

Description

This invention relates to an apparatus for use in testing the operation of fuel injectors, and to a method of using the apparatus.

In a known injector test apparatus, the fluid supplied through an injector which is being tested is supplied to a metering device including a piston displaceable within a cylinder. The supplied fluid causes the piston to move within the cylinder, and the displacement of the piston is measured. The measured displacement of the cylinder provides an indication of the quantity of fluid supplied through the injector.

After completion of a test cycle, the piston is moved to empty the cylinder of fluid ready for the next test cycle. It will be appreciated that the test procedure includes a number of delays whilst the cylinder is emptied between test cycles, and it is an object of the invention to provide an apparatus and a method of using the apparatus in which this disadvantage is reduced.

According to the present invention there is provided an injector test apparatus comprising a collection device arranged to receive fluid delivered by one or more injectors to be tested, a metering device including a piston slidable within a cylinder and defining with the cylinder a first chamber and a second chamber, a first three-way valve moveable between a first setting in which the collection device communicates with the first chamber and a second setting in which the first chamber communicates with a low pressure reservoir, and a second three-way valve moveable between a first setting in which the collection device communicates with the second chamber, and a second setting in which the second chamber communicates with the low pressure drain.

In use, when the first three-way valve occupies its first setting, the second three-way valve is in its second setting, and when the first three-way valve is switched to occupy its second setting, the second three-way valve occupies its first setting. Thus, the supply of fluid to the collection device may result in fluid being displaced into the first chamber moving the piston, resulting in fluid being displaced from the second chamber to the low pressure drain. The movement of the piston is measured, and thereafter both of the three-way valves are switched to their alternative settings. Subsequent fluid supply to the collection device causes fluid to be supplied to the second chamber moving the piston to displace fluid from the first chamber to the low pressure drain. Clearly, as the subsequent fluid supply to one of the chambers results in fluid supplied earlier to the other chamber being displaced therefrom, no step is required in which the measuring device is emptied between test cycles.

The collection device of the apparatus conveniently includes a plurality of test injector receiving stations, each station communicating through a respective non-return valve with a common line which communicates with both the first and second three-way valves.

Preferably, the metering device includes means for

damping movement of the piston. The damping means may take the form of a flow restrictor located within a hollow part of the piston, the hollow part containing fluid, and means for maintaining the flow restrictor in a fixed position whilst permitting movement of the piston. The flow restrictor is conveniently constructed from a magnetic material, the means for maintaining the flow restrictor in a fixed position comprising a magnet located externally of the piston.

The invention also relates to a method of operating the injector test apparatus defined hereinbefore comprising the steps of:

controlling the first and second three-way valves so that the first three-way valve occupies its first setting and the second three-way valve occupies its second setting;
supplying fluid through the test injector to the collection device;
measuring the displacement of the piston resulting from the supply of fluid;
switching the first and second three-way valves to their alternative settings;
supplying further fluid through the test injector to the collection device; and
measuring the displacement of the piston resulting from the further supply of fluid.

According to another aspect of the invention there is provided an injector test apparatus for use in testing the operation of a plurality of test injectors, the injector test apparatus comprising a metering device including a piston slidable within a cylinder, the piston and cylinder defining a first chamber and a second chamber, a valve arrangement whereby when fluid is supplied by at least one of the test injectors to the first chamber, the piston moves to displace fluid from the second chamber, and when fluid is supplied by at least one of the test injectors to the second chamber, the piston moves to displace fluid from the first chamber, and means for monitoring the position of the piston.

The apparatus conveniently further comprises damping means for damping movement of the piston.

The valve arrangement may comprise first and second three way valves controlling communication between respective ones of the first and second chambers, a collection device into which fluid is supplied by the test injectors, in use, and a fuel reservoir. Alternatively, the test injectors may comprise a first group arranged to supply fluid to the first chamber and a second group arranged to supply fluid to the second chamber, the valve arrangement comprising valves associated with the first and second chambers to control the displacement of fluid therefrom. In a further alternative, the valve arrangement may comprise a valve arranged such that in a first setting thereof communication between a collection device and the first chamber and between the second chamber and a reservoir is permitted, and in an alterna-

tive setting, communication is permitted between the first chamber and the reservoir and between the collection device and the second chamber.

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

Figure 1 is a diagrammatic view of an injector test apparatus in accordance with an embodiment;

Figure 2 is a view similar to Figure 1 illustrating another embodiment;

Figure 3 is a view illustrating a modification to the arrangement of Figure 2; and

Figures 4 and 5 are views similar to Figure 1 illustrating further embodiments.

Figure 1 illustrates an injector test rig which comprises a collection device 10 having a plurality of fuel injectors 12 mounted therein, the collection device 10 being arranged to receive fuel supplied through the injectors 12. The collection device 10 communicates through a passage 14 with a first three-way valve 16, conveniently a solenoid actuated valve, and through a passage 18 with a second solenoid actuated three-way valve 20.

The first three-way valve 16 communicates through a passage 22 with a metering device 24, the metering device 24 also communicating through a passage 26 with the second three-way valve 20. The metering device 24 comprises a cylinder 28 within which a piston member 30 is slidable. The cylinder 28 and piston member 30 together define first and second chambers 32, 34, the passage 22 communicating with the first chamber 32 and the passage 26 communicating with the second chamber 34.

The piston member 30 is of a magnetic material, and a magnetic pick-up 36 is used in conjunction with a linear optical encoder 38 to determine the position of the piston member 30 within the cylinder 28. In order to allow maintenance of the metering device 24, bleed bungs 40 are provided to permit drainage of fluid from the first and second chambers 32, 34, the bungs 40 being closed in normal use.

The first three-way valve 16 also communicates through a passage 42 with a low pressure drain volume 44, the drain volume 44 also communicating through a passage 46 with the second three-way valve 20. In use, fluid is drawn from the volume 44 through a pressure regulator 48, this fluid subsequently being supplied to the injectors 12 during testing.

The collection device 10 is provided with a fast acting low pressure sensor 50 which is located so as to permit sensing of the pressure at an outlet of one of the injectors 12. An appropriate one-way valve is located within the collection device 10 to prevent the low pres-

sure sensor 50 being actuated by the output of the other injectors 12. In use, the output of the low pressure sensor 50 together with the time and angular position of the rotor of a pump are used, together with the output of the metering device 24, to determine the injection rate of the injectors mounted in the collection device 10.

Filters 52 are located in the lines 14, 18 to prevent debris from the injectors passing through the three-way valves 16, 20 to the metering device 24.

In use, in the position illustrated in Figure 1, the three-way valve 16 occupies a setting in which the collection device communicates with the first chamber 32 of the metering device 24. Communication between the first chamber 32 and the low pressure drain volume 44 is prevented by the first three-way valve 16. The second three-way valve 20 is controlled so that the second chamber 34 of the metering device 24 communicates with the low pressure volume 44, the collection device 10 not communicating with the second chamber 34. In this position of the valves 16, 20, the supply of fluid to the collection device 10 through the injectors 12 results in fluid being displaced to the first chamber 32. The supply of fluid to the first chamber 32 displaces the piston member 30 within the cylinder 28, the amount of movement of the piston member 30 is being dependent upon the quantity of fluid supplied to the collection device 10. The movement of the piston member 30 results in fluid being displaced from the second chamber 34 through the second three-way valve 20 to the drain volume 44.

Fluid continues to be displaced through the injectors 12 to the collection device 10 until the piston member 30 has moved the complete length of the cylinder 28, and thereafter the first and second three-way valves 16, 20 are both switched so that the second three-way valve 20 permits communication between the collection device 10 and the second chamber 34 of the metering device 24, the communication between the second chamber 34 and the low pressure drain volume 44 being broken, and the first three-way valve 16 permits communication between the first chamber 32 and the low pressure drain volume 44, the communication between the collection device 10 and the first chamber 32 being broken. Once the three-way valves 16, 20 occupy these settings, continued supply of fluid to the collection device 10 through the injectors 12 causes fluid to be displaced to the second chamber 34, moving the piston member 30 to the left in the orientation illustrated in Figure 1, such movement of the piston member 30 displacing fluid from the first chamber 32 to the low pressure drain 44. The supply of fluid through the injectors 12 continues until the piston member 30 has returned along the complete length of the cylinder 28 as described hereinbefore.

It will be appreciated that the fluid supplied to the first chamber 32 during the first test cycle is displaced from the metering device 24 to the low pressure drain volume 44 during the second test cycle when fluid supplied to the collection device 10 causes fluid to be dis-

placed to the second chamber 34. Clearly, such an arrangement does not require a step to be performed in which fluid is drained from the metering device 24 in between test cycles. The test cycles can therefore be performed almost continuously.

In order to ensure that the apparatus operates effectively, the pressure within the low pressure drain volume 44 must be controlled accurately as this pressure is applied to the side of the piston member 30 which is not in communication with the collection device 10, thus the pressure regulator 48 must be of high quality.

In addition to reducing the time during which the apparatus is inoperable by removing the step of emptying the metering device 24 between test cycles, the apparatus is advantageous in that the quantity of fluid within the test system can be greatly reduced. The low volume of fluid, the geometry of the apparatus and the low inertia of the moving parts permit metering measurements to be carried out quickly and accurately.

The volume of the lines 22, 26 and metering cylinder 28 may be designed to be larger than the volume of the collection device 10 and filters 52. In such an arrangement, the quantity of debris passing through the filters 52 and reaching the metering device 24 may be reduced, the debris passing the three-way valves 42, 46 towards the metering device 24 subsequently being returned through the three-way valves and lines 42, 46 to the low pressure drain volume 44. In addition to reducing the risk of debris reaching the metering device 24, this and the location of the valves 16, 20 also reduce the risk of damage to the metering device 24 due to the temperature of fluid reaching the metering device 24 becoming unacceptably high. The temperature of the metering device 24 can therefore be controlled substantially independently of that of the collection device 10 permitting relatively accurate measurement of the quantity of fluid supplied through the injectors 12.

Temperature stability can also be improved by using multi-core piping in the locations denoted by 56 in Figure 1. The piping conveniently extends through the drain volume 44 to stabilize the fluid temperature within the piping. Temperature sensors 54 are provided to permit the actual fluid temperature to be monitored, and appropriate corrections applied to the measured fluid volume.

In the description hereinbefore, the piston moves the complete length of the cylinder before the three-way valves are switched. It will be appreciated, however, that other operating modes are possible, for example the piston may only move a predetermined distance in each direction, or a predetermined number of injections may be permitted between switching of the valves.

It is envisaged to replace the magnetic position sensing arrangement with another suitable sensor, for example an eddy-current type sensor.

The injector test apparatus illustrated in Figure 2 comprises a collector device 60 which comprises a body have a plurality of bores 62 formed therein, each bore 62 being arranged to receive a respective injector 64 to

be tested. Each of the bores 62 communicates through a respective non-return valve 66 with a common line or gallery 68. The provision of the non-return valves 66 effectively reduces the quantity of fluid present in the system, and in addition allows the apparatus to be operated with one or more of the bores not containing an injector. The gallery 68 communicates, via a filter 69, with a port of a first three-way valve 70 which includes a common port which communicates through a passage 72 with a first end of a metering device 74. The first three-way valve 70 also includes a port which communicates with a test fluid reservoir 76. The gallery 68 also communicates with a second three-way valve 78 the common port of which communicates through a passage 80 with a second end of the metering device 74 the second three-way valve 78 also including a port communicating with the test fluid reservoir 76. A pressure relief valve 71 communicates with the gallery 68 in order to allow venting of fluid therefrom should the pressure therein become excessively high.

As shown in Figure 2, the passages 72, 80 which connect the three-way valves 70, 78 with the metering device 74 each include regions which extend through the reservoir 76. The reservoir 76 acts to stabilise the temperature of fluid supplied through these passages 72, 80 to the metering device 74.

The metering device 74 comprises a piston 82 which is slidable within a cylinder 84. The piston 82 includes end caps 82a, 82b which are constructed of aluminium. The cylinder 84 includes plastic end caps 84a, 84b which locate Eddy current sensors 86a, 86b which, in conjunction with the aluminium end caps 82a, 82b, serve to provide an accurate indication of the location of the piston 82 within the cylinder 84. The output of each Eddy current sensor is non-linear, and the sensors can sense the position of the piston over only a relatively small range of movement. By providing two sensors, and by supplying the output signals thereof to a differential signal processor 85, the non-linear output can be compensated for, and the range of movement over which piston position can be sensed is increased.

The piston 82 is hollow, and located within the piston 82 is a plastic orifice member 92 which carries a plurality of magnetic rings, and located by means of a magnet 94 which surrounds a central part of the outer periphery of the cylinder 84. The cylinder 84 contains a relatively viscous fluid, and it will be appreciated that as the magnet 94 locates the magnetic orifice member 92 in a position which is fixed relative to the cylinder 84, movement of the piston 82 with respect to the cylinder 84 requires some of the fluid located within the piston 82 to pass through the orifice of the orifice member 92, resulting in damping of the movement of the piston 82 with respect to the cylinder 84. As the piston movement is damped, a piston of relatively small diameter can be used, allowing greater sensitivity, than where the piston movement is not damped.

In the modification illustrated in Figure 3, the orifice

member is replaced by a damping member 120 which is fixed relative to the cylinder 84 by hollow pins 122. The pins 122 extend through slots 124 provided in the piston 82 which allow the piston 82 to slide within the cylinder 84. The damping member 120 is provided with passages 126 which communicate with chambers 128a, 128b defined between the ends of the damping member 120 and the end caps 82a, 82b, the passages 126 also communicating with the pins 122. The outer ends of the pins 122 are connected together to permit fluid to flow between the chambers 128a, 128b, such flow being restricted by a needle valve or other suitable restrictor.

In order to ensure that the piston 82 can move smoothly with respect to the cylinder 84, low friction oil seals 96 are used, and an oil reservoir 98 is provided to ensure that the seals 86 can operate adequately. Alternatively, a diaphragm or tight tolerance piston may be used to achieve sufficiently good sealing.

The piston 82 defines, with the cylinder 84, a first chamber 88 which communicates with the passage 72, and a second chamber 90 which communicates with the passage 80. The three-way valves 70, 78 are controlled in a manner similar to that described hereinbefore to ensure that when fuel from the gallery 68 is supplied through the first three-way valve to the chamber 88 of the metering device 74, the chamber 90 communicates through the second three-way valve 78 with the reservoir 76, and when the gallery 68 communicates through the second three-way valve 78 with the chamber 90, the chamber 88 communicates through the first three-way valve 70 with the reservoir 76. The three-way valves 70, 78 are controlled by respective solenoid actuators to switch between their positions substantially simultaneously. It will be appreciated that when fluid is being supplied to the chamber 88, the movement of the piston 82 results in fluid being displaced from the chamber 90 to the reservoir 76, and when the gallery 68 communicates with the chamber 90, the piston 82 displaces fluid from the chamber 88 to the reservoir 76. As described hereinbefore, such an arrangement is advantageous in that testing can be carried out substantially continuously, there being no requirement to terminate injection in order to empty the metering device.

For maintenance purposes, the metering device 74 includes air bleed valve arrangements 100 to permit air to be bled from the chambers 88, 90.

The reservoir 76 is split into two chambers 76a, 76b, the three-way valves 70, 78 communicating with the first chamber 76a which is separated from the second chamber 76b by means of a flexible, for example rubber, diaphragm 104, a non-return valve 102 also being provided to permit fluid to flow from the first chamber 76a to the second chamber 76b. A cooling coil 106 passes through the first chamber 76a in order to allow for cooling of the fluid located therein for the purposes of temperature stabilization. The first chamber 76a communicates with a back pressure regulator 108 which controls the pressure within the first chamber 76a, thus control-

ling the pressure applied to the one of the chambers 88, 90 of the metering device 74 which is not, at that time, in communication with the gallery 68. Such control of the pressure is important in order to ensure that the measurements derived using the metering device 74 are accurate.

For the purposes of cooling, the collection device 60 includes passages through which fluid at a substantially constant temperature can flow, and the connections to these passages are indicated at 110 in Figure 2. Similar passages may be provided in the metering device 74 to assist temperature stabilization thereof.

One of the bores 62 is provided with a fast acting low pressure sensor 112 the output of which is used to determine when the injector located in that bore is injecting fluid. As the order of injection is known, the output of the sensor 112 can be used to determine which injector is operating at a given time. The Eddy current sensors provide a sufficiently accurate indication of piston location, and are sufficiently fast acting, that a pilot injection of fluid can be measured separately from a subsequent main injection and any post injection of fluid.

A differential pressure transducer 114 is connected to the gallery 68 to permit the injection rate profiles produced by the injectors to be compared with one another.

In addition to measuring the quantity of fluid delivered by a particular injector and the injection rate, it is envisaged that the apparatus could be used to improve dynamic timing measurement and timing settings on fuel pumps, as the timing of fuel delivery can be measured using the apparatus of the present invention.

Figure 4 illustrates an embodiment which comprises a metering device 130 including a cylinder 132 within which a piston member 134 is slidable. End caps 136 close the ends of the cylinder 132 and carry temperature and pressure sensors 138, 140. The end caps 136 further carry eddy current displacement sensors 142 arranged to monitor the position and displacement of the piston member 134, in use. An end of the piston member 134, cylinder 132 and one of the end caps 136 together define a first chamber 144, the other end of the piston member 134, the cylinder 132 and the other end cap 136 together defining a second chamber 146.

A plurality of test injectors 148a, 148b are mounted upon the cylinder, a first group of the injectors (including the injector 148a) being arranged to inject fluid into the first chamber 144 and a second group of the injectors (including the injector 148b) being arranged to supply fluid to the second chamber 146.

Solenoid controlled valves 150a, 150b are associated with each of the first and second chambers 144, 146 to control the displacement of fluid from the chamber 144, 146 through a damping orifice 152 to a fluid reservoir 154. Three way valves 156 are provided to permit filling and/or drainage of fluid from the system. A pressure regulator 158 controls the fluid pressure within the reservoir 154.

In use, when fluid is being delivered through the first

group of injectors, the valve 150a is closed, and the valve 150b is open. The supply of fluid to the first chamber 144 causes the piston member 134 to be displaced towards the right, displacing fluid from the second chamber 146 through the valve 150b and the damping orifice 152 to the reservoir 154. The displacement of the piston member 134 is monitored as described hereinbefore. Subsequently, the valves 150a, 150b are switched, and fluid is supplied to the second chamber 146 resulting in the displacement to the reservoir 154 of fluid previously delivered to the first chamber 144. The movement of the piston member 134 is monitored as described hereinbefore.

This embodiment has the advantage that the quantity of fluid present in the apparatus is low and this permits the apparatus to be used to monitor both the quantity of fuel injected and the injection rate.

Figure 5 illustrates an embodiment comprising a cylinder 160 within which a piston 162 is slidable, the piston 162 including a pair of piston members 164 interconnected by a rigid connecting member 166. A dividing wall 168 is located within the cylinder 160, the connecting member 166 extending through an opening within the wall 168 and forming a substantially fluid tight seal therewith. The piston 162, cylinder 160 and wall 168 together define a first chamber 170 and a second chamber 172.

A collection device 174 is mounted upon the cylinder 160 and arranged to collect fluid delivered by a plurality of test injectors. Fluid from the collection device 174 flows through a passage 176 to a valve arrangement including a valve member 178 rotatable within a bore provided in the wall 168 between a first position in which the collection device 174 communicates with the first chamber 170 (this position being shown in Figure 5) and a second position in which the collection device 174 communicates with the second chamber 172. It will be appreciated that the valve member 178 rotates through 180° when moving between its first and second positions. In addition to controlling which of the chambers communicates with the collection device at any instant, the valve member 178 is further arranged to permit communication between the chamber not being supplied with fluid from the collection device 174 and a passage 180 which communicates with a reservoir.

The ends of the cylinder 160 are closed by end caps 182 carrying eddy current sensors 184 arranged to monitor displacement of the piston 162. The end caps 182 and piston 162 together define chambers 186 which communicate with one another through a flow path including a variable damping orifice 188 to damp movement of the piston 162.

In use, with the valve member 178 in the position illustrated, fluid is supplied to the first chamber 170, displacing fluid from the second chamber 172 to the reservoir. The movement of the piston is monitored as described hereinbefore. Subsequently, the valve member 178 is rotated through 180° with the result that fluid is

supplied to the second chamber 172, displacing fluid previously supplied to the first chamber 170 to the reservoir. The movement of the piston is again monitored to determine the quantity of fluid delivered by the injectors.

Claims

1. An injector test apparatus comprising a collection device (10, 60) arranged to receive fluid delivered by one or more injectors (12, 64) to be tested, a metering device (24, 74) including a piston (30, 82) slidable within a cylinder (28, 84) and defining with the cylinder (28, 84) a first chamber (32, 88) and a second chamber (34, 90), a first three-way valve (16, 70) moveable between a first setting in which the collection device (10, 60) communicates with the first chamber (32, 88) and a second setting in which the first chamber (32, 88) communicates with a low pressure reservoir (44, 76), and a second three-way valve (20, 78) moveable between a first setting in which the collection device (10, 60) communicates with the second chamber (34, 90), and a second setting in which the second chamber (34, 90) communicates with the low pressure drain (44, 76).
2. An apparatus as claimed in Claim 1, wherein the position of the piston (30, 82) relative to the cylinder (28, 84) is sensed using a magnetic pick-up (36) and optical encoder (38).
3. An apparatus as claimed in Claim 1, wherein the position of the piston (30, 82) relative to the cylinder (28, 84) is sensed using an eddy current sensor (86a, 86b).
4. An apparatus as claimed in any one of the preceding claims, wherein the collection device (10, 60) is connected to the metering device (24, 74) by passages (22, 26, 72, 80) of large volume.
5. An apparatus as claimed in any one of the preceding claims, wherein the collection device (10, 60) includes a plurality of test injector receiving stations (62), each station (62) communicating through a respective non-return valve (66) with a common line (68) which communicates with both the first and second three-way valves (70, 78).
6. An apparatus as claimed in any one of the preceding claims, wherein the metering device (74) further includes damping means damping movement of the piston (82).
7. An apparatus as claimed in Claim 6, wherein the damping means comprises a flow restrictor (92,

120) controlling fluid flow between chambers located within the piston (82), and means (94, 122) for maintaining the restrictor (92, 120) in a fixed position relative to the cylinder (84) whilst permitting movement of the piston (82).

8. An apparatus as claimed in Claim 7, wherein the restrictor (92) is constructed from a magnetic material, the means (94) for maintaining the restrictor (92) in a fixed position comprising a magnet (94) located externally of the piston (82).

9. An apparatus as claimed in Claim 7, wherein the means (122) for maintaining the restrictor (120) in a fixed position comprises pins (122) extending through slots within the piston (82) and engaging the cylinder (84).

10. A method of operating an injector test apparatus of the type claimed in any one of the preceding claims, the method comprising the steps of:

controlling the first and second three-way valves (16, 20, 70, 78) so that the first three-way valve (16, 70) occupies its first setting and the second three-way valve (20, 78) occupies its second setting;

supplying fluid through the test injector (12) to the collection device (10, 60);

measuring the displacement of the piston (30, 82) resulting from the supply of fluid;

switching the first and second three-way valves (16, 20, 70, 78) to their alternative settings;

supplying further fluid through the test injector (12) to the collection device (10, 60); and

measuring the displacement of the piston (30, 82) resulting from the further supply of fluid.

11. An injector test apparatus for use in testing the operation of a plurality of test injectors, the injector test apparatus comprising a metering device (24, 74, 130) including a piston (30, 82, 134, 162) slidable within a cylinder (28, 84, 132, 160), the piston (30, 82, 134, 162) and cylinder (28, 84, 132, 160) defining a first chamber (32, 88, 144, 170) and a second chamber (34, 90, 146, 172), a valve arrangement (16, 20, 70, 78, 150, 178) whereby when fluid is supplied by at least one of the test injectors to the first chamber (32, 88, 144, 170), the piston (30, 82, 134, 162) moves to displace fluid from the second chamber (34, 90, 146, 172), and when fluid is supplied by at least one of the test injectors to the second chamber (34, 90, 146, 172), the piston (30, 82, 134, 162) moves to displace fluid from the first chamber (32, 88, 144, 170), and means (36, 38, 86, 142, 184) for monitoring the position of the piston (30, 82, 134, 162).

12. An apparatus as claimed in Claim 11, further comprising damping means (92, 94, 122, 126, 152, 188) for damping movement of the piston (30, 82, 134, 162).

13. An apparatus as claimed in Claim 11 or Claim 12, wherein the valve arrangement comprises first and second three way valves (16, 20, 70, 78) controlling communication between respective ones of the first and second chambers, a collection device (10, 60) into which fluid is supplied by the test injectors, in use, and a fuel reservoir (44, 76).

14. An apparatus as claimed in Claim 11 or Claim 12, wherein, the test injectors comprise a first group arranged to supply fluid to the first chamber (144) and a second group arranged to supply fluid to the second chamber (146), the valve arrangement comprising valves (150) associated with the first and second chambers (144, 146) to control the displacement of fluid therefrom.

15. An apparatus as claimed in Claim 11 or Claim 12, wherein the valve arrangement comprises a valve (1 78) arranged such that in a first setting thereof communication between a collection device (174) and the first chamber (170) and between the second chamber (172) and a reservoir is permitted, and in an alternative setting, communication is permitted between the first chamber (170) and the reservoir and between the collection device (174) and the second chamber (172).

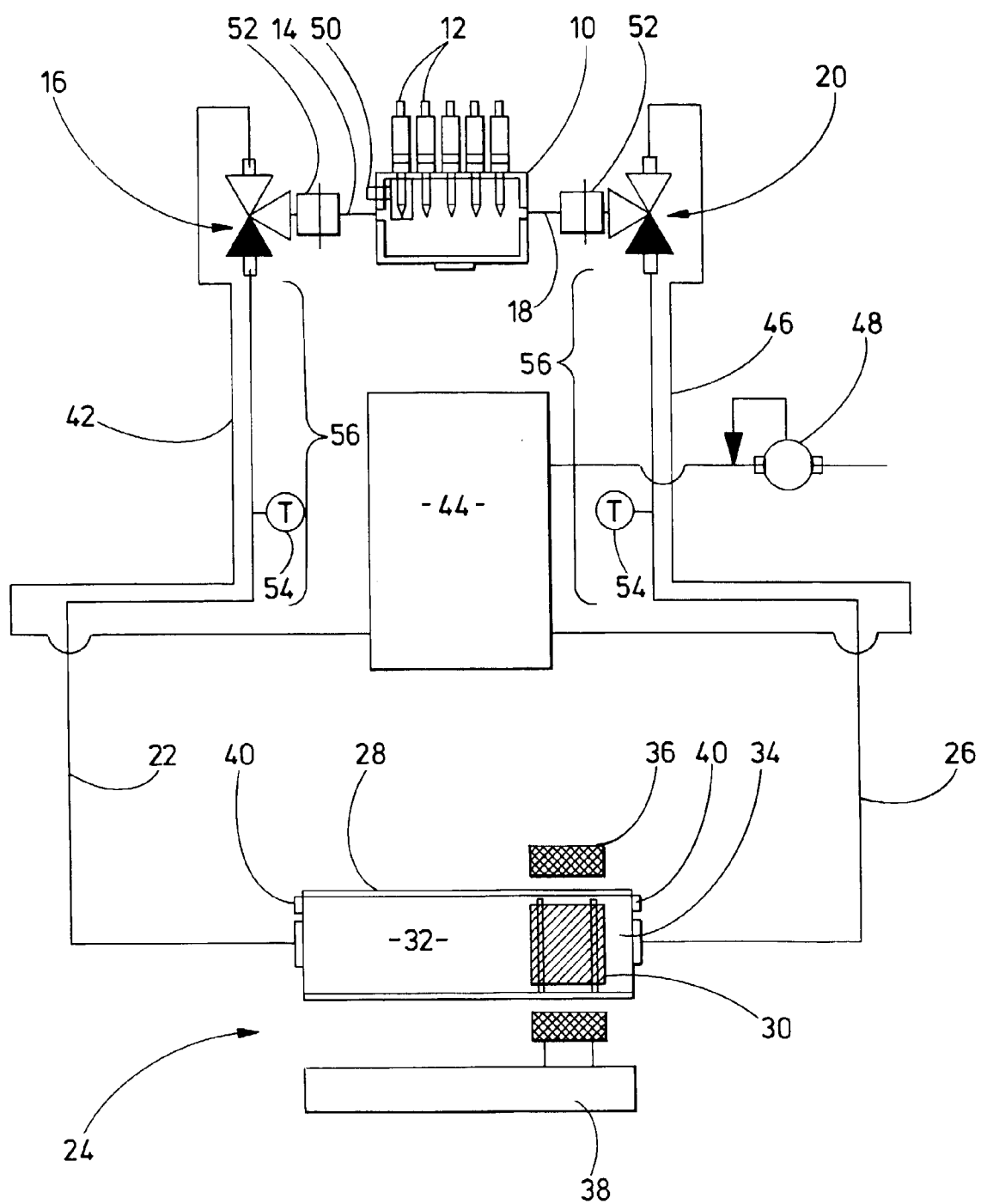


FIG 1

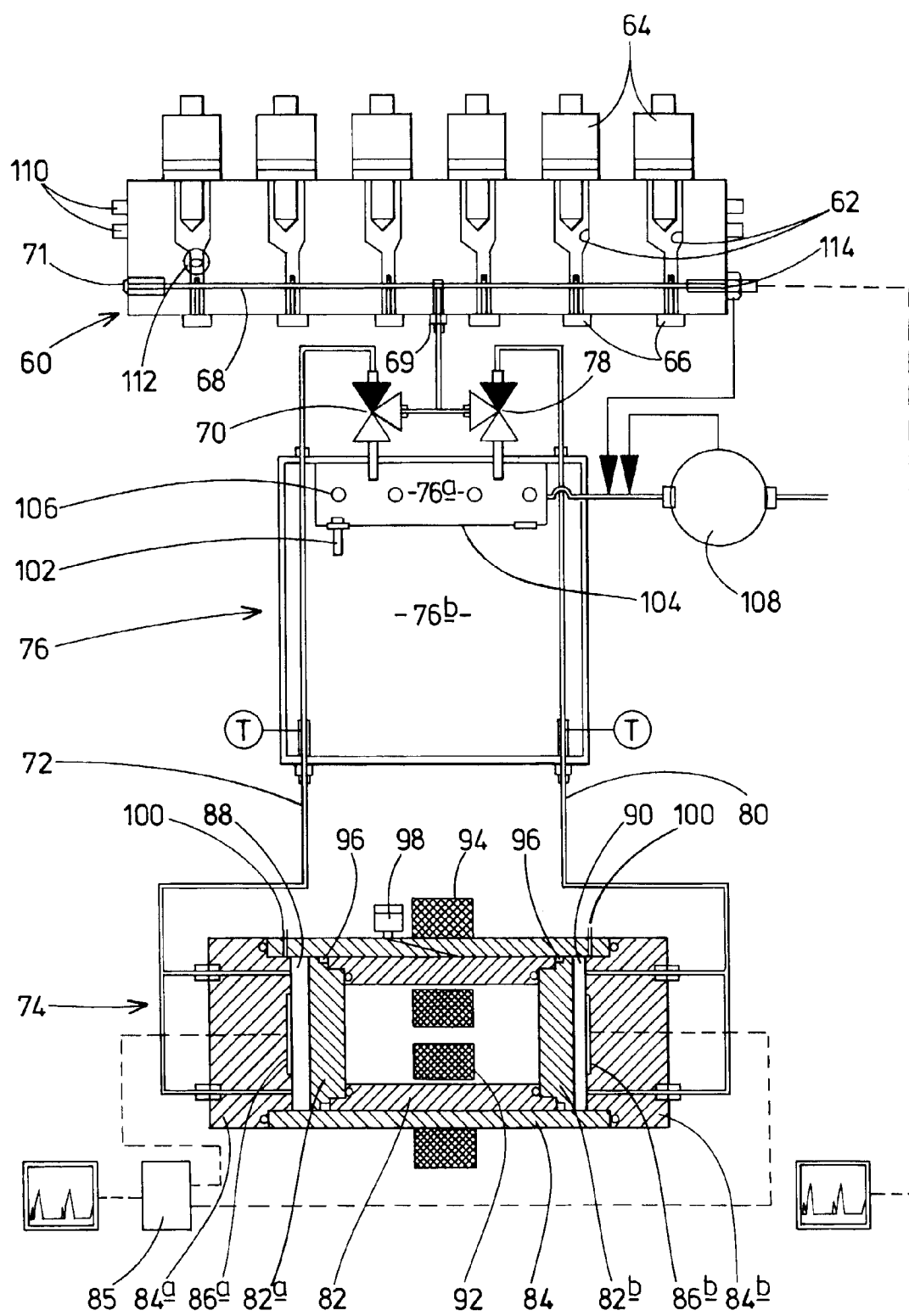


FIG 2

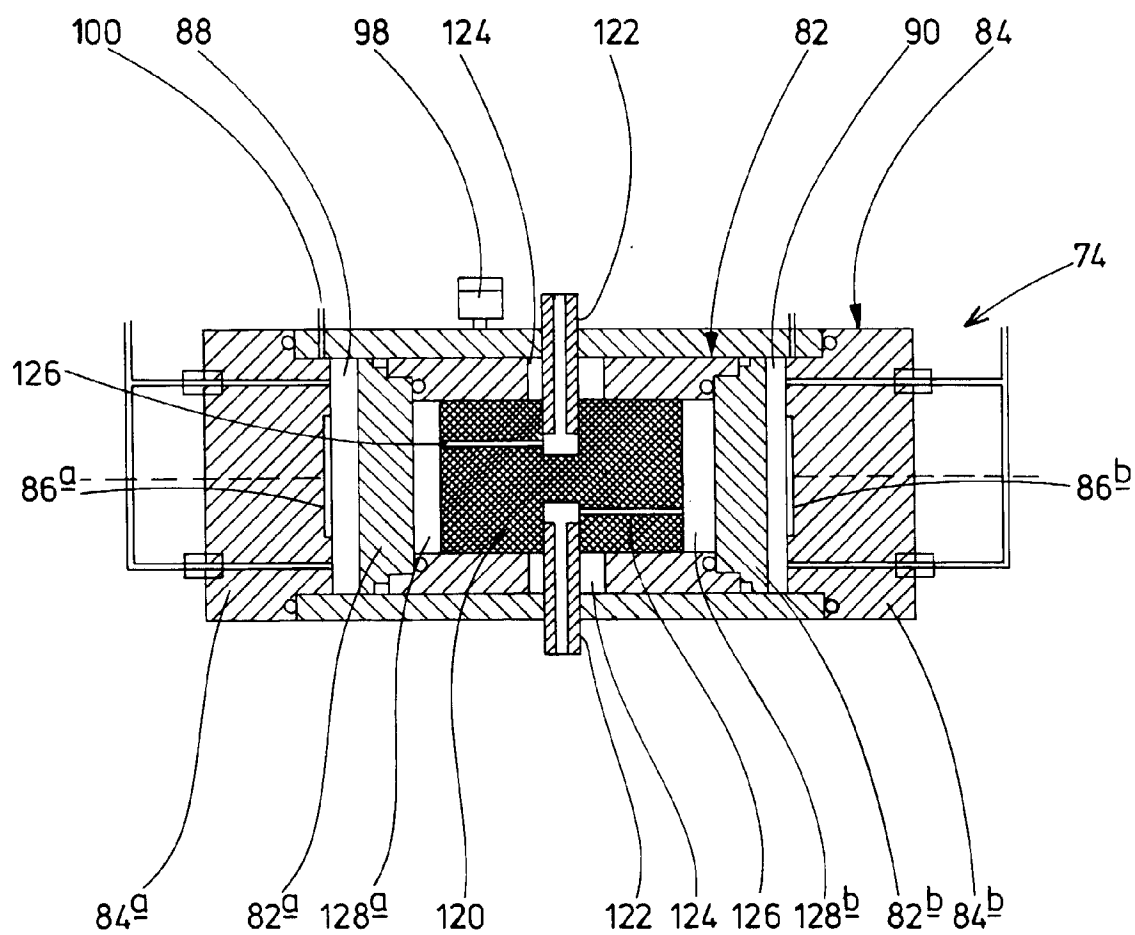


FIG 3

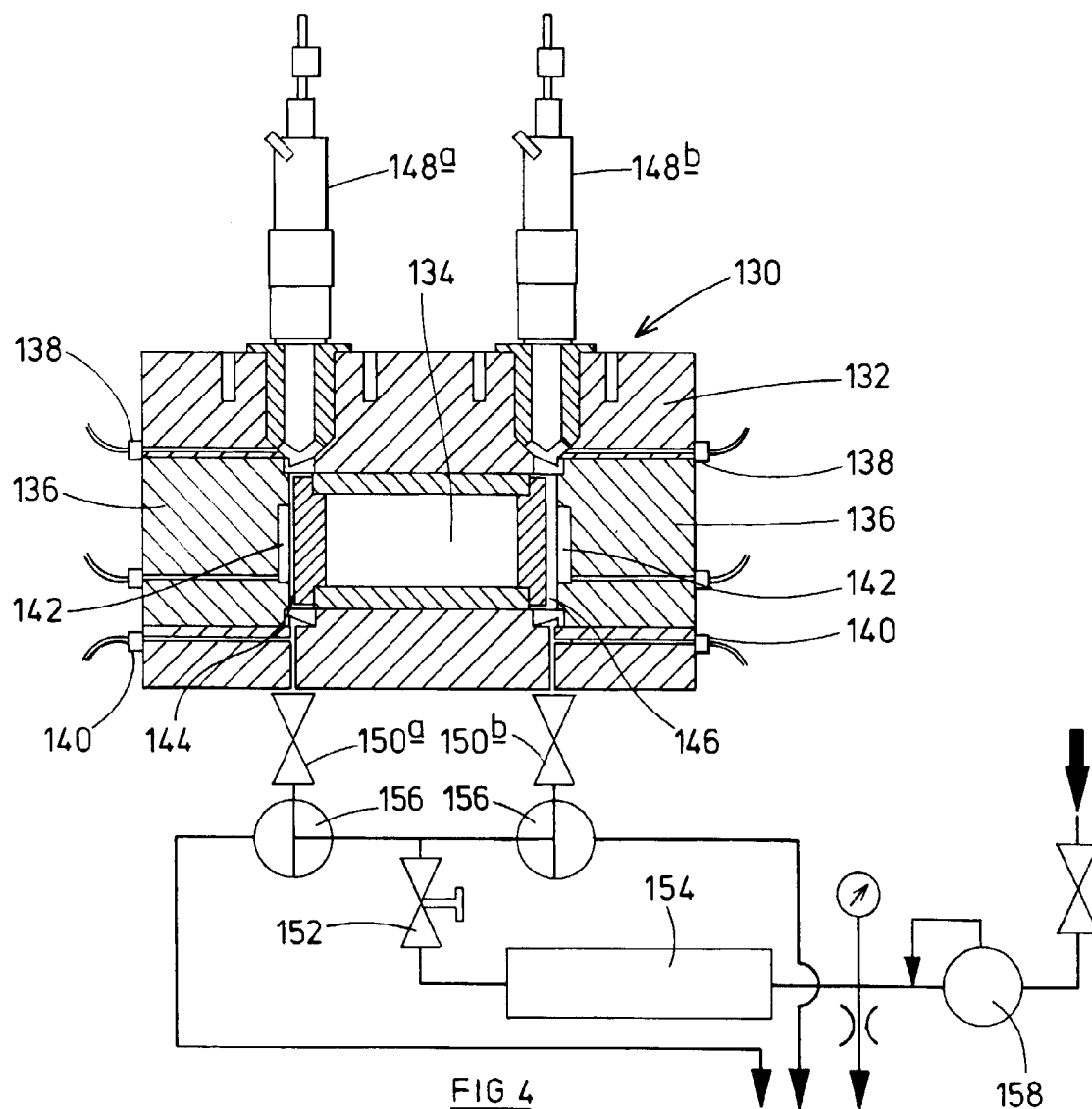


FIG 4

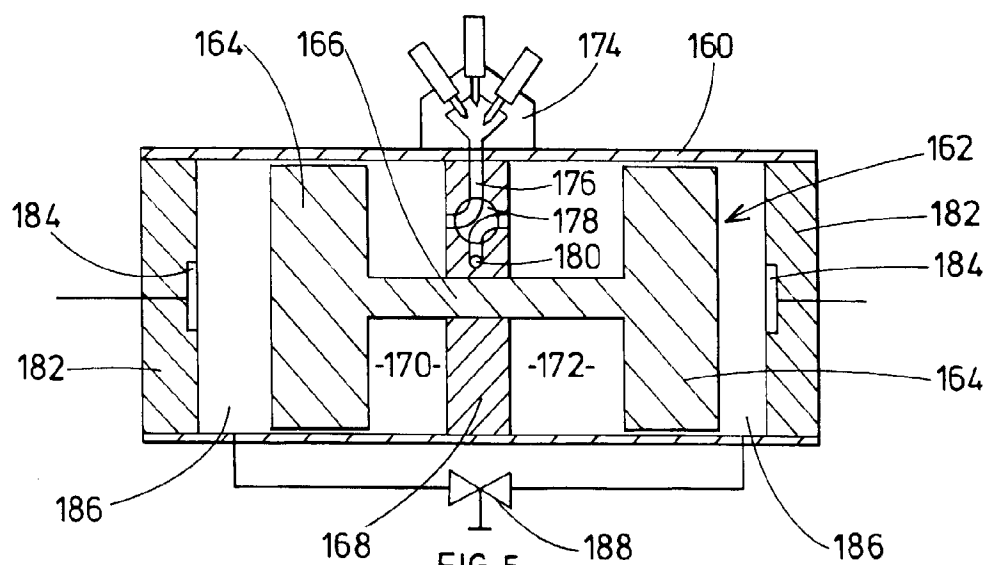


FIG 5