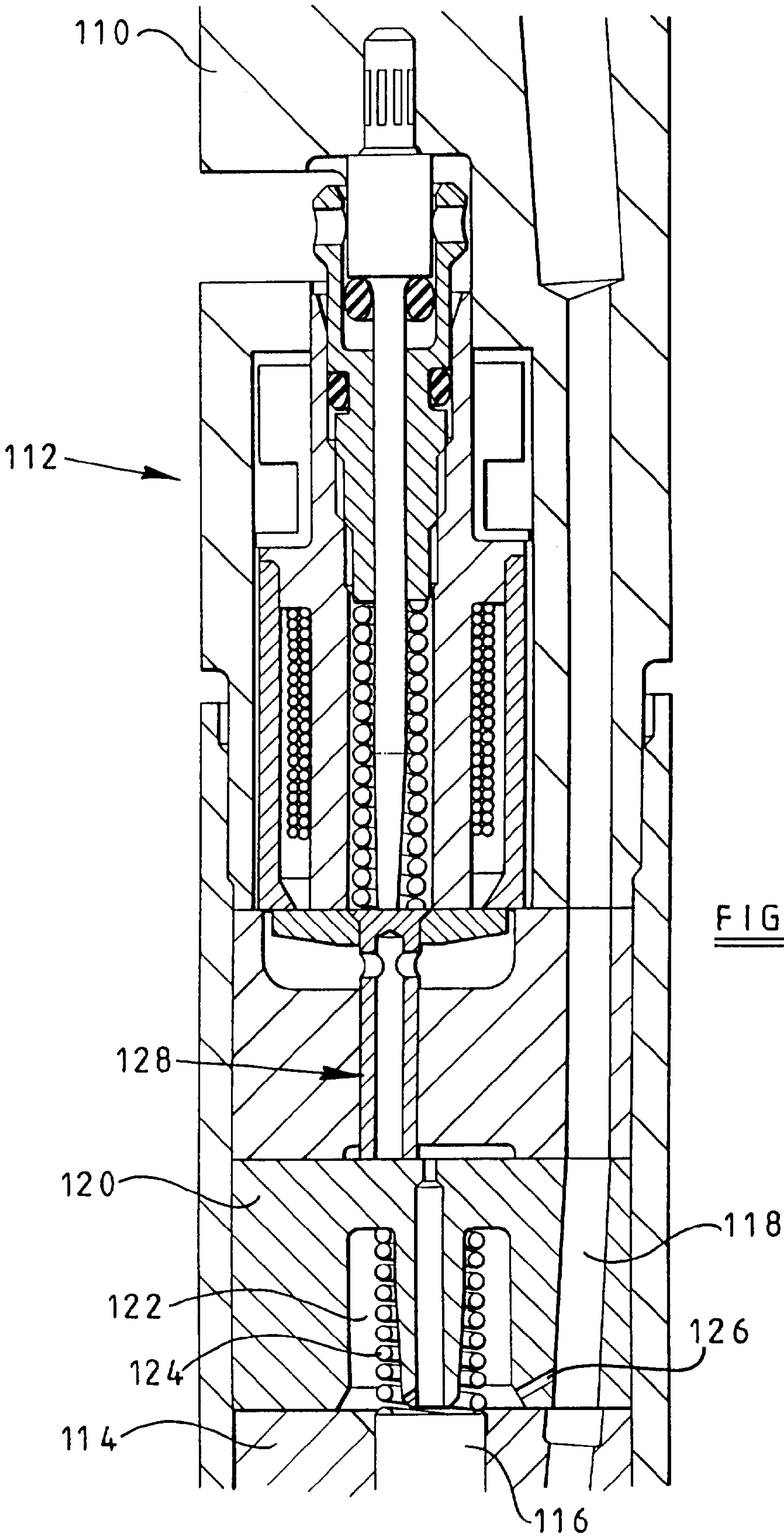

FIG 4

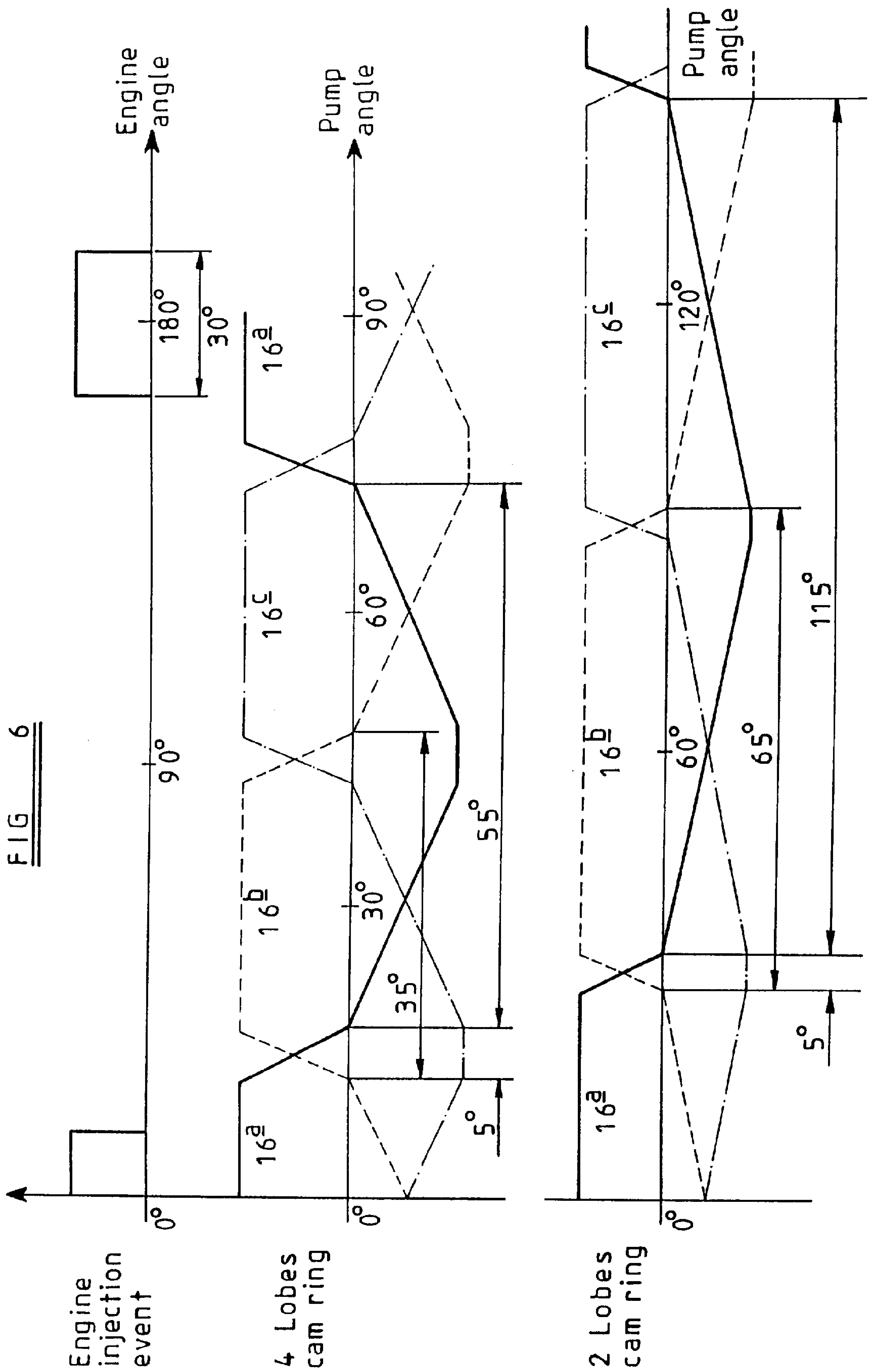
Engine injection event
4 Lobes cam ring
2 Lobes cam ring
Engine angle
Pump angle
Pump angle
0°
90°
180°
30°
16a
16b
16c
30°
60°
90°
35°
55°
5°
60°
120°
65°
115°
5°

FIG 6

FUEL PUMP

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This invention relates to a system for supplying fuel at high pressure to the cylinders of an internal combustion engine. In particular, this invention relates to a fuel supply system of the type in which a fuel pump is arranged to supply fuel at high pressure to a delivery line in order to maintain the delivery line at high pressure. A plurality of injectors are connected to the delivery line, the injectors being individually controllable in order to inject fuel from the delivery line to the cylinders of an associated engine.

According to the present invention there is provided a fuel supply system comprising a fuel pump for supplying high pressure fuel to a delivery line, a plurality of injectors connected to the delivery line and means operable to deliver fuel through the injectors to respective cylinders of an associated engine, and a control valve connected to the delivery line and operable to control the pressure of fuel within the delivery line.

The fuel supply system conveniently further comprises a fuel control arrangement for controlling the supply of fuel to the fuel pump.

Preferably, the fuel pump is arranged to supply a relatively high number of pulses of high pressure fuel to the delivery line per operating cycle of the pump. Such an arrangement is advantageous in that the fuel pressure in the delivery line remains at a relatively uniform level, in use.

The invention will further be described, by way of example, with reference to the accompanying drawings, in which:

FIG. **1** is a diagrammatic cross-sectional view of a fuel supply system in accordance with an embodiment of the invention;

FIG. **2** is a cross-sectional view along the line **2—2** of FIG. **1**;

FIG. **3** is an enlarged view of a modification to a part of FIG. **2**;

FIG. **4** is an enlarged view of part of FIG. **1**;

FIG. **5** is an enlarged view of another part of FIG. **1**; and

FIG. **6** is a cam rate diagram relating to the embodiment of FIG. **1**.

The fuel supply system illustrated in the accompanying drawings comprises a fuel pump **10** to which fuel is supplied through a throttle arrangement **12**. The fuel pump **10** comprises a generally cylindrical pump body **14** provided with three through bores **16**a, **16**b, **16**c. The through bores **16** are axially spaced from one another, and are angularly spaced from one another by 60°. Two pumping plungers **18** are provided in each of the through bores **16**, the plungers **18** being arranged to be reciprocable in the through bores **16**. The outer end of each plunger **18** is arranged to engage a shoe and roller arrangement **20** the roller **22** of which is arranged to engage the cam surface of a rotary cam ring **24**, the cam ring **24** including four equiangularly spaced cam lobes as shown in FIG. **2**.

The cam ring **24** is connected to a drive shaft **26** which is arranged to be driven at a speed associated with engine speed, the drive shaft **26** being provided with a reduced diameter region **28** such that should the fuel pump **10** seize, the reduced diameter region **28** will shear thus restricting damage resulting from the seizure of the fuel pump **10**.

The end of the drive shaft **26** facing the cam ring **24** is provided with an outwardly extending flange **30** which,

adjacent its periphery, is provided with four equiangularly spaced, axially extending, screw threaded passages. The outer peripheral surface of the cam ring **24** is provided with four grooves **32** (see FIG. **2**), each groove **32** aligning with one of the passages provided in the drive shaft flange **30**. An annular support member **34** abuts the end of the cam ring **24** remote from the drive shaft **26**, the member **34** and cam ring **24** being secured to the drive shaft **26** by means of four bolts **36**, each bolt **36** extending through an aperture provided in the member **34**, one of the grooves **32** provided in the cam ring **24** and engaging with the screw threads provided in the threaded passages of the drive shaft flange **30**. The drive shaft **26** and member **34** are supported for rotation within a housing **38** by suitable bearings **40**.

Each of the shoe and roller arrangements **20** is biased into engagement with the cam surface of the cam ring **24** by means of springs **42** housed within bores **44** provided in the pump body **14**, the springs **42** conveniently taking the form of conical helical springs. In order to avoid excessive inward movement of the plungers **18**, particularly when the pump has been at rest for some time, the outer end of each plunger **18** is provided with a recess within which a circlip **46** engages (see FIG. **2**), the circlips **46** being arranged to engage the pump body **14** in order to limit inward movement of the plungers **18**.

In order to maintain the alignment of the shoe and roller arrangements **20** with the plungers **18**, in use, the pump body **14** is provided with six equiangularly spaced, axially extending grooves **48** as shown in FIG. **2**. Each groove **48** houses one of the shoe and roller arrangements **20** thus restricting angular movement of the shoe and roller arrangements **20**. In order to restrict axial movement of the shoe and roller arrangements **20**, the parts of each groove **48** not occupied by the shoe and roller arrangements **20** are filled by means of insert pieces **50**. The insert pieces **50** on the drive shaft side of each shoe and roller arrangement **20** are integral with an end cap **52** which is secured to the pump body **14** by means of bolts **54**. Individual insert pieces **50** are provided in the parts of each groove **48** on the side of each shoe and roller arrangement **20** remote from the drive shaft, these insert pieces **50** being secured in position by individual set screws **56** as shown in FIG. **2**.

Each of the through bores **16** is connected through respective inlet non-return valves **58** and individual passages indicated by dashed lines **60** in FIG. **1** to an inlet port **62** provided at the end of the pump body **14** remote from the drive shaft **26**. Each inlet valve **58** is provided within a respective bore **64** provided in the pump body **14**, the outer end of the bore **64** being screw threaded. The inner end of the bore **64** communicates with the respective through bore **16**, and is of reduced diameter, a valve body **66** sealingly engaging the surface of the bore **64**. The valve body **66** is secured within the bore **64** by means of a screw threaded member **68** which sealingly engages the screw threaded region of the bore **64**. The valve body **66** includes an axially extending passage within which a valve member **70** is reciprocable, the valve member **70** including, at its inner end, an enlarged head which is biased into engagement with a seating provided on the valve body **66** by means of a spring **72**.

The throttle arrangement **12** referred to hereinbefore communicates with the inlet port **62**. The throttle arrangement **12** includes a throttle member **74** which is axially adjustable within a bore **76** under the action of a solenoid actuator arrangement **78** which acts against a helical spring **80**, conveniently a conical spring. As illustrated in FIG. **5**, the throttle member **74** is moveable between a position in which it covers a plurality of inlets **82** which are arranged to receive fuel at a relatively low pressure from a suitable feed pump **73**, and a position in which the inlets **82** are open thus permitting fuel to flow through the throttle arrangement **12** to the inlet port **62**. The throttle member **12** includes an axially extending pin **84** defining a spring abutment with which the spring **80** engages to act against the solenoid. The pin **84** and throttle member **74** include axially extending passages which permit the fuel pressure to act upon both ends of the throttle member **74**, thus the throttle member **74** is substantially pressure balanced. The presence of the pin **84** avoids fuel from the inlets **82** jetting around the spring **80**, and thus avoids the instability that such jetting causes.

As illustrated in FIG. **1**, the throttle arrangement **12** is secured to an end plate **86** which is secured to the housing **38** by means of bolts **88**. Fuel from the feed pump **73** is also supplied to the interior of the housing **38** in order to provide lubrication for the bearings **40** and for the shoe and roller arrangements **20**. A port **53** is provided in the housing to permit excess fuel to escape from the housing **38**.

Each of the through bores **16** further communicates through respective outlet non-return valves **90** and passages denoted by dashed lines **91** in FIG. **1** with an outlet port **92** of the pump body **14**. The outlet valves **90**, as shown in FIG. **3**, each comprise a valve body **94** which is in screw threaded engagement within a bore **96** which is diametrically opposite the inlet valve **58** of a respective through bore **16**, the bore **96** communicating with the through bore **16**. The valve body **94** includes a hollow cylindrical region housing a spring **98** which engages a valve member **100**, biassing the valve member **100** into engagement with a seating formed in the bore **96**. FIG. **2** includes a modification to the outlet valve illustrated in FIG. **3**, the arrangement of FIG. **2** further including a seating member **102** which the valve member **100** engages and towards which the valve member **100** is biased. The valve body **94** in this arrangement includes a plurality of legs which engage with the seating member **102**, securing the seating member **102** within the bore **96** so as to form a seal between the seating member **102** and the pump body **14**.

The inlet and outlet valves **58, 90** are each located adjacent the through bores **16** in order to minimise the dead volume, and hence improve the efficiency of the pump. It will be recognised that the inlet and outlet valves may be replaced by any other suitable non-return valves.

The outlet port **92** communicates with a delivery passage **104** extending through the housing **110** of a control valve **112**, the passage **104** communicating, in turn, with a delivery line **106**. The connection between the outlet port **92** and the delivery passage **104** is subject to high pressure, and in order to ensure that a good seal is formed therebetween, a deformable olive **93** is provided in the outlet port **92**.

As illustrated schematically in FIG. **1**, the delivery line **106** communicates with a plurality of injection nozzles **108** each of which is arranged to supply fuel from the delivery line **106** to a cylinder of an associated engine.

As illustrated in FIGS. **1** and **4**, the control valve **112** comprises a generally cylindrical valve body **114** having a bore extending therethrough, a valve member **116** being axially movable within the bore and engageable with a seating provided within the bore. The bore includes an annular gallery, the part of the valve member **116** extending within the gallery including an angled thrust surface against which high pressure fuel from the delivery passage **104** can act tending to lift the valve member **116** from the seating, high pressure fuel from the delivery passage **104** being supplied to the gallery through a supply line **118**.

A distance piece **120** abuts the end of the valve body **114**, the distance piece **120** defining a spring chamber **122** housing a spring **124** arranged to act against the end of the valve member **116** to bias the valve member **116** into engagement with the seating. The spring chamber **122** is supplied with fuel from the supply line **118** through a restricted passage **126**. A solenoid actuated valve arrangement **128** communicates with the spring chamber **122** so that, on energization thereof, fuel from the spring chamber **122** escapes to a suitable low pressure drain thus the pressure of fuel acting on the end of the valve member **116** is reduced. Such a reduction in pressure results in a condition being reached beyond which the pressure of fuel acting against the thrust surface is sufficient to lift the valve member **116** from its seating against the action of the spring **124** and the force due to the pressure of fuel within the spring chamber **122**. Once such movement of the valve member **116** has taken place, fuel from the delivery passage **104** can escape through the control valve **112** to a suitable low pressure drain.

When the solenoid actuator of the valve arrangement **128** is de-energised, the solenoid actuated valve **128** closes, thus the pressure of fuel within the spring chamber **122** rises, and a condition is reached beyond which the pressure within the spring chamber **122** and the spring force acting on the valve member **116** are sufficient to move the valve member **11 6** into engagement with the seating. Bleeding of fuel through the control valve **112** is therefore terminated.

Such a control valve **112** has a relatively fast response time, and in use it is operated to maintain the fuel pressure within the delivery line **106** at a relatively uniform level. If the pressure of fuel within the delivery line **106** exceeds a predetermined level, the control valve **112** is operated to allow fuel to escape therethrough until the pressure has fallen to an acceptable level.

In use, an appropriate quantity of fuel from the feed pump **73** is supplied through the throttle arrangement **12** to the inlet port **62** of the pump body **14**. As shown in FIGS. **1** and **2**, one of the pairs of plungers **18** occupies its innermost position. Rotation of the cam ring **24** results in the rollers **22** associated with these plungers **18** riding down the trailing flanks of the cam lobes, the shoe and roller arrangements **20** being biased outwardly by the springs **42**. The fuel supplied to the inlet port **62** flows along the passages **60**, through the inlet valve **58**, the pressure of the fuel supplied by the feed pump **73** being sufficient to move the valve member **70** against the action of the spring **72**, and enters the through bore **16** pushing the plungers outwardly.

Continued rotation of the cam ring **24** results in the next of the cam lobes engaging the shoe and roller arrangements **20** pushing the shoe and roller arrangements **20**, and hence the plungers **18**, inwardly. The inward movement of the plungers pressurizes the fuel within the through bore **16** such that the inlet valve **58** closes, the fuel being pumped out of the through bore **16** through the outlet valve **90**. The fuel is supplied to the outlet port **92** of the pump body **14** through the passages **91** where it is supplied through the delivery passage **104** to the delivery line **106**.

The other pairs of plungers **18** function in the same manner as described above, but are out of phase with the above described pair of plungers with the result that for each complete revolution of the cam ring **24**, twelve pulses of fuel are supplied to the outlet port **92**. The supply of such a relatively large number of pulses, a relatively small quantity of fuel being supplied in each pulse, results in the pressure of fuel within the delivery line remaining substantially constant.

Although the illustrated embodiment includes three pair of plungers and a cam ring having four equiangularly spaced cam lobes, it will be recognised that other arrangements are possible, but it is preferable for the relationship between the number of plungers and cam lobes to be such that a relatively high number of pulses of fuel are supplied to the delivery line during each revolution of the cam ring. FIG. **6** is a typical cam rate diagram which illustrates that there is some overlap between the end of pumping from one of the bores **16** and the commencement of pumping from another of the bores **16**. FIG. **6** also includes a typical cam rate diagram for the case where the cam ring includes two cam lobes rather than four as described hereinbefore.

The supply of twelve pulses of fuel to the delivery line **106** per revolution of the cam ring **24** permits several pulses of fuel to be supplied between each injection of fuel to the cylinders of an associated engine. Conveniently, the fuel supply system is arranged such that one of the pulses is supplied at the commencement of each injection of fuel to the engine. Such an arrangement improves control of the pressure of fuel within the delivery line **106**, particularly when the pump is operating below its maximum capacity.

In use, the throttle arrangement **12** is controlled so that the amount of fuel supplied therethrough is substantially equal to the quantity of fuel being delivered through the injection nozzles **108**. The pressure of the fuel within the delivery line **106** is therefore maintained at a relatively constant level, and it is envisaged that this system will operate with fuel at a pressure of approximately 1600 Bar.

The presence of the springs **42** results in the rollers **22** remaining in contact with the cam surface both when the pump is operating at its maximum pumping capacity and when smaller quantities of fuel are being pumped. It is advantageous for such contact to be maintained as it results in the pump operating more quietly than is the case where the rollers **22** are allowed to leave the cam surface, for example when the pump is not operating at its maximum capacity. The presence of the springs **42** is also advantageous as the weight of the shoe and roller arrangements **20** is carried, at least in part, by the springs **42**, thus the gravitational forces acting on the plungers due to the weight of the shoe and roller arrangements **20** are reduced.

Although the quantity of fuel supplied is controlled by the throttle arrangement **12**, and the relatively large number of pulses results in the delivery line **106** being at a substantially constant pressure, there may be occasions where the pressure in the delivery line **106** rises unacceptably. In these circumstances, the control valve **112** is operated as described hereinbefore to bleed fuel from the delivery line **106**, thus reducing the pressure until its falls within an acceptable range. In addition to, or as an alternative to,the control valve **1 12** acting as a trim valve as described hereinbefore, the control valve **112** may act as a safety release valve arranged to open when the pressure of fuel within the delivery line becomes unacceptably high in order to prevent or limit damage to the fuel supply system.

It will be recognised that the fuel system could operate without the throttle arrangement, the fuel pump being supplied with an unregulated supply of fuel, and hence operating at its maximum capacity at all times. The pressure of fuel within the delivery line would then regularly fall outside of the desired range, hence the control valve would be regularly bleeding fuel from the delivery line. It will be recognised that as this control valve bleeds fuel to a low pressure drain, such an arrangement would be inefficient compared to that described hereinbefore.

The injectors **108** may be of any suitable type, and are not described herein in detail. One particularly suitable type of valve is similar to the control valve described hereinbefore, the outlet of the valve defining a nozzle having one or more small apertures arranged to supply fuel to an injector of an associated engine. Alternatively, the injectors may be of the fuel pressure operable type, the supply of high pressure fuel thereto being controlled by a separate valve.

What is claimed is:

1. A fuel supply system comprising a fuel pump for supplying high pressure fuel to a common delivery line, a plurality of individually actuable injectors connected to the delivery line and control means associated with each injector operable to deliver fuel through the respective injector of an associated engine, and a control valve connected to the delivery line and operable to control the pressure of fuel within the delivery line, wherein the control valve comprises a housing defining a bore within which a valve needle is slidable, the valve needle being engageable with a seating to control fuel flow to an outlet, wherein the valve needle is moveable by fuel pressure exerted on said needle, which pressure is controlled by an electromagnetically actuable valve.

2. A fuel supply system as claimed in claim **1**, wherein the electromagnetically actuable valve is arranged to control the fuel pressure within a control chamber, the valve needle of the control valve being influenced by the pressure within the control chamber.

3. A fuel supply system as claimed in claim **1**, further comprising a fuel control arrangement for controlling the supply of fuel to the fuel pump.

4. A fuel supply system as claimed in claim **1**, wherein the fuel pump comprises a pump body provided with a radially extending bore, a pumping plunger being reciprocable within the bore under the action of a cam surface provided on a cam ring which is rotatable relative to the pump body, the bore communicating through an inlet valve with a source of fuel, and through an outlet valve with the delivery line.

5. A fuel supply system as claimed in claim **4**, wherein the inlet and outlet valves are provided in respective radially extending drillings provided in the pump body.

6. A fuel supply system as claimed in claim **1**, wherein during the time between the commencement of a first injection and the commencement of the next injection a plurality of pulses of fuel at high pressure are supplied to the delivery line.

7. A fuel supply system as claimed in claim **6**, wherein during the time between the commencement of a first injection and the commencement of the next injection, at least three pulses of fuel are supplied to the delivery line.

8. A fuel supply system as claimed in claim **7**, wherein one of the pulses is supplied to the delivery line at the commencement of the first injection.

9. A fuel supply comprising:

(a) A fuel pump supplying high-pressure fuel to a delivery line, the fuel pump having a pump body provided with a radially extending bore, a pumping plunger, being reciprocable within the bore under the action of a cam surface provided on a cam ring which is rotatable relative to the pump body, the bore communicating through an inlet valve with a source of fuel, and through an outlet valve with the delivery line wherein the inlet and outlet valves are provided in respective radially extending drillings provided in the pump body;

(b) A plurality of injectors operably connected to the delivery line, such that fuel is deliverable through the injectors to respective cylinders of an associated engine;

(c) A control valve connected to the delivery line and operable to control the pressure of fuel within the delivery line.

* * * * *