



US00RE36768E

**United States Patent** [19]

[11] E

**Patent Number: Re. 36,768**

**Lear et al.**

[45] **Reissued Date of Patent: Jul. 11, 2000**

[54] **FUEL INJECTION SYSTEM FOR A MULTI-CYLINDER ENGINE**

[58] **Field of Search** ..... 123/531, 456, 123/533, 470; 239/408, 416.5, 417.5, 585.4

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[21] **Appl. No.:** 08/789,606

[22] **PCT Filed:** Apr. 5, 1988

[86] **PCT No.:** PCT/AU88/00096

§ 371 Date: Jan. 30, 1989

§ 102(e) Date: Jan. 30, 1989

[87] **PCT Pub. No.:** WO88/07628

PCT Pub. Date: Oct. 6, 1988

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**Related U.S. Patent Documents**

Reissue of:

[64] **Patent No.:** 4,934,329  
**Issued:** Jun. 19, 1990  
**Appl. No.:** 07/294,627  
**Filed:** Jan. 30, 1989

U.S. Applications:

[63] Continuation of application No. 08/431,464, May 1, 1995, abandoned, which is a continuation of application No. 08/261,882, Jun. 17, 1994, abandoned, which is a continuation of application No. 07/899,211, Jun. 19, 1992, abandoned.

[30] **Foreign Application Priority Data**

Apr. 3, 1987 [AU] Australia ..... PI1246  
Jul. 20, 1987 [AU] Australia ..... PI3270  
Oct. 26, 1987 [AU] Australia ..... PI5101

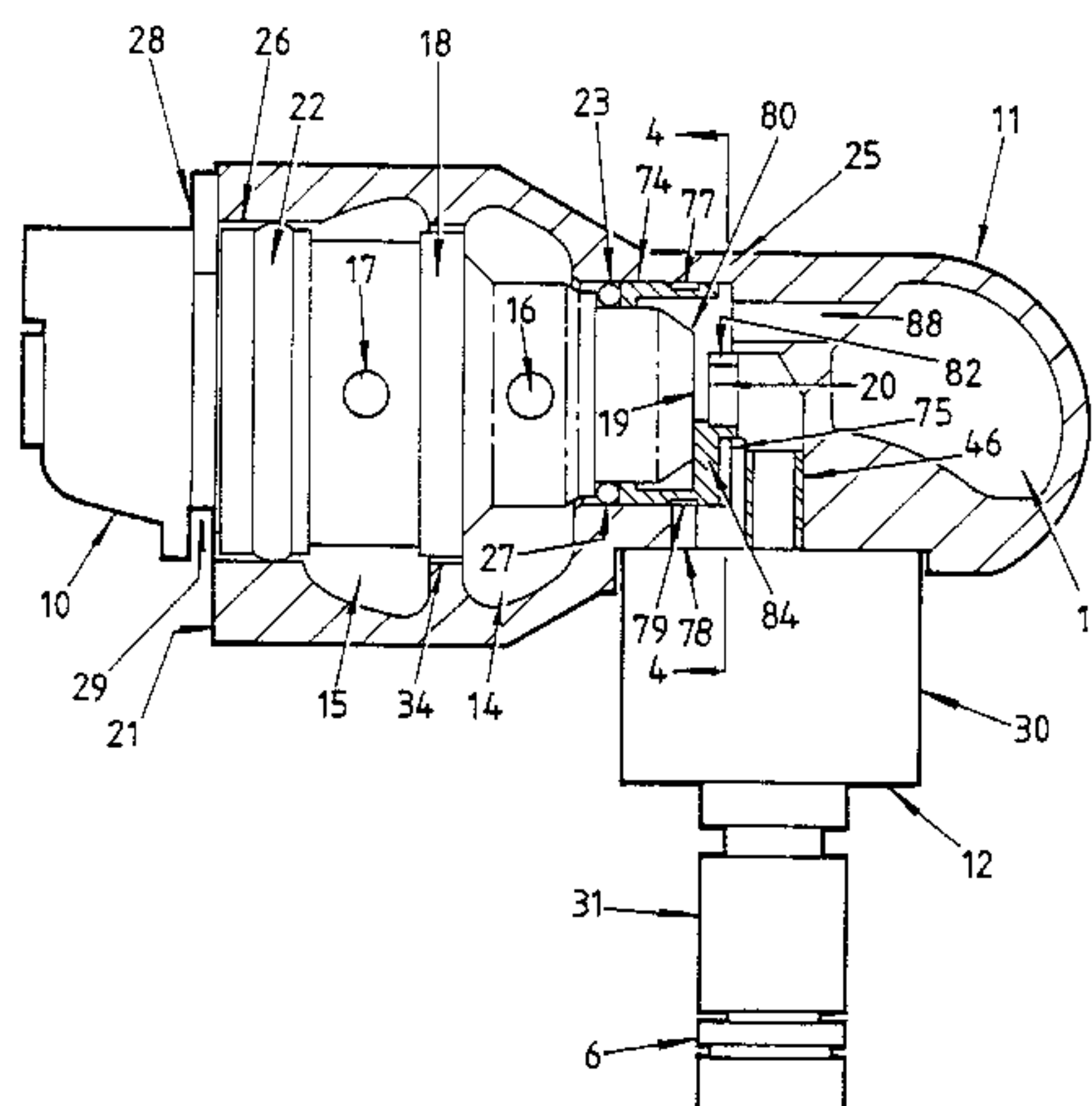
[51] **Int. Cl.<sup>7</sup>** ..... F02M 69/08; F02M 55/00; F02M 67/02

[52] **U.S. Cl.** ..... 123/531; 123/456; 239/408; 239/416.5; 239/417.5; 239/585.4

[57] **ABSTRACT**

A fuel injection system for a multi-cylinder internal combustion engine, which includes a rigid elongated unitary member incorporating a gas supply duct, a fuel supply duct and a fuel return duct, each of which extends in the direction of elongation of the unitary member. A separate fuel metering device and fuel injecting device is provided for each engine cylinder. The fuel metering device is arranged to deliver metered quantities of fuel to the fuel injection device and is in communication with the fuel supply and fuel return ducts so that fuel can be circulated through each of the fuel metering devices. The fuel injecting devices are each in communication with the gas duct and communicable with one of the engine cylinders. The fuel injection devices are adapted to effect delivery of a metered quantity of fuel entrained in gas supplied from the gas duct when the fuel injecting device is in fluid communication with a cylinder.

**62 Claims, 7 Drawing Sheets**



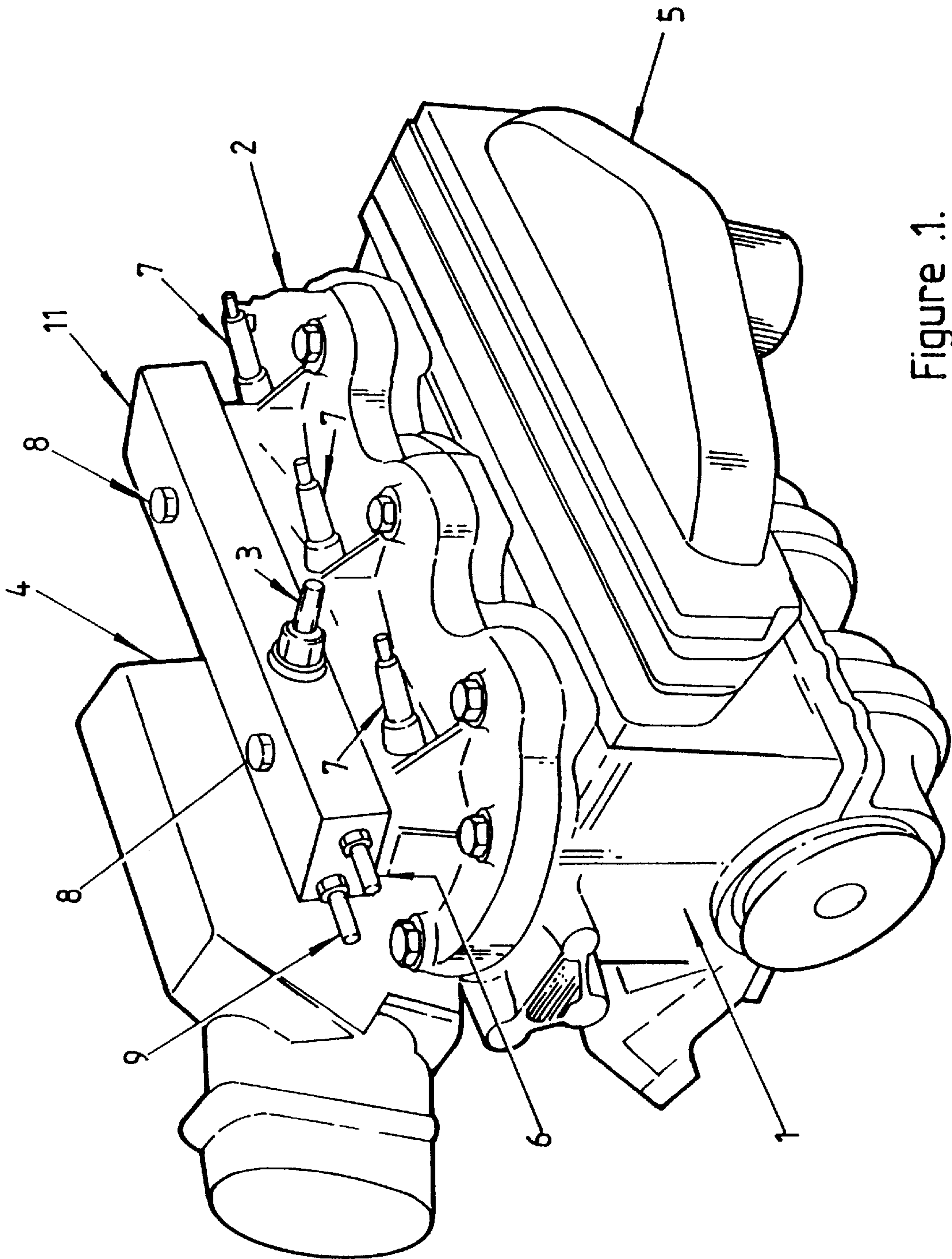


Figure 1.





Figure .3.

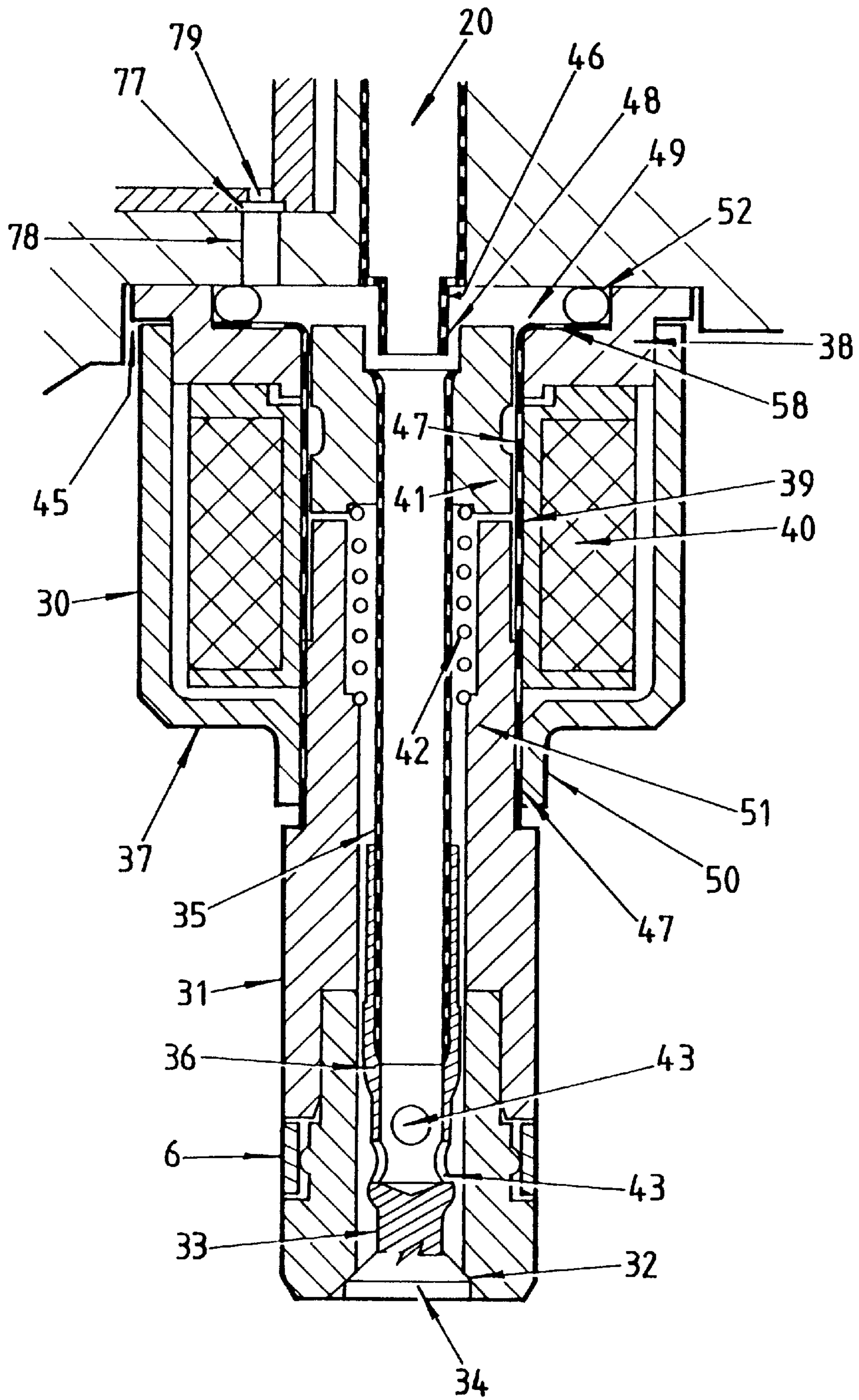


Figure 4.

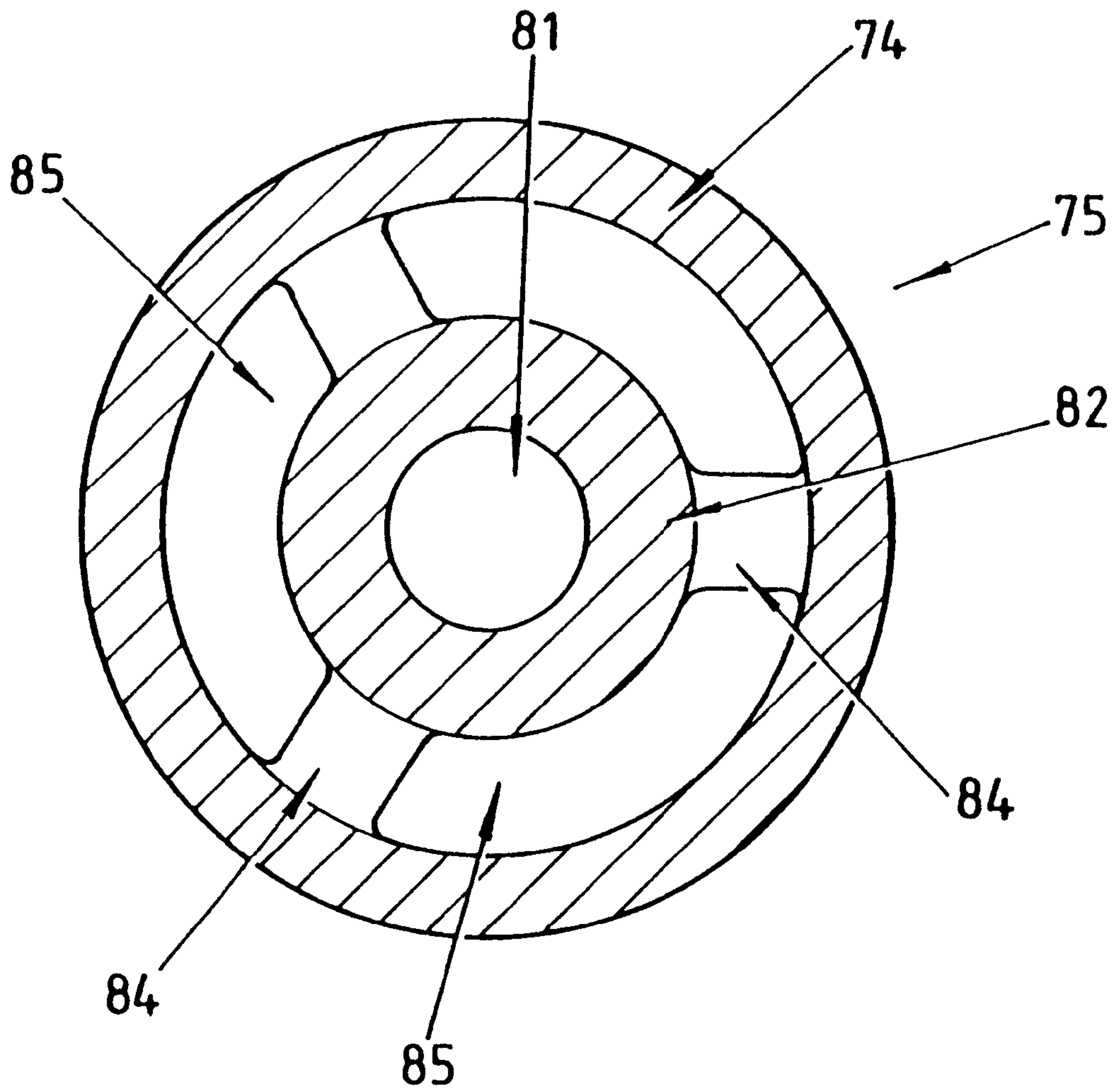


Figure 5.

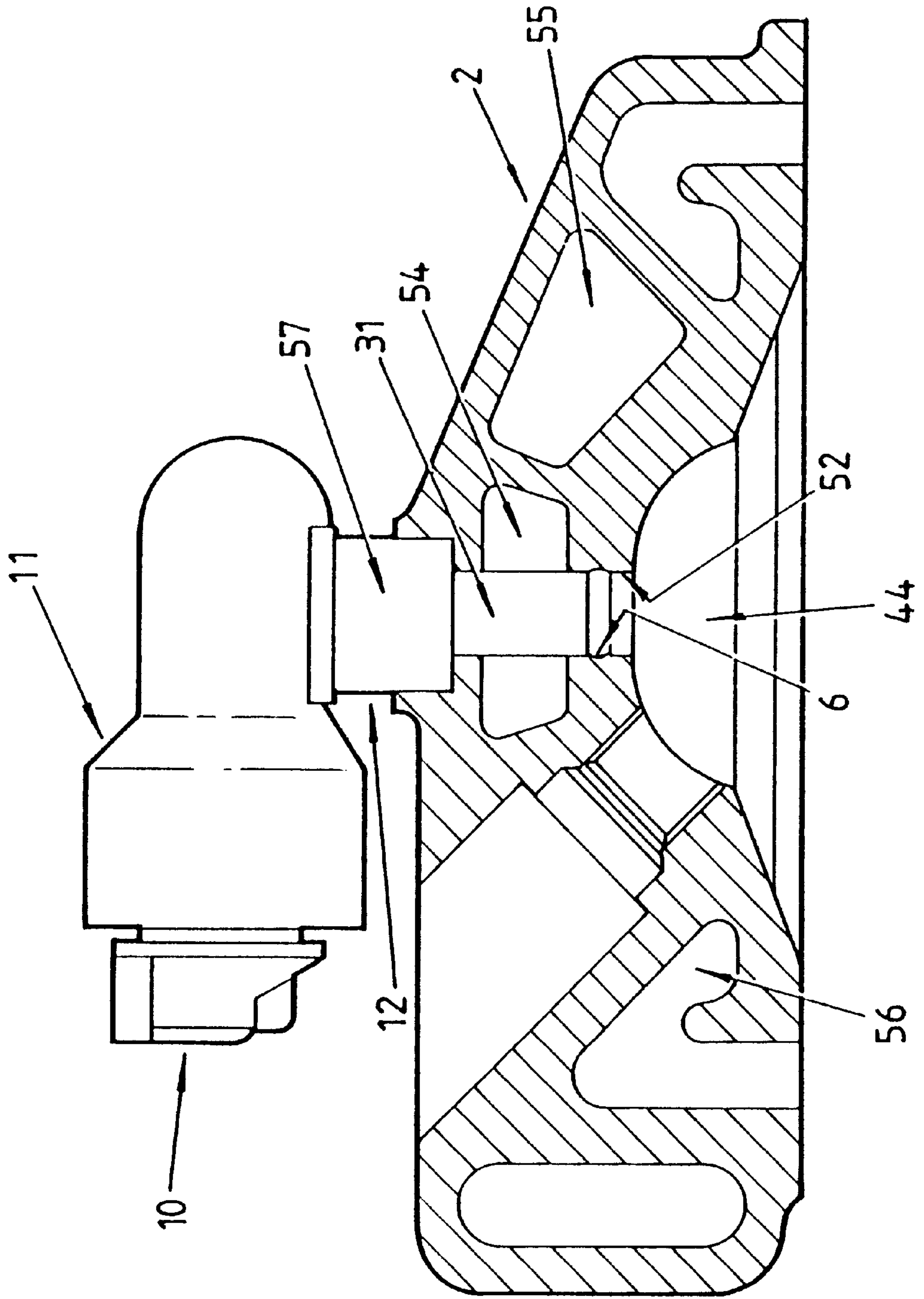


Figure .6.

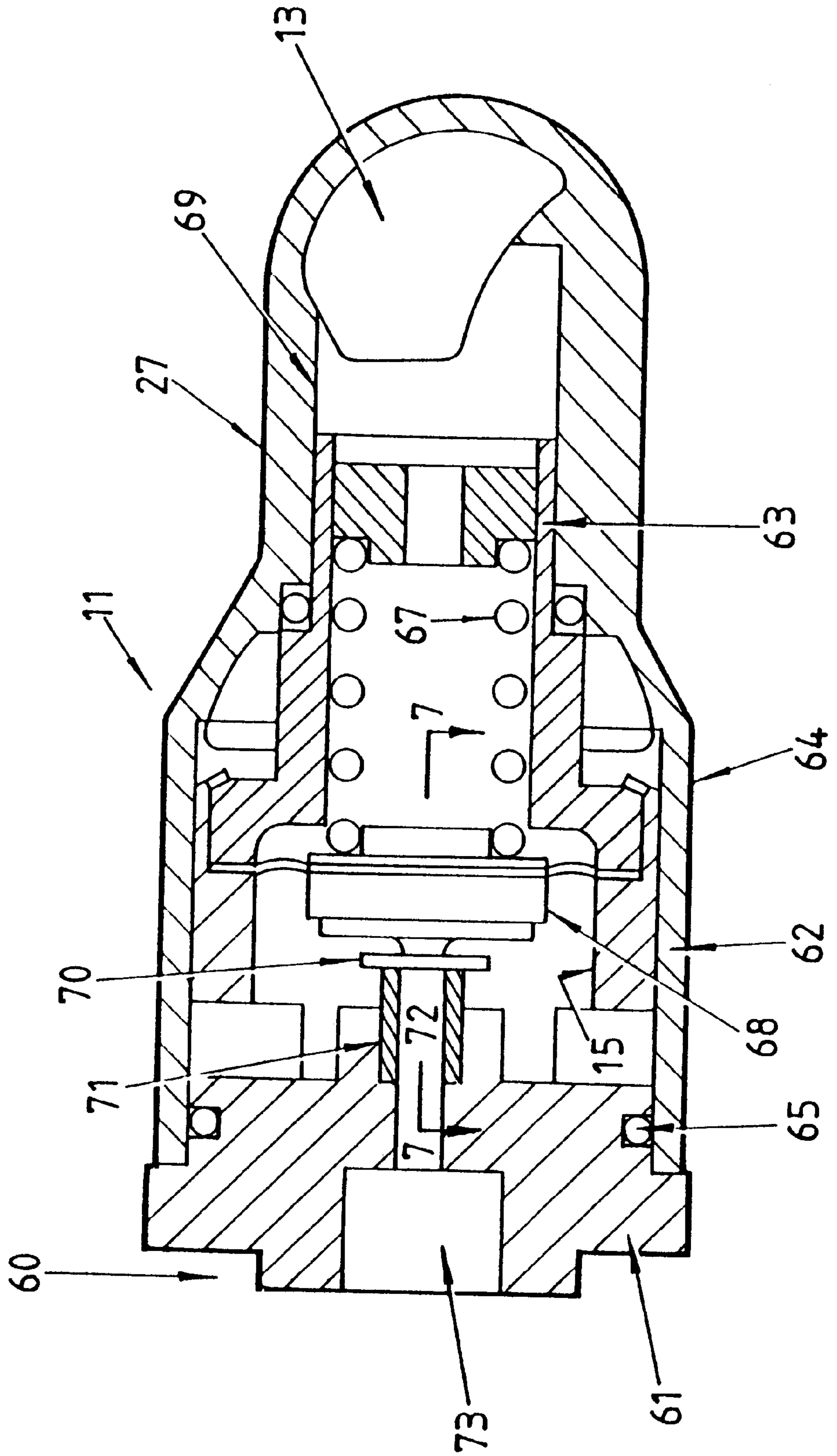




Figure .7.

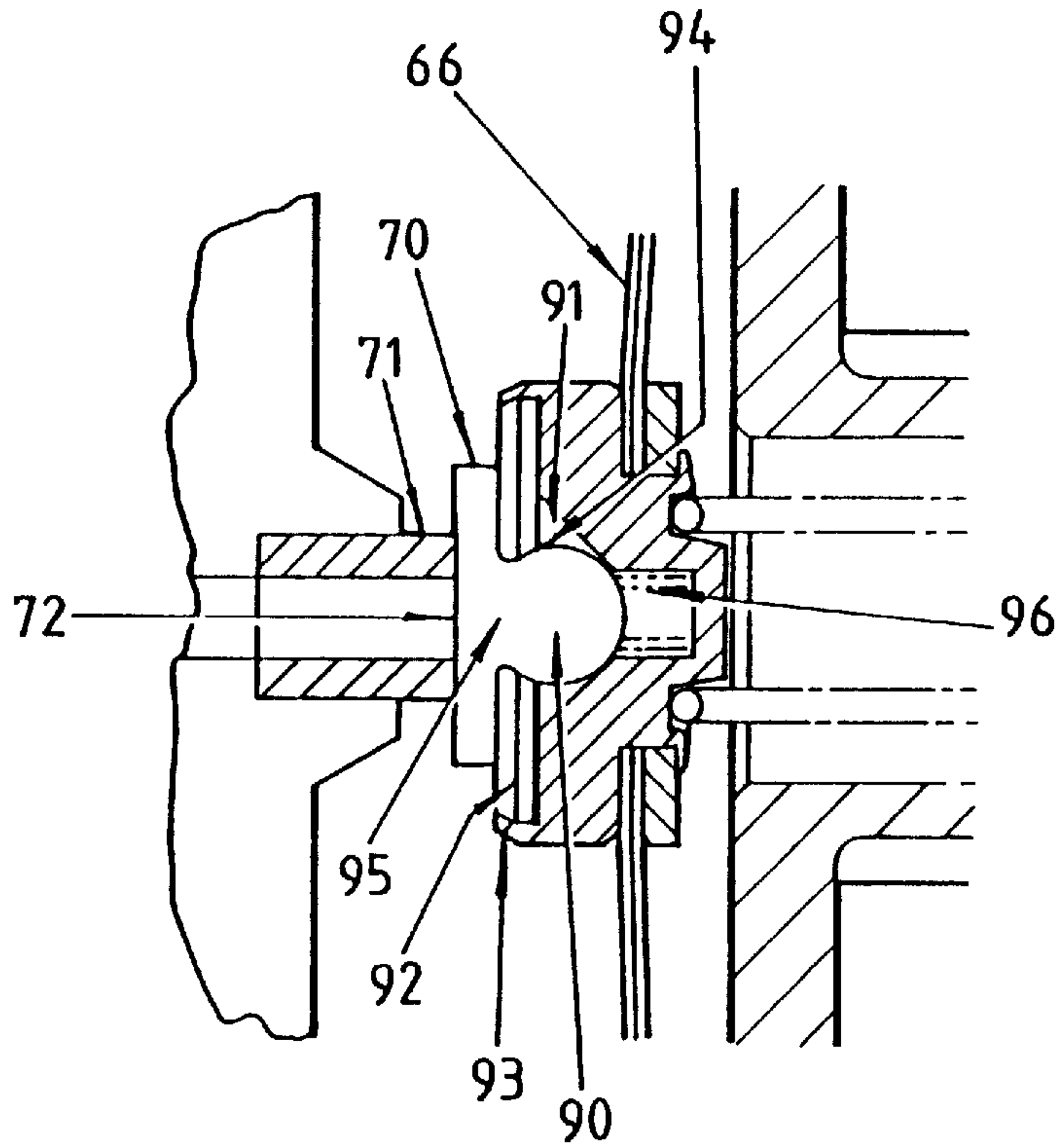
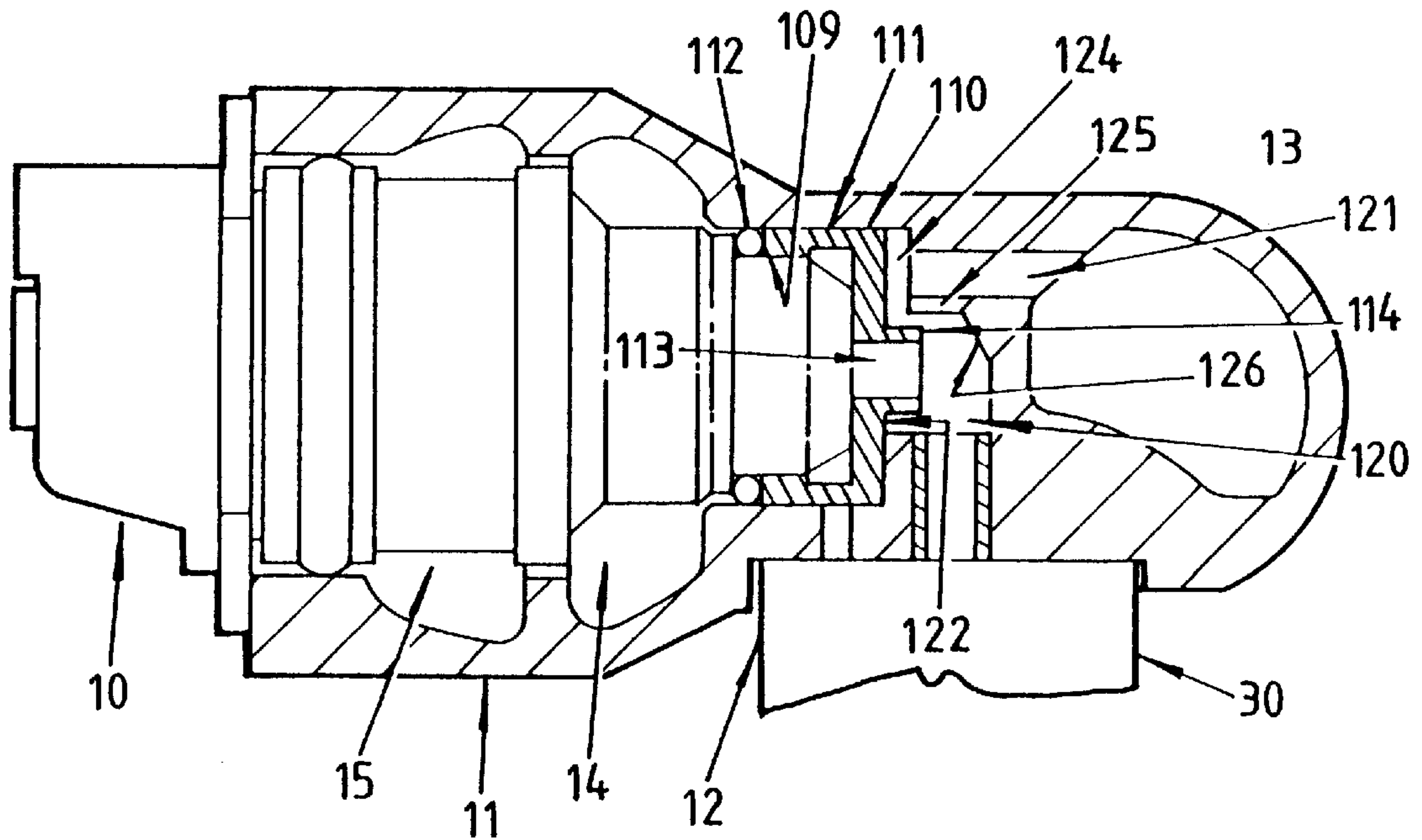


Figure .8.





## FUEL INJECTION SYSTEM FOR A MULTI-CYLINDER ENGINE

**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 application is a continuation of U.S. Ser. No. 08/431,464, filed May 1, 1995, now abandoned, which is a continuation of U.S. Ser. No. 08/261,882, filed Jun. 17, 1994, now abandoned, which is a continuation of U.S. Ser. No. 07/899,211, filed Jun. 19, 1992, now abandoned, which is a reissue of U.S. Pat. No. 4,934,329, which issued from U.S. Ser. No. 294,627, filed Jan. 30, 1989.*

This invention relates to a fuel injection system for internal combustion engines having two or more cylinders and wherein metered quantities of fuel are delivered to the respective cylinders entrained in a gas, preferably a combustion supporting gas, such as air.

It has previously been proposed to deliver a metered quantity of fuel to an engine entrained in a body of gas, with the pressure of the gas being sufficient to effect delivery of the fuel either directly into the cylinder of the engine or into the induction system through which the air charge passes for delivery to the cylinder. This form of fuel metering and injection requires the supply of both fuel and gas to each metering and injecting unit associated with the respective cylinders of the engine. Also, most fuel metering devices require the fuel to be circulated therethrough to prevent the collection of fuel vapour therein. Accordingly, in a multi-cylinder engine, having an individual fuel metering device for each cylinder, it is necessary to provide for fuel to be returned from each fuel metering device to the principal fuel source, such as the fuel reservoir. Further, it is normally necessary to provide a substantially fixed pressure differential between the fuel supply and the gas supply, as this differential is relevant to the metering characteristics of the fuel metering device, and variations therein can result in inaccuracy in the fuel metering process.

Because of manufacturing cost considerations, it is customary to provide a single pump which provides the fuel circulation from a fuel reservoir to each of the fuel metering devices, with appropriate return lines to the fuel reservoir from each metering device. Also it is customary for cost saving reasons to provide a single pressure regulator to control the pressure differential between the gas and the fuel as supplied to each fuel metering and injecting unit. This construction results in a multitude of fuel lines between the fuel metering and injection units and the fuel pump, and between said units and the pressure regulator, which significantly contribute to manufacturing costs. It will be appreciated that in this construction the fuel and gas lines must be provided with suitable end connectors, which are usually threaded in order to provide an effective leak proof connection, and the provision of complementary threaded components on the fuel metering and injecting units, fuel pump and pressure regulator. The manufacture and assembly of these multiplicity of threaded components is a further cost factor. Also additional costs are involved in the installing of the numerous fuel and gas lines. Further the multitude of fuel and gas lines detract from the overall neatness of the installation.

The use of the number of lines for the fuel and gas also present operational disadvantages as the resilient nature of the plastic lines usually used results in variations in line cross-sectional area with internal pressure, and so it is difficult to maintain the required control of the pressure differential between the fuel and gas supplies.

In many applications, such as automobiles and outboard marine engines, the physical size of an engine and its associated accessories is of major importance. There is limited scope for reduction in the size of the engine itself, and accordingly it is important to maintain to a minimum the extent that accessories, added to the basic engine, increase the overall size thereof.

In the light of the above discussed construction, operational and cost disadvantages of currently known fuel injection systems, it is the object of the present invention to provide an improved system whereby these disadvantages are at least reduced so as to provide a more effective operational system and to also reduce the manufacturing and installation costs of the system.

With this object in view, there is provided according to the present invention a fuel injection system for a multi-cylinder internal combustion engine comprising a rigid elongated unitary member having formed therein a gas supply duct, a fuel supply duct and a fuel return duct, each said duct extending in the direction of elongation of the unitary member and each adapted for connection to a gas supply, a fuel supply and a fuel return respectively, at least one fuel metering and injecting apparatus for each cylinder of the engine each integrated with the unitary member and each comprising a fuel metering means and a fuel injecting means, the fuel metering means being adapted to deliver metered quantities of fuel to the fuel injecting means, each fuel metering means being in communication with the fuel supply and fuel return ducts so that in use fuel can be circulated through each fuel metering means, and each fuel injecting means being in communication with the gas duct and communicable with a respective cylinder directly or induction duct communicating with a respective cylinder of the engine, each said fuel injecting means being adapted to effect delivery of the metered quantity of fuel entrained in gas supplied from the gas duct when the fuel injecting means is in communication with the cylinder or induction duct.

Conveniently there is also integrated with the unitary member a pressure regulating means which controls the pressure differential between the fuel in the fuel supply duct and the gas in the gas supply duct between predetermined limits. Preferably the pressure regulating means controls the rate of return of fuel from the return duct to a fuel reservoir and so regulates the pressure of the fuel in the fuel supply duct. It is preferable that the pressure of the fuel delivery to the fuel supply duct is such that the regulating means is required to return fuel to the reservoir over substantially the whole range of operating conditions of the engine. This ensures circulation of fuel through the fuel metering means is maintained to thereby reduce the possibility of an accumulation of fuel vapour in the fuel supply or return ducts. The presence of such vapour, apart from creating a vapour handling problem in relation to emissions control, also contributes to the effective maintenance of the required pressure differential between the fuel supply and the gas supply.

Conveniently each fuel metering means has a body with spaced fuel inlet and fuel outlet ports and the fuel metering means body extends into the elongate unitary member in a direction transverse to the direction of elongation of the unitary member so the fuel inlet port is located in the fuel supply duct and the fuel outlet port is located in the fuel return duct. Each fuel metering means body has a fuel metering port through which the metered quantity of fuel is delivered, and preferably each fuel metering means body is located so the fuel metering port delivers the fuel into a respective fuel cavity located within the unitary member,



each fuel cavity being in communication with the gas supply duct. The fuel cavities may be formed in the unitary member or may be part of the fuel injecting means that extends into the unitary member.

Preferably the fuel supply and return ducts and the gas duct are arranged so that the fuel metering means body projects into the unitary member in a direction inclined to the direction that the fuel injection means projects into the unitary member. Conveniently each fuel metering means body extends into the unitary member from one side thereof and each fuel injecting means includes a body that extends from another side of the unitary member so as to be located generally at a right angle to the fuel metering means body. This arrangement contributes to containing the extent by which the componentry of the fuel injection system increases the overall outside dimensions of the final engine assembly, as at least part of the body of the fuel metering means and/or the fuel injecting means body may be located within the elongated unitary member.

Preferably each fuel cavity is a passage formed within the unitary member located to receive the metered quantity of fuel from the fuel metering means and to deliver it to the fuel injecting means. Conveniently the arrangement is such that the fuel is delivered into the fuel cavity at a level above the fuel injecting means so gravity will assist in the transporting of the fuel to the fuel injecting means. Preferably the fuel cavity communicates with the gas supply duct at a level above that of the entry of the fuel to the cavity so the flow of gas from the gas supply duct to the fuel injecting means will promote the flow of fuel to the fuel injecting means. The fuel cavity may be configured to present, opposite the location of entry of the fuel, a face inclined to the trajectory of the incoming fuel so the fuel rebounding off that face will be deflected toward the fuel injecting means.

The above discussed construction incorporating a unitary rigid member providing fuel and gas to a plurality of fuel metering and injecting means, each servicing a respective cylinder of a multi-cylinder engine, substantially reduces the number of fuel and gas lines required in the installation. In particular, only a single fuel supply line from the fuel pump and a single gas supply line from the pressurised gas source are required to service all of the fuel metering and injecting means. Further only a single fuel return line is required from the unitary member to the fuel reservoir for by-passing excess fuel. Apart from the substantial improved appearance which arises from this construction, the reduction in the number and length of resilient fuel and gas lines substantially reduces the effects on metering accuracy arising from variation in the cross-section of these lines with variation of the fluid pressure therein. In addition the number of fuel and gas connections required to be made is substantially reduced, which contribute to both space savings and cost savings and to a reduction in the potential areas of leakage in the system.

Further, it is possible by the use of a rigid elongate unitary member carrying a number of fuel injecting means, one to be associated with each cylinder of the multi-cylinder engine, to use the rigid elongate unitary member as a holding down bar that clamps the fuel injecting means in the required assembled relation with the respective cylinders of the engine. Accordingly, the need to provide individual threaded holes for the securement of the respective fuel injection means to each cylinder is avoided, and a lesser number of threaded holes is required to hold the rigid elongate unitary member in clamping relation with the fuel injection means and the engine structure to maintain all of the fuel injecting means in the required operating relationship to the engine.

A number of operational factors must also be considered in the design of the metering and injecting unit, including such factors as the weight of the valve controlling the delivery of fuel, including the valve stem, as inertia loadings and valve bounce are important in the maintenance of accurate fueling. Also the extent of the surfaces wetted by the fuel after it has been metered influences the variations in fuel quantity delivered to the engine on a cycle to cycle basis, and the response of the engine to changes in the metered quantity of fuel. There is also the necessity to protect the fuel metering and injecting unit from heat build-up that may damage electrical components and/or lead to fuel vaporisation or other hot fuel handling problems.

It is therefore desirable to provide apparatus for delivering fuel to an internal combustion engine that is small and compact and will operate with the required reliability, accuracy and durability demanded with modern engines.

There is therefore proposed a fuel injection system for an internal combustion engine comprising a body having an internal port cavity, a port in the body providing communication between the port cavity and the exterior of the body, valve means to selectively open and close said port, said valve means including a valve element adapted to co-operate with the port to close same and a valve stem attached to the valve element and extending through the port cavity, selectively energisable electromagnetic means within the body disposed about and operably connected to the valve stem whereby the valve element is displaced to open the port when the electromagnetic means are energised, a passage through the valve stem communicating the port cavity with a fuel cavity located at that side of the electromagnetic means opposite to the port, metering means to selectively deliver fuel to the fuel cavity, and means to supply gas to the fuel cavity at least when the port is open to convey fuel from the fuel cavity through the valve stem passage and the port cavity to and through the open port.

Conveniently the electromagnetic means is in the form of a solenoid having a coil disposed concentric to the valve stem with a co-axial armature attached to the valve stem. Preferably the armature extends into, or is located substantially within, an annular space between the coil and the valve stem. The valve stem is preferably of tubular form with the valve element secured to one end and the other end open to receive the fuel. At the valve element end communication is provided between the interior of the tubular valve stem and the port cavity. Preferably the communication is arranged so a significant quantity of fuel may not be trapped in the tubular valve stem below the point of communication with the port cavity and so not pass into the port cavity. Conveniently the fuel may be injected from the port directly into a combustion chamber of the engine.

In the above proposed construction, a number of benefits arise in the operation of the fuel injection system. The passing of the fuel through a passage in the valve stem, such as is provided by the tubular valve stem, reduces the surface area to which the fuel is exposed as it passes from the point of metering to the port through which it is delivered to the engine, particularly in comparison with prior constructions where the fuel has passed through an annular passage. The surface area wetted by the fuel influences the delay that may occur between the variation of the fueling rate at the point of metering and the consequent variation at the port where the fuel is delivered to the engine. During each injection cycle, and with changes in fueling rates, there is a change in the thickness of the film of fuel adhering to the surfaces over which the fuel passes from the metering point to the port. Accordingly, if the surface area in contact with the fuel is



reduced there is a reduction in the total quantity of fuel involved in changes in thickness of the fuel film. This is reflected in an improvement in the response time of the engine and a reduction in instability of the engine arising from variability in the quantity of fuel delivered between each cycle of the engine.

There is also a benefit arising from locating the electromagnetic means, such as the solenoid assembly, between the injection port and the fuel metering point, as compared with previously proposed constructions wherein the fuel metering point is between the solenoid and the injection port. The resulting reduction in the length of the valve stem reduces the weight thereof, and reduces the natural frequency of the valve stem, and hence reduces the amount of valve bounce that may occur on valve closure. The relatively large quantities of fuel passing through the valve stem when the engine is operating at high loads provides a significant cooling effect on the solenoid at a time when the rate of heat generation is high.

Also, location of the solenoid assembly between the injection port to the engine and the metering point, and the symmetric external shape of the solenoid, enables that portion, or part thereof, of the fuel injection apparatus to be recessed into the head of the engine to which the apparatus is fitted, thereby providing a reduction in the overall height of the engine and injector apparatus assembly. This location also provides the ability for the fuel to be raised in temperature by heat input from the cylinder head, particularly at low fuelling rates, and will assist in atomisation.

The invention will now be described with reference to the accompanying drawings, which depict one practical arrangement of a fuel injection system incorporating the present invention.

In the drawings,

FIG. 1 is a perspective view of a typical three cylinder engine having a fuel injection system of the present invention fitted thereto;

FIG. 2 is a transverse sectional view of the fuel and gas rail at the location of a fuel metering and injecting unit;

FIG. 3 is an axial sectional view of fuel injecting unit and an adjoining portion of the fuel and gas rail;

FIG. 4 is a view of the air control ring in the direction 4—4 in FIG. 2;

FIG. 5 is a sectional view of an engine cylinder head with the fuel and gas rail and the fuel metering and injecting units installed thereon;

FIG. 6 is a sectional view of a pressure regulator fitted to the fuel and gas rail;

FIG. 7 is a fragmentary sectional view of portion of the pressure regulator along the line 7—7 in FIG. 6;

FIG. 8 is a fragmentary sectional view of an alternative arrangement of directing the fuel and air into the fuel cavity.

Referring now to FIG. 1 of the drawings, the three cylinder two stroke cycle engine depicted therein is of basically conventional construction, having a cylinder block and crankcase unit **1**, a detachable cylinder head **2**, and an air induction system **4** on one side of the cylinder block and an exhaust system **5** on the opposite side of the block. Fitted to the cylinder head **2** are respective spark plugs **7**, one for each cylinder of the engine. Extending generally centrally along the top of the cylinder head is the fuel and air rail unit **11** attached to the cylinder head by the mounting bolts **8**.

The fuel injection system for the engine as shown in FIG. 2 comprises the air and fuel supply rail unit **11**, with a metering unit **10** and an injecting unit **12** for each engine cylinder. The rail unit **11** is an extruded component with internal longitudinally extending air passage **13**, fuel supply

passage **14**, and fuel return passage **15**. These passages are closed at each end of the rail. At appropriate locations, as seen in FIG. 1, there are provided an air supply conduit connector **9** communicating with the air passage **13**, a fuel supply conduit connector **6** communicating with the fuel supply passage **14**, and a fuel return conduit connector **3** communicating with the fuel return passage **15** via a pressure regulator as hereinafter described.

The fuel metering unit **10** is a commercially available component and will not be described in detail herein. A suitable commercially available metering unit is that marketed by Rochester Products Division of General Motors Corporation under the Trade Mark "Multec". A fuel inlet port **16** and a fuel outlet port **17** are provided in the body **18** of the metering unit **10** to permit the flow of fuel therethrough, and a metering nozzle is provided in the area **19** to deliver fuel to the passage **20**, as hereinafter described.

The body **18** of the metering unit **10** is received within a lateral bore **26** provided in the external wall **21** of the rail unit **11**, with an "O" ring seal **22** between the body **18** and the bore **26**, and a further "O" ring seal **23** between the body **18** and the bore **27** in the internal wall **25** between the air passages **13** and fuel supply passage **14**. The position of the nozzle area **19** of the metering unit **10** with respect to the passage **20** is controlled by the clamp plate **28** received in the recess **29** provided in the body **18**. The clamp plate **28** is held against the wall **21** by a suitably located bolt or set screw (not shown). The body **18** of the metering unit passes through the wall between the passages **14** and **15** at **34** with a close toleranced fit so fuel leakage therebetween is very restricted.

The injecting unit **12** as seen in FIG. 3 has a housing **30** with a cylindrical spigot **31** projecting from the lower end thereof with an injection port **32** therein communicating with an internal cavity **33**. The poppet valve head **34**, which co-operates with the port **32**, is secured to the tubular valve stem **35**. The tubular valve stem **35** is slidably supported in the cavity **33** by guide ribs **36** spaced equally about the periphery of the valve stem **35**.

The solenoid coil **40** is located in the housing **30** concentric with the tubular valve stem **35** and is retained between the base **37** of the housing **30** and the cover-plate **38**. The solenoid armature **41**, affixed to the upper end of the tubular valve stem **35** has limited axial movement as indicated by the gap **39** and is urged in an upward direction by the spring **42** to normally maintain the valve head **34** in a closing relation with the port **32**. The lower end of the valve stem **35** is provided with opposed apertures **43** to provide constant communication between the interior of the stem **35** and the cavity **33**. Energising of the solenoid coil **40** draws the armature **41** downward to close the gap **39**, thereby displacing the stem **35** and valve head **34** to open the port **32**.

The cover plate **38**, being the upper end of the housing **30**, is received in the bore **45** in the rail unit **11** so that the bore **48** at the upper end of the armature **41** receives the tube **46** mounted in the rail unit **11**. The tube **46** is a sealed press fit in passage **20** formed in the wall **25**, of the rail unit **11**, and directs the fuel from the passage **20** into the open upper end of the valve stem **35**.

Attached to the end of the metering unit **10** which is located in the bore **27** in the wall **25** of the rail unit **11** is an air flow control ring **75**. The annular flange **74** of the air flow control ring **74** fits over the metering unit body **18**. In the external face of the flange **74** is an annular groove **77** which communicates with the passage **78**, and via the series of apertures **79** with the interior cavity **80** of the ring **75**. As seen in FIG. 4 of the drawings, the end of the ring **75** has a



central fuel passage **81** defined by the collar **82**, which is secured to the peripheral portion of the ring **75** through the three equally spaced arms **84**. The spaces defined between the periphery of the ring **75**, the central collar **82** and the three arms **84** define three arcuate openings **85** for the flow of air from the air passage **13**.

As seen in FIG. 2, the passage **88** communicates the air passage **13** with the annular cavity **80** about the collar **82** whereby air from the air passage **13** may pass through the passage **88** and the arcuate openings **85** and hence into the internal cavity **80** within the ring **75**. This air can then pass adjacent the nozzle area **19** into the fuel passage **81** through the collar **82**. It will thus be seen that when the fuel injection system is in operation air may pass from the air passage **13** to establish a radially inward flow around the area **19** of the metering unit **10**, from which the metered quantity of fuel is delivered, and that air will then move axially through the passage **81** into the passage **20** to then pass through the tube **46** into the hollow interior of the valve stem **35**. This form of air flow will inhibit the loss of fuel by a back flow through the passage **88** into the air passage **13**.

The annular groove **77**, apertures **79** and passage **78**, provide a substantially unrestricted flow path for air from the air passage **13** into the bore **49** in the cover plate **38**. From the bore **49** the air may enter the hollow valve stem **35** and also pass between the external surface of the armature **41** and the sleeve **47**, through the gap **39** and into the cavity **33**. This communication between the air passage **13** and the cavity **33** maintains an air flow and a pressure in the cavity **33** sufficient to prevent an accumulation of fuel in, or a back flow of fuel from, the cavity **33** past the armature **41** that could detract from the accuracy of the fuel metering to the engine.

The sleeve **47** is outwardly flanged at **58** to seat on the base of the bore **49** in the cover plate **38**. The lower end of the sleeve **47** is located between the neck **50** of the housing **30** and the extension **51** of the spigot **31**. These three components are welded together in the area of overlapping relation to form a fuel and air tight junction.

The apparatus as above described is intended to be used on a multi-cylinder engine as shown in FIG. 1 with the single air and fuel rail unit **11** having assembled thereto a metering unit **10** and injecting unit **12** for each cylinder of the engine. As seen in FIG. 5 the spigot **31** of the injecting unit **12** is received in an appropriate stepped bore **57** in the engine cylinder head **2** so that the fuel delivered through the port **32** will directly enter the cylinder combustion chamber **44**. The seal ring **6**, located in the spigot **31** will seal against an appropriate surface of the cylinder head. Suitable clamping arrangements, such as the bolts **8**, are provided to secure the rail unit **11** to the cylinder head **2**, so that the rail unit **11** is held in assembly with the injecting units **12**, and the injecting units are in turn held in assembly with the cylinder head. The "O" ring **52** located in the bore **49** forms a seal between the rail unit **11** and the flange **58** of the sleeve **47** to prevent leakage of fuel or air between the rail unit **11** and the injecting unit **12**.

As can be seen in FIG. 5, the engine cylinder head has coolant cavities and passages **53**, **54** and **55**, and a spark plug opening **56**. The injection unit **12** received within a stepped bore **57**, has part of the housing **30** disposed within the coolant cavity **54**, so as to provide direct cooling of the injection unit to dissipate the heat generated by the solenoid coil **40** and to limit the transfer of heat from the combustion chamber to the injector unit and metering unit.

In FIG. 8 there is provided a modified construction of the air control ring **75** as described with reference to FIG. 2. In

the construction shown in FIG. 8 the sleeve **110** and fuel guide tube **114** replace the fuel control ring **74** and collar **82**.

It is to be noted that the provision of the sleeve **110** is a modification to the previously disclosed construction. The sleeve **110** is a close fit, preferably a light interference fit in the bore **111** in the rail unit **11**, with the portion **109** of the fuel metering unit **10** a close fit in the sleeve **110**. The 'O' ring **112** prevents leakage of fuel from the fuel supply passage **14**.

The delivery nozzle of the fuel metering unit **10** is located at **113**, in alignment with the fuel guide tube **114** formed integral with the sleeve **110**, and delivers the metered quantity of fuel into the fuel cavity **120**. The fuel injecting unit **12** is in communication with the cavity **120** to receive the fuel therefrom and is of the same construction as previously described with reference to FIG. 2.

The cavity **120** is in communication with the air passage **13** via the bore **121**, annular passage **122** surrounding the fuel guide tube **114**, and the arcuate passage **124** therebetween. The bore **121** and the outer wall of the annular passage **122** are formed by respective parallel holes drilled prior to assembly of the fuel metering unit **10** and sleeve **110**, and the arcuate passage **124** is formed by machining away portion of the wall between these two holes. As a result of these machining operations, the wall portion **125**, between the two holes is retained and extends to over-lap part of the fuel guide tube **114**, and a part conical surface **126** extending over an arc of 180° is formed. It is to be noted that the cavity **120**, bore **121**, annular passage **122** and arcuate passage **124** are individual to each metering and injecting units **10** and **12**, where the fuel supply and return passage **14** and **15** and air supply passage **13** are common to all such units. The inclination of the surface **126** will direct fuel rebounding thereoff towards the injecting unit **12** rather than directly back towards the annular passage **122**.

In use, during a fuel injection phase, an air flow exists from the passage **13** through the bore **121** arcuate passage **124** and annular passage **122** into the cavity **120**, and on through the cavity **120** to the fuel injecting unit **12**. This air flow carries the fuel that has been delivered into the cavity **120**, by the fuel metering unit **10**, into and through the fuel injecting unit **12** to deliver it to the engine.

It is not uncommon to deliver the fuel, or at least part thereof, into the cavity **120** prior to the commencement of the injection of fuel into the engine, that is at a time when there is substantially no air flow into the cavity **120** from the air passage **13**. The above described arrangement of the bore **121** and passages **122** and **124** are such that a tortuous path is presented to any fuel that may otherwise have a tendency to flow back from the cavity **120** into the air passage **13**. Also fuel droplets rebounding off the surfaces of the cavity **120**, after issuing from the metering unit **10**, have a high probability of striking another wall of the cavity or of the annular passage **122**, and so dissipate their kinetic energy and/or be directed on a path that will avoid escape of the fuel into the air passage **13**. The use of an annular passage, as in annular passage **122**, to provide the only point of entry of any fuel from the cavity **120** to a path to the air passage **13**, has the advantage of providing a relatively unrestricted flow area for the air passing to the cavity but presents a narrow opening to fuel droplets passing in the reverse direction.

The prevention of the escape of fuel from the cavity **20** in FIG. 2 or **120** in FIG. 8 to the air passage **13** has the advantage of improving the accuracy of metering the fuel to the engine with resultant improvements in fuel efficiency and emissions control of the engine, and avoidance of fuel accumulation in the air passage and the problem of purging thereof.



As the fuel is delivered from the metering unit **10** into the passage **20** against the air pressure which exists therein, being substantially the pressure in the air passage **13**, it is necessary to regulate the fuel pressure with respect to the air pressure to obtain the required accuracy in the metering of the fuel. As a plurality of metering and injecting units are incorporated in the single rail unit **11**, the provision of a single regulator, also incorporated into the rail unit **11**, can provide the required pressure regulation for all metering and injecting units.

A typical construction of a regulator unit is depicted in FIG. **6** of the accompanying drawings. The regulator unit **60** comprises a body **61** having a fuel portion **62** and an air portion **63** secured together by the swaged flange **64**. The fuel portion **62** is a close fit in the bore **56** that extends through the external wall **21** of the rail unit **11** and also through the wall **74** between the fuel supply passage **14** and the fuel return passage **15**. The fuel return passage **15** communicates with the hollow interior of the fuel portion **62** through apertures **59** in the peripheral wall of the fuel portion **62**. An "O" ring seal **65** is provided between the fuel portion **62** of the body **61** and the wall of the rail unit **11**. The fuel portion **62** also extends partly into the wall **25** between the fuel supply passage **14** and the air passage **13** with the air portion **63** extending through the remainder of the wall **25** into the air passage **13**.

The diaphragm **66** is clamped between opposite shoulders on the fuel portion **62** and air portion **63** so as to form a barrier between the fuel and the air, but may flex in the normal manner of a diaphragm. The pre-load spring **67** acts against the pressure plate **68** secured to the diaphragm **66** and the force applied by the spring can be controlled by the adjusting plug **69**, which has an aperture therethrough to communicate the air passage **13** with the interior of the air portion **63**.

The pressure plate **68** carries a valve disc **70**, which co-operates with the port sleeve **71**, which defines the port **72**. The body **61** is provided with a suitable threaded aperture **73** to which a fuel return connector **3** may be fitted to return released fuel to a fuel reservoir. As seen in more detail in FIG. **7**, the valve disc **70** may be of a form having an integral spherical head **90** received in a conical cavity **91** in the pressure plate **68**. The head **90** is held in assembly by the retainer plate **92**, that is secured about the periphery by the swaged rim **93** of the pressure plate **68**. The retainer plate **92** has a slot extending to the periphery thereof from the central opening **94** to permit entry of the neck portion **95** into the central opening **94**. The spring **96** urges the spherical head **90** toward the retainer plate **92** to maintain the central location of the valve disc **70**. This construction improves the accuracy of the sealing of the valve disc **70** with port sleeve **71**.

It is to be understood that the construction of the regulator above described may be varied by having the port sleeve **71** attached to the diaphragm **66** and the valve disc stationary.

In use, if the fuel pressure remains below the pressure represented by the combined affect of the air pressure on the diaphragm **66** and the load applied by the spring **67**, the valve plate **70** will remain in the position as shown closing the port **72**. However, if the fuel pressure rises to a level sufficient to overcome the combined load of the air pressure and spring **67** on the diaphragm **66**, then the diaphragm will deflect to the right as shown in the drawing, thereby displacing the valve disc **70** to open the port **72**. The fuel released through the port **72** is returned to the fuel reservoir.

The above described construction results in the regulator device being substantially contained within the confines of

the rail unit **11** and thus does not in real terms contribute to an increase in the overall dimensions of the engine and fuel injection system. Also in this construction the volume of fuel within the rail unit damps the pressure fluctuations arising from the operation of the regulator.

It is to be understood that the fuel injection system as above described may be used in respect of any form of internal combustion engine, including engines operating on either the four stroke or two stroke cycle. Such engines incorporating the fuel injection system above described are particularly suitable for use in all forms of vehicle engines, including engines for aircraft, land vehicles and marine applications, the latter including outboard marine engine.

The claims defining the invention are as follows:

1. A fuel injection system for a multi-cylinder internal combustion engine comprising a rigid elongated unitary member having formed therein a gas supply duct, a fuel supply duct and a fuel return duct, each said duct extending in the direction of elongation of the unitary member and each adapted for connection to a gas supply, a fuel supply and a fuel return respectively, at least one fuel metering and injecting apparatus for each cylinder of the engine arranged in a spaced relation along the length of the unitary member and each integrated with the unitary member and each comprising a fuel metering means and a fuel injecting means, the fuel metering means being adapted to deliver metered quantities of fuel to the respective fuel injecting means, each fuel metering means being in direct continuous communication with the fuel supply and fuel return ducts respectively so that in use fuel [can be] is circulated through each fuel metering means, and each fuel injecting means being in direct continuous communication with the gas duct and selectively communicable with a respective cylinder of the engine, each said fuel injecting means being adapted to effect delivery of the metered quantity of fuel entrained in gas supplied from the gas duct [for delivery] to the cylinder.

2. A fuel injection system as claimed in claim 1 wherein a respective fuel cavity is provided in the unitary member to interact with each fuel metering and injection apparatus, the fuel cavity being located to receive the metered quantity of fuel delivered from the fuel metering means and is in communication with the fuel injecting means, said cavity is also in communication with the gas duct, whereby when the fuel injecting means is in communication with the engine, gas from the gas duct flows through the cavity and fuel injecting means to transport the metered quantity of fuel to the engine cylinder.

3. A fuel injection system as claimed in claim 2 wherein a conduit extends from the fuel metering means to the fuel cavity, the conduit being located so the metered quantity of fuel passes from the fuel metering means through the conduit into the fuel cavity.

4. A fuel injection system as claimed in claim 3, wherein the conduit adjacent the location of the entry of the fuel thereinto communicates with the gas duct so that gas passes through the conduit to enter the fuel cavity.

5. A fuel injection system as claimed in claim 4 wherein the conduit extends through an opening in the wall of the fuel cavity, said conduit defining with said opening an annular passage about the conduit, said annular passage providing communication between the gas duct and the fuel cavity, whereby gas flows through the annular passage into the fuel cavity.

6. A fuel injection system as claimed in claim 4 wherein the fuel cavity is configured to present an inclined face opposite the location of the entry of the fuel into the fuel cavity, said face being inclined to the trajectory of the



incoming fuel so the fuel rebounding from said inclined face is directed toward the fuel injecting means.

7. A fuel injection system as claimed in claim 4 wherein a gas cavity is provided about the conduit, said gas cavity being in communication with the gas duct, and apertures are provided about the periphery of the conduit adjacent the fuel metering means communicating the gas cavity with the interior of the conduit.

8. A fuel injection system as claimed in any one of claims 2-7 wherein the fuel injecting means comprises a body having an axial bore with a valve controlled delivery port at one end, and communicating at the other end with the fuel cavity in the unitary member, and including electromagnetic means mounted in the body co-axial with the axial bore and operable to selectively open and close said delivery port.

9. A fuel injection system as claimed in claim 8 wherein the valve controlled delivery port includes a valve element adapted to sealably engage the delivery port, a hollow valve stem secured at one end to the valve element, said valve stem extending co-axially along said bore, and means arranged to direct fuel from the fuel cavity into the other end of the hollow valve stem.

10. A fuel injection system as claimed in claim 9 wherein the electromagnetic means comprises a stationary solenoid coil located concentrically about the hollow valve stem, and an armature secured to the hollow valve stem adjacent said other end thereof.

11. A fuel injection system as claimed in claim 9 wherein the hollow valve stem has an aperture in the wall thereof adjacent the valve element to permit fuel to pass from within the hollow valve stem into the axial bore for delivery through the delivery port.

12. A fuel injection system as claimed in claim 9, wherein means are provided to communicate the bore in the body of the fuel injecting means with the gas duct independently of the communication through the hollow valve stem, whereby during delivery of fuel through the delivery port, further gas flows through said communication means and said bore to the delivery port.

13. A fuel injection system as claimed in any one of claims 1, 2, 3, 4, 5, 6 or 7 wherein the injecting means includes selectively openable valve means to establish direct communication between a respective cylinder of the engine and the gas duct.

14. A fuel injection system as claimed in claim 13 wherein the fuel injecting means comprises a body having an axial bore with a valve controlled delivery port at one end, and communicating at the other end with the fuel cavity in the unitary member, and including electromagnetic means mounted in the body co-axial with the axial bore and operable to selectively open and close said delivery port.

15. A fuel injection system as claimed in claim 13 wherein the fuel supply duct and fuel return duct are in a side by side relation with a first internal wall therebetween, each fuel metering means having a body with spaced fuel inlet and fuel outlet ports therein, each fuel metering means being mounted in the unitary member with the body thereof passing through an external wall of the unitary member and said first internal wall with the fuel inlet port communicating with the fuel supply duct and the fuel outlet port communicating with the fuel return duct.

16. A fuel injection system as claimed in claim 15 wherein each fuel injecting means is mounted to the unitary member to project from a further external wall thereof in a direction inclined to the direction of projection into the unitary body of the associated fuel metering means.

17. A fuel injection system as claimed in claim 16 wherein the fuel injection means projects in a direction at right angles

to the direction that the fuel metering means projects into the unitary member.

18. A fuel injection system as claimed in claim 15, wherein the external wall and the first internal wall are generally parallel and the body of the fuel metering means extends through said external and first internal walls substantially at a right angle thereto.

19. A fuel injection system as claimed in claim 15 wherein a second internal wall in the unitary member separates the fuel supply duct from the gas duct, the fuel cavity being at least partly formed in said second internal wall, and the body of the fuel metering means extends into said second internal wall to communicate with the fuel cavity to deliver fuel thereto.

20. A fuel injection system as claimed in claim 19 wherein the fuel injection means projects in a direction at right angles to the direction that the fuel metering means projects into the unitary member.

21. A fuel injection system as claimed in claim 13 including pressure regulator means mounted to extend into the unitary member to communicate with the gas duct and one of the fuel supply and return ducts, said pressure regulator means being adapted to in use maintain a predetermined pressure differential between the gas in the gas duct and the fuel in the fuel supply duct.

22. A fuel injection system as claimed in claim 21 wherein the regulator means is adapted to control the rate of flow of fuel from the fuel return duct to a fuel reservoir in relation to the pressure in the gas duct to maintain said predetermined pressure differential.

23. A fuel injection system for an internal combustion engine comprising a body having an internal port cavity, a port in the body providing communication with the port cavity from the exterior of the body, valve means including a valve element adapted to co-operate with the port to close same and a valve stem attached to the valve element and extending through the port cavity, electromagnetic means within the body disposed about and operably connected to the valve stem whereby the valve element is moved to open and close the port when the electromagnetic means is selectively energised and de-energised, a passage through the valve stem communicating the port cavity with a fuel cavity located at that side of the electromagnetic means opposite to the port, metering means to selectively deliver fuel to the fuel cavity, and means to supply gas to the fuel cavity at least when the port is open to convey fuel from the fuel cavity through the valve stem passage and the port cavity to and through the open port.

24. A fuel injection system as claimed in claim 23 wherein the injecting means includes selectively openable valve means to establish direct communication between a respective cylinder of the engine and the gas duct.

25. A fuel injection system as claimed in claim 23 or claim 24 wherein the electromagnetic means comprises a stationary solenoid coil located concentrically about the valve stem; and an armature secured to the valve stem adjacent said other end thereof.

26. A fuel injection system as claimed in claim 25 wherein the armature is located substantially within an annular space formed between the valve stem and the solenoid coil.

27. A fuel injection system as claimed in claim 26 wherein the valve stem extends through the solenoid armature to communicate with the fuel cavity, said valve stem having apertures in the wall thereof adjacent the valve element to permit fuel to the passage within the valve stem into the port cavity.

28. *A fuel injection system for a multi-cylinder internal combustion engine, the fuel injection system comprising:*



a fuel injecting apparatus for each cylinder of the engine, each fuel injecting apparatus incorporating a body having therein a fuel cavity communicating with a port cavity, metering means to selectively deliver fuel to the fuel cavity, a port in the body providing communication between the port cavity and the exterior of the body, valve means including a valve element adapted to cooperate with the port to selectively open and close the port and a valve stem attached to the valve element, selectively operable electromagnetic means within the body operably connected to the valve stem to move the valve element to open and close the port, and means to supply gas to the fuel cavity at least when the port is open to convey fuel from the fuel cavity to and through the open port, wherein

the valve stem extends from the port cavity to the fuel cavity through the electromagnetic means, and a passage extends through the valve stem so as to communicate the port cavity with the fuel cavity, such that the fuel from the fuel cavity is delivered through the valve stem passage and the port cavity to and through the open port,

said fuel injecting apparatus being arranged to deliver fuel to a respective cylinder of the engine through the port provided in the body of the fuel injecting apparatus, said fuel injecting apparatus being associated with a single rigid elongated unitary member, the unitary member having a fuel supply duct and a gas supply duct formed therein extending in the direction of elongation of the unitary member, each fuel metering means being in direct communication with the fuel supply duct, each fuel cavity being located in the unitary member in communication with the gas supply duct, whereby when the port is open gas from the gas supply duct conveys fuel from the fuel cavity through the valve stem passage and the port cavity to and through the open port.

29. A fuel injection system as claimed in claim 28, wherein the electromagnetic means includes a stationary solenoid coil located concentrically about the valve stem and an armature secured to the valve stem.

30. A fuel injection system as claimed in claim 29, wherein the armature is located substantially within an annular space formed between the valve stem and the solenoid coil.

31. A fuel injection system as claimed in claim 28 wherein the valve stem is hollow and has an aperture in the wall thereof adjacent the valve element to permit fuel to pass from the interior of the hollow valve stem into the port cavity.

32. A fuel injection system as claimed in claim 28, wherein a conduit within the unitary member extends from the fuel metering means to the fuel cavity, the conduit being located so the metered quantity of fuel passes from the fuel metering means through the conduit into the fuel cavity.

33. A fuel injection system as claimed in claim 32, wherein the gas supply duct communicates with the conduit adjacent the location of the entry of the fuel to the conduit so that gas passes through the conduit to enter the fuel cavity.

34. A fuel injection system as claimed in claim 32 or 33, wherein the conduit extends through an opening in the wall of the fuel cavity, the conduit defining with the opening an annular passage about the conduit, the annular passage providing communication between the gas supply duct and the fuel cavity such that gas flows through the annular passage into the fuel cavity.

35. A fuel injection system as claimed in claim 32 or 33, wherein the fuel cavity is arranged to present an inclined face opposite the location of the entry of the fuel into the fuel

cavity, the face being inclined to the trajectory of the incoming fuel so the fuel rebounding from the inclined face is directed to enter the valve stem passage.

36. A fuel injection system as claimed in claim 34, wherein each fuel injecting apparatus is mounted to the unitary member with the body projecting from one external wall of the unitary member and the fuel metering means projecting from another external wall of the unitary member in a direction inclined to the direction of projection into the unitary member of the body of the fuel injecting apparatus.

37. A fuel injection system as claimed in claim 36, wherein the body of each fuel injecting apparatus projects in a direction at right angles to the direction that the fuel metering means projects into the unitary member.

38. A fuel injection system as claimed in claim 34, wherein the body of each fuel injecting apparatus has an end portion thereof remote from the port, each end portion being received in a respective recess in the rigid elongated unitary member, the recesses being arranged so the bodies are spaced from each other in the direction of elongation of the unitary member, the end of each body in which the port is located being seated against a portion of the engine with the port therein in communication with a respective cylinder, and means securing the unitary member to the engine so the bodies are clamped therebetween.

39. A fuel injection system for a multi-cylinder internal combustion engine, the fuel injection system comprising:

a fuel injecting apparatus for each cylinder of the engine, each fuel injecting apparatus incorporating a body having therein a fuel cavity communicating with a port cavity, metering means to selectively deliver fuel to the fuel cavity, a port in the body providing communication between the port cavity and the exterior of the body, valve means including a valve element adapted to cooperate with the port to selectively open and close the port and a valve stem attached to the valve element, selectively operable electromagnetic means within the body operably connected to the valve stem to move the valve element to open and close the port, and means to supply gas to the fuel cavity at least when the port is open to convey fuel from the fuel cavity to and through the open port, wherein

the valve stem extends from the port cavity to the fuel cavity through the electromagnetic means, and a passage extends through the valve stem so as to communicate the port cavity with the fuel cavity, such that the fuel from the fuel cavity is delivered through the valve stem passage and the port cavity to and through the open port, and

the body of each fuel injecting apparatus has an end portion thereof remote from the port, each end portion being received in a respective recess in a rigid elongated unitary member so the bodies are spaced from each other in the direction of elongation of the unitary member, the opposite end of each body being seated against the engine with the port therein communicating with a respective cylinder of the engine, and means securing the unitary member to the engine so the bodies are clamped therebetween.

40. A fuel injection system as claimed in claim 34, further comprising pressure regulator means mounted to extend into the unitary member to communicate with the gas supply duct and the fuel supply duct, the pressure regulator means being adapted for in use maintaining a predetermined pressure differential between the gas in the gas supply duct and the fuel in the fuel supply duct.

41. A fuel injection system as claimed in claim 36, further comprising pressure regulator means mounted to extend into



the unitary member to communicate with the gas supply duct and the fuel supply duct, the pressure regulator means being adapted for in use maintaining a predetermined pressure differential between the gas in the gas supply duct and the fuel in the fuel supply duct.

42. An apparatus for injecting fuel into an internal combustion engine, wherein the apparatus is integrated with a single elongated unitary member, the unitary member having a fuel supply duct and a gas supply duct formed therein extending in the direction of elongation of the unitary member, the fuel injecting apparatus comprising:

a body having an internal port cavity;

a port in said body providing communication with said port cavity from an exterior of said body;

valve means including a valve element adapted to cooperate with and close said port, and a valve stem attached to the valve element and extending through the port cavity;

electromagnetic means within the body operably connected to the valve stem so as to move the valve element to open and close said port when said electromagnetic means is selectively energized and de-energized;

a passage extending through the valve stem communicating the port cavity with a fuel cavity located in the unitary member in communication with the gas supply duct opposite to said port relative to said electromagnetic means;

metering means for selectively delivering fuel to the fuel cavity; and

means to supply gas to the fuel cavity at least when said port is open to convey fuel from the fuel cavity through the valve stem passage and the port cavity to and through said open port.

43. An apparatus for injecting fuel as claimed in claim 42, wherein said electromagnetic means includes a stationary solenoid coil located concentrically about the valve stem and an armature secured to the valve stem.

44. An apparatus for injecting fuel as claimed in claim 43, wherein the armature is located substantially within an annular space formed between the valve stem and the solenoid coil.

45. An apparatus for injecting fuel as claimed in claim 42 wherein the valve stem is hollow and has an aperture in a wall thereof adjacent the valve element to permit fuel to pass from an interior of the hollow valve stem into the port cavity.

46. An apparatus for injecting fuel as claimed in claim 42, wherein a conduit within the unitary member extends from said fuel metering means to the fuel cavity, the conduit being located so the metered quantity of fuel passes from said fuel metering means through the conduit into the fuel cavity.

47. An apparatus for injecting fuel as claimed in claim 46, wherein the gas supply duct communicates with the conduit adjacent the location of entry of the fuel to the conduit so that gas passes through the conduit to enter the fuel cavity.

48. An apparatus for injecting fuel as claimed in claim 46 or 47, wherein the conduit extends through an opening in the wall of the fuel cavity, the conduit defining with the opening an annular passage about the conduit, the annular passage providing communication between the gas supply duct and the fuel cavity such that gas flows through the annular passage into the fuel cavity.

49. An apparatus for injecting fuel as claimed in claim 46 or 47, wherein the fuel cavity is arranged to present an inclined face opposite the location of entry of the fuel into the fuel cavity, the face being inclined to the trajectory of the incoming fuel so the fuel rebounding from the inclined face is directed to enter the valve stem passage.

50. An apparatus for injecting fuel as claimed in claim 48, wherein said fuel injecting apparatus is mounted to the unitary member with the body projecting from one external wall of the unitary member and said fuel metering means projecting from another external wall of the unitary member in a direction inclined to the direction of projection into the unitary member of the body of said fuel injecting apparatus.

51. An apparatus for injecting fuel as claimed in claim 50, wherein said body of the fuel injecting apparatus projects in a direction at right angles to the direction that said fuel metering means projects into the unitary member.

52. An apparatus for injecting fuel as claimed in claim 48, wherein said body of the fuel injecting apparatus includes an end portion thereof remote from said port, the end portion being received in a recess in the rigid elongated unitary member, the recess being arranged so said body is formed in the direction of elongation of the unitary member, the end of said body in which said port is located being seated against a portion of the engine with said port therein in communication with a cylinder.

53. An apparatus for injecting fuel as claimed in claim 48, further comprising pressure regulator means mounted to extend into the unitary member to communicate with the gas supply duct and the fuel supply duct, said pressure regulator means being adapted for in use maintaining a predetermined pressure differential between the gas in the gas supply duct and the fuel in the fuel supply duct.

54. An apparatus for injecting fuel as claimed in claim 50, further comprising pressure regulator means mounted to extend into the unitary member to communicate with the gas supply duct and the fuel supply duct, said pressure regulator means being adapted for in use maintaining a predetermined pressure differential between the gas in the gas supply duct and the fuel in the fuel supply duct.

55. An apparatus for injecting fuel into an internal combustion engine, wherein the apparatus is integrated with a single elongated unitary member, the unitary member having a fuel supply duct and a gas supply duct formed therein extending in the direction of elongation of the unitary member, the fuel injecting apparatus comprising:

a body having an internal port cavity;

a port in said body providing communication with the port cavity from an exterior of said body, said body having an end portion thereof remote from said port, the end portion being received in a respective recess in the elongated unitary member so that an opposite end of said body is seated against the engine with said port therein communicating with a respective cylinder of the engine;

valve means including a valve element adapted to cooperate with and close said port, and a valve stem attached to the valve element and extending through the port cavity;

electromagnetic means within the body operably connected to the valve stem so as to move the valve element to open and close said port when said electromagnetic means is selectively energized and de-energized;

a passage extending through the valve stem communicating the port cavity with a fuel cavity located opposite to said port relative to said electromagnetic means;

metering means for selectively delivering fuel to the fuel cavity; and

means to supply gas to the fuel cavity at least when said port is open to convey fuel from the fuel cavity through the valve stem passage and the port cavity to and through said open port.



56. A fuel injection system for a multi-cylinder internal combustion engine comprising a rigid elongated unitary member having formed therein a fuel supply duct and a gas supply duct, each said ducts extending in the direction of elongation of the unitary member, said fuel duct being adapted for connection to a fuel supply, said gas supply duct being adapted for connection to a compressed gas supply, fuel metering means for each cylinder of the engine each in direct communication with the fuel duct, fuel injecting means for each cylinder each in continuous communication with the gas duct, each fuel injecting means being located relative to a respective fuel metering means so a metered quantity of fuel can be delivered by the fuel metering means to the fuel injecting means and entrained in gas passing therethrough from the gas duct,

each fuel injection means communicates with a respective fuel cavity, said fuel cavities being provided in the unitary member and arranged to receive the metered quantity of fuel from the respective fuel metering means, and gas from the gas duct,

a conduit provided within the unitary member extends from the fuel metering means to the fuel cavity, the conduit being located so the metered quantity of fuel passes from the fuel metering means through the conduit into the fuel cavity, and

the gas supply duct communicates with the conduit adjacent the location of the entry of the fuel to the conduit so that gas passes through the conduit to the fuel cavity.

57. A fuel injection system as claimed in claim 56, wherein a gas cavity is provided about the conduit and communicating with the gas duct, and apertures are provided in the conduit adjacent the fuel metering means to provide communication between the gas cavity and the interior of the conduit.

58. A fuel injection system as claimed in claim 56, wherein the conduit extends through an opening in the wall of the fuel

cavity, said conduit defining with said opening an annular passage about the conduit, said annular passage providing communication between the gas supply duct and the fuel cavity, whereby gas flows through the annular passage into the fuel cavity.

59. A fuel injection system as claimed in claim 56 or 57, wherein the fuel cavity is formed so as to present an inclined face opposite the location of the entry of the fuel into the fuel cavity, said face being inclined to the trajectory of the incoming fuel so the fuel rebounds from said inclined face in a direction towards said fuel injecting means.

60. A fuel injection system as claimed in any one of claims 56 or 57, wherein each fuel injecting means is mounted to the unitary member to project from one external wall of the unitary member and the fuel metering means is mounted to project from another external wall of the unitary member in a direction inclined to the direction of projection into the unitary member of the body of the fuel injecting means.

61. A fuel injection system as claimed in claim 60, wherein the body of each fuel injecting apparatus is formed so as to project in a direction at right angles to the direction that the fuel metering means projects into the unitary member.

62. A fuel injection system as claimed in any one of claims 56 or 57, wherein each fuel injecting means has a first end portion having a valve means and a second end portion received in a respective recess in the rigid elongated unitary member, said recesses being arranged so said fuel injecting means are spaced from each other in the direction of elongation of the unitary member, the first end of each fuel injecting means being seated against the engine with the valve means therein in communication with a respective cylinder, and means securing the unitary member to the engine so said first and second end portions are clamped therebetween.

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