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(54) **An internal combustion engine and a fluid flow control device.**

(57) An internal combustion engine comprises a flow control device (6), for controlling the flow of petroleum fuel into the engine, and which comprises regulator elements (18, 19), the relative positions between which controlling the flow rate, the positions of the regulator elements being controlled by an input element (23). The device comprises an adjustment means (30) which can be set to a number of different values, which provide for different response rates of the regulator elements (18, 19) to movement of the input element (23). Liquid fuel is thus injected at a desired rate into a stream of air, utilising a closure member (66) which when the pressure at which fuel is delivered to an outlet nozzle (51) is less than a predetermined value, prevents flow of fuel through the outlet nozzle, and when the pressure at which fuel is delivered the outlet nozzle exceeds said predetermined valued, the closure member moves to open the outlet a distance proportional to the pressure in the outlet nozzle. The engine also comprises a cylinder (110) and a piston (112) slidably mounted in the cylinder. The piston (112) is provided with a cooling passageway (122) which at or adjacent the bottom dead centre position of the piston is aligned with inlet and outlet ports (124, 126) of the cylinder. In the use of the engine, gas, which may be air or a mixture of fuel and air, is caused to flow through the cooling passageway during part at least of the cycle of reciprocation of the piston in the cylinder, to remove heat from the piston (112).

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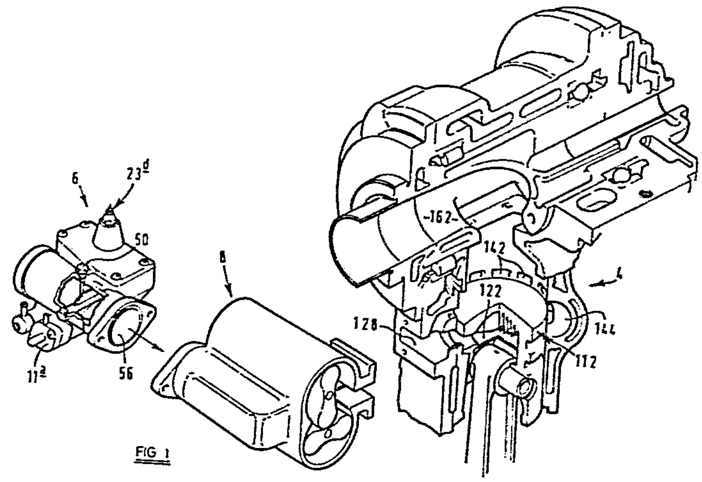

FIG 1

Title: "An internal combustion engine and a fluid flow control device"

One of the difficulties encountered in two-stroke or four-stroke internal combustion engines is that of regulation of fuel to the engine, and a first aspect of the invention is in the provision of a fluid flow control device, particularly but not exclusively for an internal combustion engine.

According to a first aspect of the invention, there is provided a fluid flow control device comprising a body having a passageway therethrough for the flow of the fluid to be controlled, regulating means including flow regulating elements movable relatively to each other by an input element between first positions and second positions respectively providing, on the one hand, closure of the passageway or greater resistance to flow and, on the other hand, lesser resistance to the flow of the fluid through the passageway and defining a flow characteristic of a predetermined form relating flow resistance (and hence rate of flow of fluid under a given pressure) to displacement of the input element from an initial position (e.g. corresponding to closure of, or maximum flow resistance presented by, the regulating elements), wherein the relationship between displacement of the input element and the relative positions of the regulator elements is determined by an adjustment means which can be pre-set into a plurality of different settings providing respectively different values of velocity ratio between the input element and the regulator elements.

The primary application of the first aspect of the invention is the provision of a device for regulating the flow of liquid fuel to the combustion chamber or chambers of an internal combustion engine either 4-stroke or 2-stroke and provided with fuel injection means (as distinct from carburettor means in which the rate of flow of fuel is determined by means responsive to the rate of flow of inlet air into the engine) for introducing the fuel into the combustion chamber or chambers, and which is simple, and hence inexpensive to manufacture and install, and will enable the user readily to vary the "tuning" of the engine by varying the rate of flow of the fuel for any given setting of the device between its first and second positions. Such injection means may supply fuel continuously, e.g. from a low pressure fuel supply pump, e.g. 40 lbs. p.s.i. or from a tank by gravity as in a motor cycle. It is, however, to be understood that certain forms of this aspect of the invention are more generally applicable to any application where the flow of fluid is required to be controlled whether such fluid is of liquid form, gaseous form or a combination of the two forms, and specifically the invention may be applied to a fuel flow regulating device intended for use on ordinary vehicle engines, or to miniature engines (e.g. in the order of 10cc capacity) as are used to power model aircraft and the like.

The adjustment means may comprise a ramp member cooperating with a follower member, one of these members being mounted on the body of the device and the other on the input element in a manner such that as the input element is moved from its initial position the follower member moves relatively over the slope presented by the ramp member, and thereby imparts to the input element the required movement to cause it to effect relative movement of the regulator element.

Whatever the form of the adjustment means, the arrangement is preferably such that when the input element is in its initial position adjustment of the setting of the adjustment means does not alter the relative positions of the regulator elements.

Adjustment of the setting may be provided for by so constructing, or so mounting, the ramp member as to enable the slope of the ramp to be varied. Preferably, such adjustment is effected angularly about an axis passing through or near the point of engagement between the follower member and the ramp member when the input element is in its initial position, so that variation of the setting of the adjustment means does not vary the positions of the regulator elements when in their first relative position, but does vary the relative positions of these elements for positions of the input element displaced from its initial position thereby changing the form of said characteristic.

As applied to a device intended to regulate the flow of liquid fuel for the purpose aforesaid or otherwise, one of the regulator elements may comprise a male valve element having an axially tapering control surface, and the other of the regulator elements may comprise a female seat element defining, in combination with the tapering surface of the valve element, an annular constriction in or controlling flow through said passageway, the valve and seat elements being relatively axially movable to determine the radial dimensions and hence the flow resistance presented by the constriction.

Preferably there may be associated with the valve element a closure element which in the first relative position of the valve and seating elements entirely closes the constriction so as to provide complete shut off of fuel when required.

A second aspect of this invention is concerned with the delivery of fuel under pressure along a fuel flow line into a chamber of an internal combustion engine, which chamber may be afforded by the engine cylinder, or may be a pre-chamber, for example a chamber in which the fuel is mixed with the air or other combustion-supporting gas prior to delivery into the engine cylinder.

Thus according to the second aspect of this invention there is provided a device for controlling the flow of liquid fuel to a chamber and which comprises an outlet nozzle which in use is secured in a position in which an outlet thereof opens into the chamber, and a closure member which is biased towards the outlet into a position in which it prevents any significant flow of fuel through the outlet into the chamber when the pressure at which fuel is delivered to the outlet nozzle is less than a predetermined value, and when the pressure at which fuel is delivered to the outlet nozzle exceeds said predetermined value, the closure member is moved against said bias away from the outlet a distance functional of the pressure in the outlet nozzle to permit fuel to flow into the chamber.

Preferably the closure member is flexible and is secured to the outlet nozzle in a manner such that, when the pressure at which fuel is delivered to the outlet nozzle is less than said predetermined value, said closure member lies across the outlet to prevent dribbling of fuel into the chamber.

Preferably the extent of movement of the closure member away from the outlet is sufficiently small that the flow area caused by opening of the closure member is less than the flow area of the outlet itself, whereby the closure member provides a positive restriction to flow of fuel into the chamber, and causes the stream of fluid to be sprayed into the chamber in the form of small droplets.

Preferably the closure member is pre-biased, e.g. by being provided with a preformed shape before being secured to the outlet nozzle, to achieve desirable response characteristics of the closure member to increase in the pressure within the outlet nozzle.

Preferably the closure member is pre-biased to a shape opposite to that which it would adopt in response to increase in pressure, were it not so pre- biased.

Thus if a non-pre-biased closure member were caused to adopt a parabolic deflection from the outlet in one direction, preferably the closure member is provided to a parabolic shape in the opposite direction, before being mounted on the outlet nozzle.

The device in accordance with the second aspect of this invention may be utilised in the direct injection of liquid fuel into an engine cylinder, or may be utilised for the injection of liquid fuel into a chamber in which the fuel is mixed with air prior to delivery to the engine cylinder. In the latter instance, preferably the orientation of the outlet nozzle and closure member in relation to the direction in which air flows through the chamber is such as to cause fuel impinging on the closure member to be provided with a component of motion opposed to the direction of flow of air through the chamber, whereby a more uniform dispersion of the fuel in the air stream is effected.

Another of the difficulties encountered in internal combustion engines is the temperature to which the piston is subjected in use. For example, in general terms, the maximum temperature which is attained by the piston during continued use must be taken into account in determining the piston running clearance. Clearly if the maximum temperature which a piston reaches may be reduced, the piston running clearance may also be reduced.

Further however, in high performance engines the temperature attained by the piston is or may be a limiting factor on continued development of such engines. This is particularly so in the case of supercharged or turbocharged engines.

In accordance with this invention there is provided an internal combustion engine comprising a cylinder and a piston reciprocably mounted in the cylinder, wherein a cooling passage extends through the piston, through which cooling passage gas flows prior to its entry into the combustion chamber to participate in a combustion reaction, during part at least of a cylce of reciprocation of the piston in the cylinder.

Preferably the cooling passageway, during part of the movement of the piston in the cylinder, is aligned with inlet and outlet ports in the walls of the cylinder, to which inlet port a supply of cooling gas under pressure is applied and through which outlet port gas may flow.

Thus when the cooling passageway is aligned with the inlet and outlet ports, gas will flow through the cooling passageway removing some heat from the piston. In this manner, the overall temperature of the piston may be reduced, allowing the piston running clearance to be decreased.

Preferably the inlet and outlet ports are so positioned as to be aligned with the cooling passageway at or adjacent to the bottom dead centre of the piston. In this manner the period of alignment may be relatively extensive, and the ports will not interfere with the normal combustion processes in the cylinder.

Preferably the passageway is of a relatively large cross-sectional area, as viewed in axial cross-section, compared with the cross-sectional area of the piston as a whole. Thus, the piston may comprise a body portion and a crowned portion spaced from the body portion by supporting portions or pillars, the space between the body portion and crowned portion, other than as is occupied by the pillars, providing the cooling passageway for flow of gas through the piston. The pillars will be of a cross-sectional area adequate for stable support of the crowned portion, and are conveniently elongate in cross-section, having a smaller dimension at right angles to the direction of flow of gas from the inlet to the outlet port, as compared with the dimension parallel to such direction of flow, whereby to provide reduced impedence to such flow through the cooling passageway.

Preferably the pillars extend, in their longitudinal direction, at right angles to the axis of the gudgeon pin.

Preferably the area of the inlet and outlet ports into the cylinder is of appropriately large size, preferably subtending an angle of at least 90° at the centre of the cylinder. Where the cylinder is afforded by a sleeve, preferably the sleeve is provided with pillars extending across the openings therein, to provide adequate strength and rigidity of the sleeve, and/or to permit the smooth passage thereacross of a piston oil control ring. Alternatively, where the cylinder bore is integral with cylinder block, pillars may be provided which are cast in members.

Preferably at least the surface of the cooling passageway close to the crown is provided with heat transfer enhancement formations, such as fins, which are preferably effective to increase the surface area of said surface by a factor of 2 at least. Preferably the passageway is defined on the surface thereof remote from the crown by a member which is produced separately and secured to the piston. In this manner, the passageway, together with the heat transfer enhancement formations, may be produced integrally with the crown portion by a diecasting or forging operation, whereby temperature gradients across the piston may be reduced, subsequent to which the cavity afforded by such operation may be closed by said separately-produced member to afford the cooling passageway.

Preferably the cooling gas is afforded by a charge of air/fuel prior to its admission to the engine cylinder. For example, in a two-stroke engine, the inlet port may be connected by a duct to the cylinder block, and the outlet port may be connected to a transfer duct opening into the engine cylinder. Thus, as the piston falls to bottom dead-centre, the cooling passageway opens communication between the ports in the cylinder wall, allowing the compressed charge to flow from the cylinder block through the cooling passageway, and by way of the transfer duct, into the cylinder at a position just above the piston top, thus serving to cool the piston crown.

The invention described in the last preceding paragraph may be used when the charge delivered to the crank case is supercharged.

Alternatively, in a four-stroke engine, a charge of air/fuel may be fed through the cooling passageway and thence to the inlet manifold, such charge optionally being supercharged. However, if desired only part of the charge for the engine may be delivered to the inlet manifold via this route.

The above and other of the various aspects of the invention will become clear from the following detailed description, which is to be read with reference to the accompanying drawings, of an internal combustion engine which is a preferred embodiment of this invention, and which has been selected for the purposes of illustrating the various aspects of this invention.

In the accompanying drawings:-

FIGURE 1 is an exploded perspective view of the preferred embodiment, parts thereof having been broken away for the purpose of clarity;

FIGURE 2 is an exploded perspective view, again with parts thereof broken away for the purpose of clarity of a fluid flow control device in accordance with the first aspect of the invention;

FIGURE 3 is a simplified view, part in side elevation and part in vertical cross-section, through the flow control device;

FIGURE 4 is a plan view of the flow control device, taken on Figure 3;

FIGURE 5 is a sectional view of the device, taken on the line A-A of Figure 4;

FIGURE 6 is a graph illustrating the flow characteristics of the embodiments of the first aspect of the invention provided with needle valves having respective control surfaces of a profile such as to provide a linear characteristic and a characteristic having an increasing slope plotting input element displacement against rate of flow;

FIGURE 7 is a sectional view of a flow control device in accordance with the second aspect of the invention, said flow control device comprising an outlet nozzle secured to the mixing chamber of the device;

FIGURE 8 is a plan view showing part of the outlet nozzle;

FIGURE 9 is a perspective view of a closure member of the outlet nozzle;

FIGURE 10 is an enlarged view of the engine cylinder of the preferred embodiment;

FIGURE 11 is a simplified view in longitudinal section of part of the cylinder shown in Figure 10;

FIGURE 12 is a simplified view in cross-section of part of the piston of the preferred embodiment; .

FIGURE 13 is a longitudinal sectional view, taken on the line B-B of Figure 11;

FIGURE 14 is a longitudinal sectional view of a modified form of cylinder; and

FIGURE 15 is a sectional view, taken on the line C-C of Figure 14.

The preferred embodiment of this invention is an internal combustion engine, specifically a uniflow two-stroke engine, comprising a piston/cylinder assembly 4 (see in particular Figures 1 and 10), a flow control or metering device 6 (see in particular Figures 1 and 2) and a super charger 8, through which an accurately determined flow of fuel/air mixture is delivered from the metering device 6 to the piston/cylinder assembly 4.

The metering device (shown in detail in Figures 3 to 6) comprises a body 10 having an internal chamber 11 which may be cylindrical, and which is closed by a cover 11a. Liquid fuel (such as petroleum) is delivered to the metering device through a fuel supply pipe 12 from a fuel tank under gravity, or by a fuel supply pump, which may be a low pressure pump, the supply pipe 12 being suitably fixed in a radial bore 13 communicating with the chamber 11, and such fuel may be delivered from a pipe 14 fixed in a socket 15 in the cover 11a co-axial with the axis 16 of the chamber 11. The pipe 14 communicates with the chamber by way of an orifice 17 afforded by a seating 18 also co-axial with the axis 16. In certain cases it may be convenient for the fuel to be delivered in the reverse direction, i.e. entering by way of pipe 14 and delivered from pipe 12.

For controlling flow of the fluid from the inlet pipe 12 to the outlet pipe 14 regulator means are provided comprising the seating 18 already referred to and a needle 19 having an axially tapering control surface 19a which in combination with the interior circumferential surface of the seating 18 defines an annular constricting passageway of variable radial dimensions depending upon the axial position of the needle 19.

The needle 19 is carried in a fluid-tight manner by a tubular holder 20 which is slidably mounted in a bore 20a of the body 10, which has a longitudinal axis coincident with the axis 16. The needle 19 may be externally screw threaded for cooperation with an internal screw thread in the holder to permit of axial adjustment of the needle relatively to the holder, any leakage of fluid from the outer end of the holder 20 being prevented by a seal comprising an O-ring 22 contained in an annular recess at the extremity of the holder 20.

The needle 19 may be held against rotation with respect to the holder 20 either by friction arising from sealing ring 22 or by provision of a lock nut (not shown) abutting the outer end of the holder surrounding the O-ring 22.

Thus, the needle 19 and holder 20 may move along the axis 16 as a unitary assembly.

In one position of the needle 19 (hereinafter called the first position) one end of the holder acts as a closure element, completely to close communication between the pipes 12 and 14 at the seating 18, a resilient seal 21 provided on the holder engaging against the inwardly axially presented face of the seating 18.

Axial movement of the needle/holder assembly as a unit is effected by an input device 23 which may comprise an input element afforded by an arm 23a operatively connected to the holder 20, and a control member 23b afforded by a further arm also fixedly secured to the holder 20 and which carries a follower member 24 such as a roller which cooperates with an inclined plane or ramp surface 25 afforded by a ramp member 26. The arm 23a is connected to the throttle cable 23d, such that on movement of the throttle controlling the engine, the arm 23a is moved. The arm 23a may either be connected directly to the holder 20, whereby such movement of the arm 23a causes direct rotation of the holder 20, as is shown in Figure 3, or may be mounted at a position spaced from the holder 20, such movement of the arm 23a causing rotation of the holder by gearing, as is shown in Figure 2.

In the operation of the regulator means to control the position of the needle/holder assembly relative to the seating 18, the arm 23a is moved to rotate the assembly about the axis 16, causing the arm 23b and the follower member 24 carried thereby to move across the ramp member 26, causing axial movement of the needle/holder assembly relative to the seating 18. A torsion spring 31 acting between a bracket 32 and a nut 22a of the arm 23a acts torsionally and compressively to urge the input device to a rest position, and the needle/holder assembly to its first position.

Mounted on the body 10 is a housing 10a, being separably secured in position by a screw 10c carried by the housing and which co-operates with a circumferential groove 10d in the body, whereby the orientation of the housing 10a on the body 10 may be adjusted.

Provided in an upper surface of the housing 10a is a part-circular recess 10b, whose centre lies on a vertical axis 27 (see Figures 4 and 5) the ramp member being mounted in the recess 10a in a manner whereby it may be moved angularly about said axis 27. Such adjustment of the position of the ramp member 26 is preferably effected by an adjusting screw 30 which extends through the housing 10a through a recess 10c thereof, and a complementarily threaded member (which may be afforded by a half nut 28) located in a transverse slot 28a of the member 26, said half nut 28 being urged by a spring 29 into engagement with the screw 30. Thus by rotation of the adjusting screw 30, the member 28 may be caused to move longitudinally, to produce a turning movement of the member 26 about the axis 27.

As an alternative, such angular adjustment of the member 26 may be effected by a worm element meshing with a toothed sector which may be integral with the member 26, the worm being rotatable by an adjusting screw in the body 10, which restrains the worm element against axial movement.

In the preferred embodiment, the construction and arrangement is preferably such that, in the first position of the needle/holder assembly, the follower member 24 engages the inner extremity of the ramp surface 25 at a position coincident with, or adjacent to, the axis 27 so that angular adjustment of the inclined plane member 26 does not in fact produce any displacement of the follower in the direction of the axis 16. The ramp surface would have a tangential relation to the follower at this position. As soon, however, as the input device 23 is rotated about the axis 16, the follower will move outwardly over the ramp surface to a second position such as 25b, and will produce axial movement of the needle/holder assembly, permitting of flow of fluid from the inlet to the outlet pipe. The degree of constriction is determined by the axial position of the needle 19 within the holder 20.

The needle 19 has a tapering control surface 19a which may be straight, or convexly or concavely curved in profile, or a combination of these. The ramp surface may also be shaped to provide a linear relation between angular movement of the input element (arm 23) and axial movement of the holder 20 and needle 19, or again may be convexly or concavely shaped in profile.

A set of needles 19 having different dimensions/ tapers may be provided if desired and each would preferably have a shoulder at the junction of the tapering and non-tapering parts for registration with the end face of the holder. Each set may include tapers of the same or different kinds, e.g. linear, concave or convex.

By removal of the cover 11a and replacement thereof with another cover, the seating 18 may be changed. Alternatively, the seating 18 may be made as a replaceable (e.g. screw in) part of the cover and a set of different diameter orifice seating parts may be provided. Similarly, if desired, the ramp member 26 may be readily replaceable.

A front cover 11b is provided, having access hatches 30a and 19a, providing for access respectively to the adjusting screw 30 and the needle 19 for adjustment purposes.

Figure 6 illustrates the effect of adjusting the slope of the ramp surface.

The upper set of characteristics A1, A2, A3 shown in Figure 6 are intended to represent the relationship between rate of flow and displacement of the input element, namely arm 23a, where a linear characteristic is required.

When the arm 23a is moved from its initial position in which flow through the device is shut off entirely, there will immediately be a rate of flow F_a established dependent upon the annular area of the orifice between the seat element and the needle existing at that position of the latter. Thereafter the area of the annular orifice will increase with each angular increment of movement of the arm 23*a* and may, depending upon the profile of the control surface 19*a*, produce linear increase in the rate of flow as illustrated, so that at the fully open position the rate of flow may be represented by ordinate Sa1 when the ramp member is in its position of minimum slope.

By adjusting the ramp member rate of flow at the fully open position can be brought to values represented by ordinates Sa2 and Sa3, the characteristic connecting point F_a with these being represented by lines A2, A3 of increasing slope.

Adjustment of the needle 19 relatively to the holder 20 in an axial direction will shift the initial point F_a upwards or downwards as indicated by the arrow adjacent thereto and will similarly shift the ordinates Sa1 to Sa3 up or down.

The lower set of curves represent a situation in which the characteristics required are that the rate of flow of fuel shall increase non-linearly with respect to increments of displacement of the arm 23*a* in such a manner that the characteristics present upward concavities.

Again the starting point may be adjusted by adjusting the initial position of the needle relatively to the holder producing the effect illustrated by the arrow adjacent to the point F_b and likewise shifting the ordinates to the fully open positions Sb1 to Sb3.

It will be appreciated that in theoretical terms, over a very small range of movement of the needle/holder assembly from the seating 18, the rate of flow of fluid will be determined not only by the axial position of the needle 19 relative to the holder 20, but also by the physical characteristics of the seal 21. However, under normal circumstances this factor is not significant, and in circumstances where the factor becomes significant, action may be taken (such as by the use of a seal of a suitable construction and profile) to minimise this effect.

Thus in general terms, axial adjustment of the needle has the effect that a different longitudinal portion of the control surface 19a is brought into use, so that apart from adjusting the starting point F_a, F_b, it is also possible to vary the shape of the characteristic produced.

By the use of the two adjustments, namely the initial axial position of the needle and the slope of the ramp surface, a very wide variety of characteristics can be achieved. Additionally, the capability for changing the slope of the curve without alteration to the base value, and the capability of changing the base value without alteration to the slope, allow an engine to be tuned to obtain optimum performance with exceeding simplicity.

Further, any given setting can readily be reproduced by providing indicator means in association with each adjustment such as graduation marks on the needle to register with a datum surface such as the end surface of the holder and angular graduation marks on the ramp member to register with an appropriate mark or feature on the body.

Whilst in the embodiment above described fuel is delivered to the pipe 12 under pressure, it is possible for the fuel to be drawn into the pipe 14 by low pressure therein, as may be achieved by a venturi device.

Whilst the metering device above described has been described in relation to the control of fuel delivered to an internal combustion engine, it is to be appreciated that the metering device may be utilised in other applications, such as industrial or chemical equipment, where accurate and versatile control over the flow of a liquid is require.

In accordance with the second aspect of the invention, a flow control device is utilised (see Figures 7, 8 and 9 which controls the flow of fuel delivered under pressure into a mixing chamber 56 through which air flows towards the engine.

The device comprises a body 50 provided with an axial bore 52 and an outlet passage 54, and the mixing chamber 56 is defined by a housing 58. The body is secured into the wall of the housing and affords an outlet nozzle 51 providing an outlet which opens into the chamber 56, the axis of the passage 54 extending generally at right angles to the direction of air flow through the chamber 56, indicated in Figure 5 by the arrow A.

A forward end face 60 of the body, being that through which the passage 54 opens, is inclined at about 45° to the longitudinal axis of the passage 54, a recess 62 being provided above an upper end region of said surface 60. Extending generally at right angles to the longitudinal axis of the passage 54, from an upper portion of the body 50 towards the passage 54, is a slot 64.

Secured to the body is a closure member 66, said member being secured in position by a packing member 68 which is press-fitted into the recess 62, and subsequent downward deformation of the forward end portion of the body 50 (Figure 7) by the insertion of a bush 70 into the slot 64, to open said slot and partially to close the recess 62 firmly to clamp the member 68 and the end portion of the member 66 within the recess 62.

In the use of the engine of which the device of the second aspect of the present invention forms part, fuel under pressure is delivered into the axial bore 52, through the passage 54 and into the chamber 56, wherein it is mixed with air flowing in the direction A for subsequent combustion by the engine.

When the pressure within the axial bore 52 is less than a predetermined minimum, the closure member 66 lies flat against the surface 60, closing the opening of the passage 54 and preventing any significant flow of fuel (such as dribbling of residual fuel) into the chamber 56. However when fluid under pressure is delivered to the axial bore 52, the pressure acting within the passage 54 serves to lift the closure member 66 away from the face 60, opening the passage 54 and allowing fuel to flow under pressure into the chamber 56.

Preferably the extent of movement of the closure member 66 away from the outlet of the passage 54 is sufficiently small to ensure that the flow area produced by such opening movement of the closure member does not exceed the flow area of the passage 54 itself. In this manner, the closure member acts on liquid fuel flowing through the outlet to break up the stream and to direct it against the direction of flow of air through the chamber 56. In this manner, a desirable distribution of the very small droplets of fuel within the air stream is obtained.

In the embodiment described above, it is envisaged that the closure member 66 may be deflected away from the outlet in the surface 60 by a distance of about 0.002 inches.

Conveniently the closure member 66 is afforded by a thin, resilient sheet of metal, such as an alloy comprising beryllium and copper, or stainless steel, whereby the member 66 returns to its closed position of its own volition, on reduction of pressure within the bore 52. However if desired other biasing means may be utilised.

Were the member 66 afforded by a flat sheet, it would respond to increase in pressure within the bore 52 by adopting a somewhat parabolic shape. Desirably therefore the member 66 is preformed to a parabolic shape, of opposite direction, as shown in Figure 9, the area 66a shown therein being that portion which on assembly of the member 66 is located within the recess 62. Thus the response characteristics of the closure member will be such as to ensure a more uniform movement of the opposite end portion thereof away from the face 60, in response to an increase in pressure within the housing 50.

The construction and manner of mounting of the closure member, as described above, additionally prevents or minimises a "blow back" entering the bore 52 from the chamber 56.

Whilst the flow control device described above is specifically for controlling the flow of liquid fuel into a stream of air, prior to delivery thereof to an internal combustion engine, it is envisaged that the flow control device may be designed to operate as an intermittent, high pressure injecter (for example operating in the order of 2000 p.s.i.) for direct or indirect injection of fuel into the combustion cylinder of an engine.

In the operation of the engine which is the preferred embodiment of this invention, a mixture of liquid petroleum fuel and air flows from the metering device 6 to the supercharger 8, from which it flows into the engine cylinder, to participate in a combustion operation.

If desired, an intercooler may be interposed between the turbo charger and the inlet manifold, to reduce the temperature of the charge delivered to the engine cylinder, and a turbocharger may be substituted for the supercharger.

The engine cylinder, which is in accordance with the third aspect of this invention, comprises a cylinder block 104, in which there is provided a bore 106, lined with a liner 108 to provide a cylinder 110. Slidably mounted in the cylinder chamber 110 is a piston 112 (Figure 13) comprising a body portion 114, and an upper, or crown portion 116 integral with the body portion 114, and spaced therefrom by a plurality of, preferably two, pillars 118.

Mounted on the cylinder block 104 is a cylinder head 160, in which there is mounted a rotary exhaust valve 162.

The underside of the crown portion 116 is provided with a number of elongate fins 120, said fins extending parallel to the longitudinal axis of the pillars 118. Mounted across the body portion 114, generally between the pillars 118, is a separately-formed closure disc 121.

The cylinder liner 108 is provided with two apertures 124, 126 on diametrically opposite sides thereof, each of said apertures subtending at the centre of the cylinder, in said cross-section, an angle of about 110° (see Figure 13). Extending through the cylinder block to the aperture 124 is an inlet duct 128, and extending at a diametrically opposite part of the cylinder block to the port 126 is an outlet duct 130.

In the use of the engine shown in Figures 11 to 13, on movement of the piston 112 to its bottom dead-centre position (shown in Figures 10 and 11) the cooling passageway 122, defined between the crown underside 120 and the closure disc 121, is aligned with the ducts 124 and 126 of the cylinder sleeve, and air under pressure flows through the inlet duct 128, through the inlet port afforded by the aperture 124, through the cooling passageway 122, and out through the outlet port afforded by the aperture 126 and through the duct 130.

Additionally, air under pressure will flow through sub-passages 122' situated outwardly of the pillars 118, and located between said pillars and the cylinder liner, the upper surfaces of which sub-passageway may also be finned.

In this manner, heat may be removed from the crown portion 116 of the piston as it reaches bottom dead-centre, reducing the temperature of the piston as a whole, and also reducing the temperature gradient within the piston and reducing physical and/or thermal stresses to which the piston is, in use, subjected.

Preferably, the cooling gas is afforded by fuel/air used in the operation of the engine, and prior to its admission to the engine cylinder. Thus, fuel/air may be fed through the inlet duct 128, through the inlet port afforded by the aperture 124, through the cooling passageway 122, and out through the outlet port afforded by the aperture 126 and through the duct 130, from whence the fuel/air mixture is ducted to the engine. However, not all the petrol/air mixture required for the engine may be so ducted, and some may be ducted directly to the inlet manifold, only part of the charge required for the engine being fed through the cooling passageway. Preferably, as is shown in the accompanying drawings, the charge fed through the cooling passageway may be delivered thereto from the supercharger 8.

In view of the circumferential extent of the inlet and outlet ports 124, 126, as seen in the sectional view of Figure 13, if desired vertical pillars 125, 127 may be respectively provided, to add stability to the cylinder liner, and to ensure a smooth passage across said ports of the lower oil control ring, if provided.

As will be seen from Figure 11, the upper oil control ring does not pass across the ports 124 and 126.

Additionally, there may be provided vertical pillars across the inlet duct 128, indicated by the members 129 in Figure 13, to provide for stability of the inlet duct 128, and to reduce turbulence of air striking the pillars 125.

Thus in the engine which is the preferred embodiment of this invention, there is provided in the cylinder block an annular passage 140, from which ports 142 extend through the liner 108 and open into the cylinder 110, and the outlet duct 130 is connected to the annular passage 140 by a transfer duct 144.

By-pass ducts 146 are also provided, which extend from the inlet passage 128 to the annular passage 140.

Thus in the operation of the engine, when the piston reaches its bottom dead-centre position (shown in Figure 11) a charge for the next firing cycle of the engine flows through the inlet duct 128 and part of said inlet charge flows through the cooling passageway 122 to the outlet duct 130, from which said charge passes through the transfer duct 144, into the annular passage 140, and through the ports 142 into the engine cylinder above the crown upper face. Other gas flowing through the inlet duct 128 will flow through the ducts 146 into the opposite side of the annular passage 140 and pass into the engine cylinder directly.

In this manner, flow of a charge of air and fuel into the engine cylinder for the next firing cycle is utilised to cool the crown portion of the piston, both by passage of the gas through the cooling passageway 122, and the cooling action thereof on the fins 120, and by flow of the gas across the crown upper surface. In this manner the temperature of the piston is reduced.

In a modified form of the third aspect of the invention, illustrated in Figures 14 and 15 of the drawings, in which similar numerals with the suffix a are used, rather than the charge of liquid petroleum fuel and air, after flowing through the cooling passage 122a, flowing directly into the engine cylinder to participate in a combustion reaction, the duct 130a is connected to a supercharger or turbocharger.

CLAIMS:

1. A flow control device comprising a body having a passageway (14,11,13) therethrough for the flow of fluid to be controlled, regulating means including flow regulating elements (18,19) movable relative to each other by an input element (23) between first positions and second positions respectively providing, on the one hand, closure of the passageway or greater resistance to flow and, on the other hand, lesser resistance to flow of fluid through the passageway and defining a flow characteristic of a predetermined form relating flow resistance to displacement of the input element (23) from an initial position, wherein the relationship between displacement of the input element (23) and the relative positions of the regulator elements (18,19) is determined by an adjustment means (23b,24,25,30) which can be preset into a plurality of different settings providing respectively different values of velocity ratio between the input element (23) and the regulator elements (18,19).

2. A device according to Claim 1 comprising a ramp member (26) co-operating with a follower member (24), one of these members being mounted on the body (10) of the device and the other on the input element (23) in a manner such that as the input element (23) is moved from its initial position the follower member (24) moves relatively over the slope (25) presented by the ramp member, and thereby imparts to the input element (23) the required movement to cause it to effect relative movement of the regulator elements (18,19).

3. A device according to one of Claims 1 and 2 wherein when the input element (23) is in its initial position adjustment of the setting of the adjustment means (30) does not alter the relative positions of the regulator elements (18,19).

4. A device according to any one of the preceding claims adapted for use in the regulation of flow of liquid fuel, one of the regulator elements (19) comprising a male valve element (19a) having an axially tapering control surface, and the other of the regulator elements (18) comprising a female seat element defining, in combination with the tapering surface of the valve element, an annular constriction (17) in or controlling flow through said passageway, the valve and seat elements (19a,17) being relatively axially movable to determine the radial dimensions and hence the flow resistance presented by the constriction.

5. A device for controlling the flow of liquid fuel to a chamber (56) and which comprises an outlet nozzle (51) which in use is secured in a position in which an outlet (54) thereof opens into the chamber (56), and a closure member (66) which is biased towards the outlet (54) into a position in which it prevents any significant flow of fuel through the outlet (54) into the chamber (56) when the pressure at which fuel is delivered to the outlet nozzle (51) is less than a predetermined value, and when the pressure at which fuel is delivered to the outlet nozzle (51) exceeds said predetermined value, the closure member (66) is moved against said bias away from the outlet (54) a distance functional of the pressure in the outlet nozzle to permit fuel to flow into the chamber.

6. A device according to Claim 5 wherein the closure member (66) is flexible and is secured to the outlet nozzle (51) in a manner such that, when the pressure at which fuel is delivered to the outlet nozzle is less than said predetermined value, said closure member (66) lies across the outlet (54) to prevent dribbling of fuel into the chamber.

7. A device according to one of Claims 5 and 6 wherein the extent of movement of the closure member (66) away from the outlet (54) is sufficiently small that the flow area caused by opening of the closure member is less than the flow area of the outlet itself, whereby the closure member provides a positive restriction to flow of fuel into the chamber (56), and causes the stream of fluid to be sprayed into the chamber (56) in the form of small droplets.

8. A device according to any one of Claims 5 to 7 wherein the closure member (66) is pre-biased to a shape opposite to that which it would adopt in response to increase in pressure, were it not so pre-biased.

9. A device according to any one of Claims 5 to 8 adapted for use in the injection of liquid fuel into a chamber (56) in which the fuel is mixed with air prior to delivery to the engine cylinder, wherein the orientation of the outlet nozzle (51) and closure member (66) in relation to the direction (A) in which air flows through the chamber (56) is such as to cause fuel impinging on the closure member (66) to be provided with a component of motion opposed to the direction of flow of air through the chamber (56).

10. An internal combustion engine comprising a cylinder (110) and a piston (112) reciprocably mounted in the cylinder, wherein a cooling passage (122) extends through the piston, through which cooling passage (122) gas flows prior to its entry into the combustion chamber to participate in a combustion reaction, during part at least of a cycle of reciprocation of the piston (112) in the cylinder (110).

11. An internal combustion engine according to Claim 10 wherein the cooling passageway (122), during part of the

movement of the piston (112) in the cylinder, is aligned with inlet and outlet ports (128,130) in the walls of the cylinder, to which inlet port (128) gas under pressure is applied and through which outlet port (130) gas may flow.

12. An internal combustion engine according to one of Claims 10 and 11 wherein the piston (112) comprises a body portion (114) and a crowned portion (116) spaced from the body portion by supporting members (118) , the space between the body portion and crowned portion, other than as is occupied by the supporting members, providing the cooling passageway (122) for flow of gas through the piston, the supporting members (118) being elongate in cross-section and have a smaller dimension at right angles to the direction of flow of gas from the inlet port (128) to the outlet port (130), as compared with the dimension parallel to such direction of flow.

13. An internal combustion engine according to any one of Claims 10 to 12 wherein the surface of the passageway is provided with heat transfer enhancement formations, preferably provided by fins (120), which are effective to increase the surface area of said surface by a factor of 2 at least.

14. An internal combustion engine according to any one of Claims 10 to 13 wherein the cooling gas is afforded by air under pressure applied to the cooling passage (122) via an inlet duct (128) extending through the cylinder block after passage through an engine supercharger (8).

15. An internal combustion engine according to any one of Claims 10 to 13 wherein a charge of air/fuel is utilised as cooling gas prior to its admission to the engine cylinder (110).

16. An internal combustion engine according to Claim 15 wherein the engine is a two-stroke engine, and the outlet port (130) is connected by a transfer duct (144) opening into the engine cylinder.

17. An internal combustion engine according to Claim 15 wherein the charge delivered to the inlet port (128) is supercharged.

18. An internal combustion engine according to Claim 15 wherein the engine is a four-stroke engine, and a charge of air/fuel is fed through the cooling passageway (122) and thence to the inlet manifold of the engine.

19. An internal combustion engine according to Claim 18 wherein said charge of air/fuel is supercharged.

20. An internal combustion engine according to one of Claims 18 and 19 wherein part only of the charge for the engine is delivered to the inlet manifold via this route.

21. An internal combustion engine including the features set out in one or more of the preceding claims.

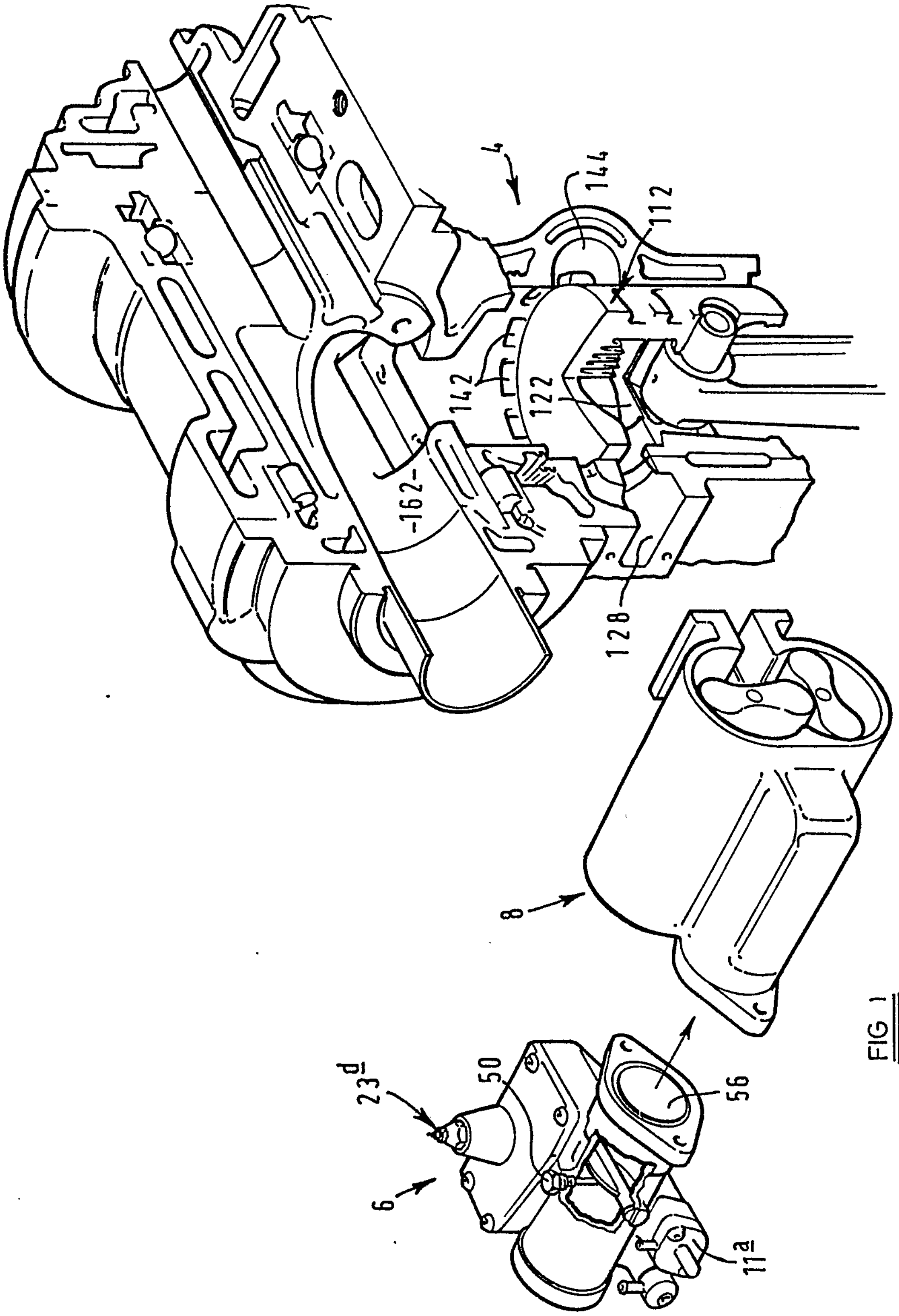

FIG 1

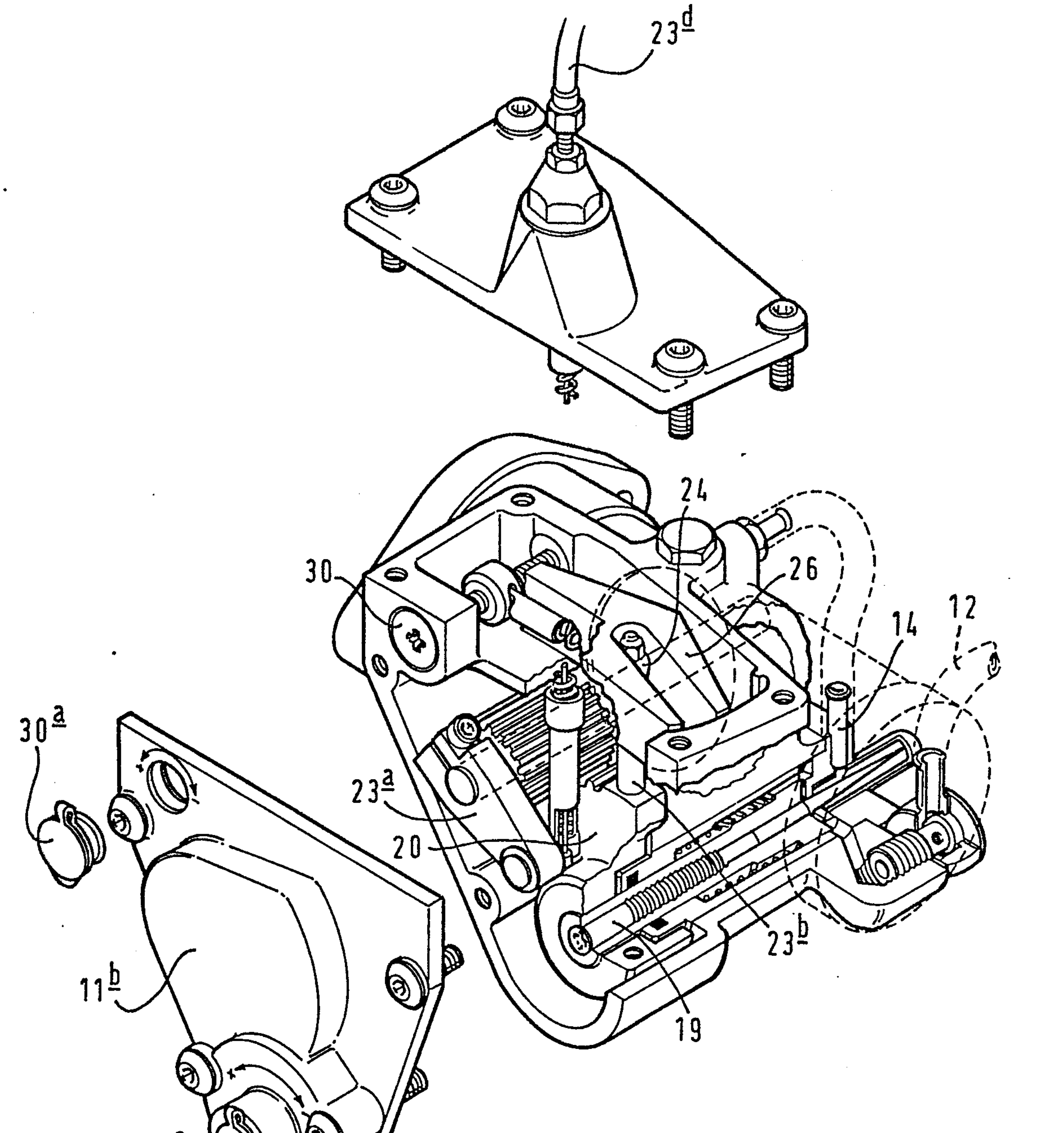

FIG 2

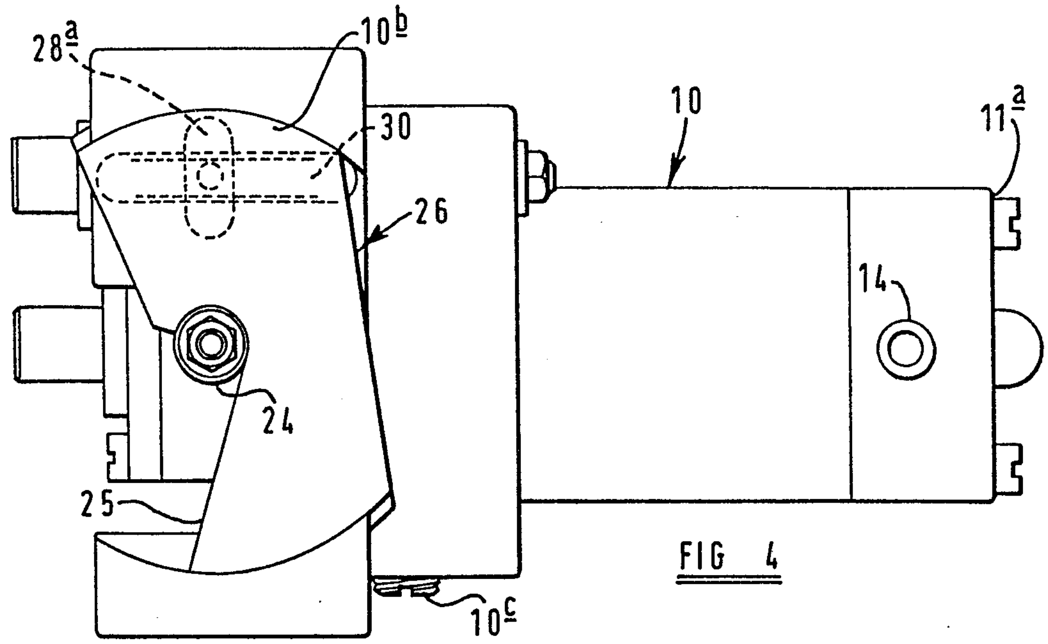
28a
10b
30
10
11a
26
14
24
25
10c

FIG 4

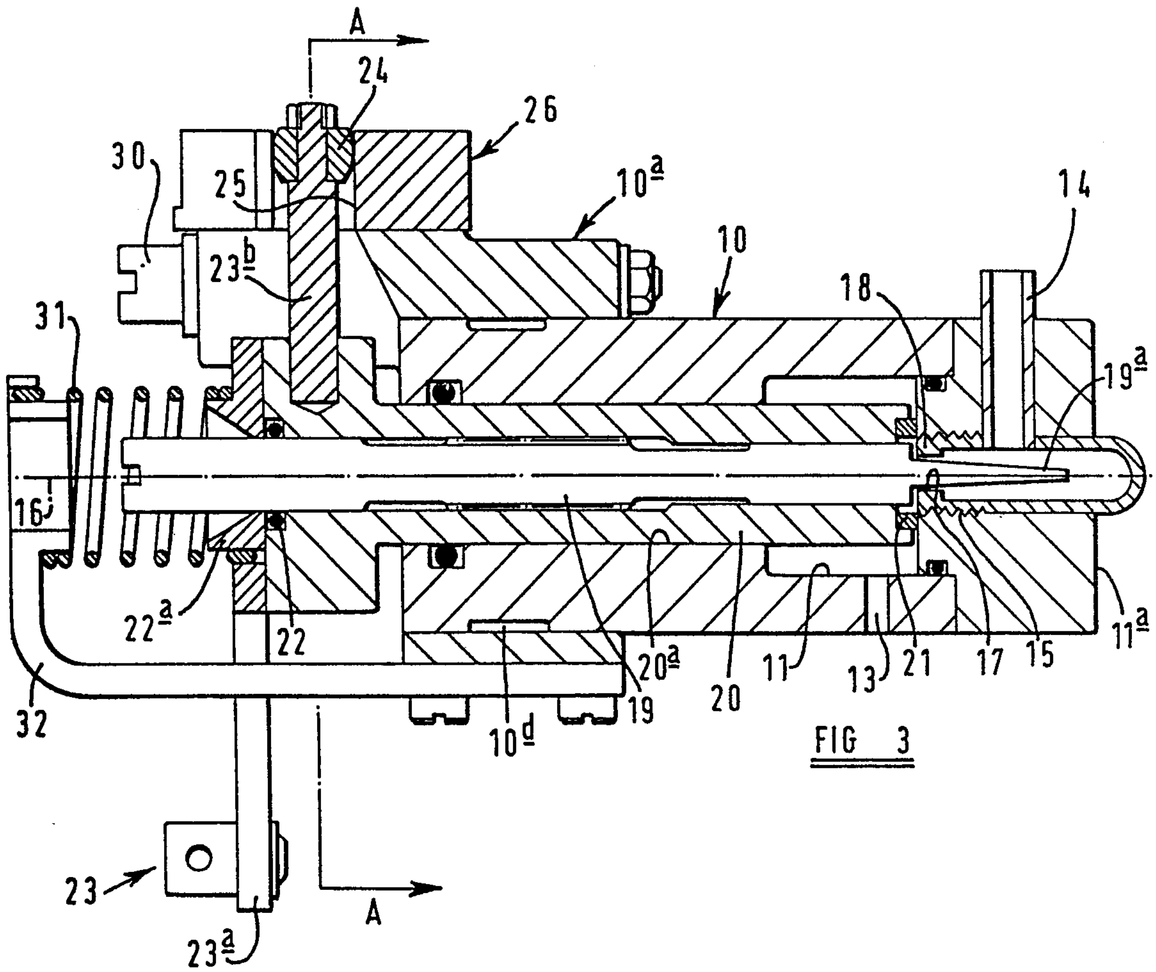
A
24
26
30
25
10a
10
23b
18
14
31
19a
16
22a
22
20a
11
13
21
17
15
11a
32
19
20
10d
23
23a
A

FIG 3

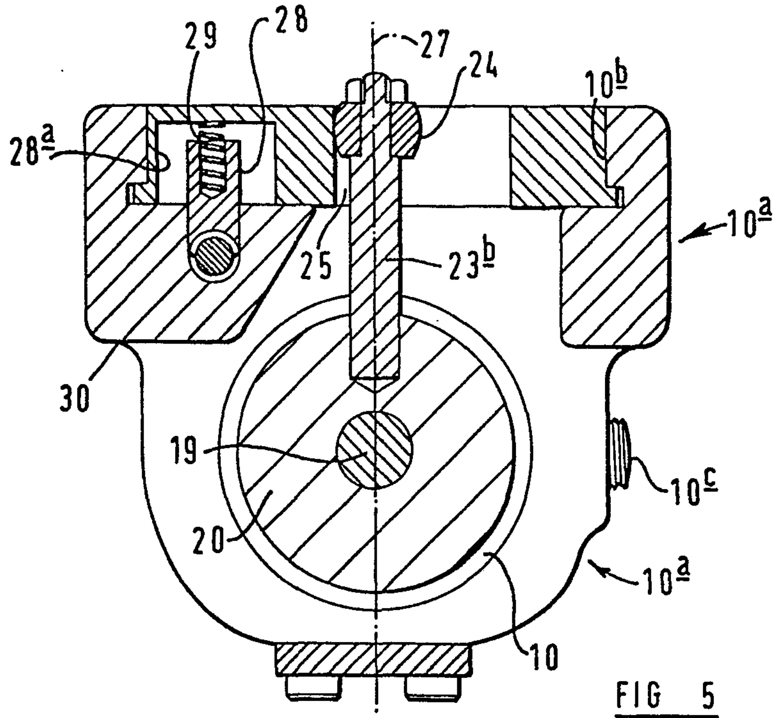
29
28
27
24
10b
28a
10a
25
23b
30
19
10c
20
10a
10

FIG 5

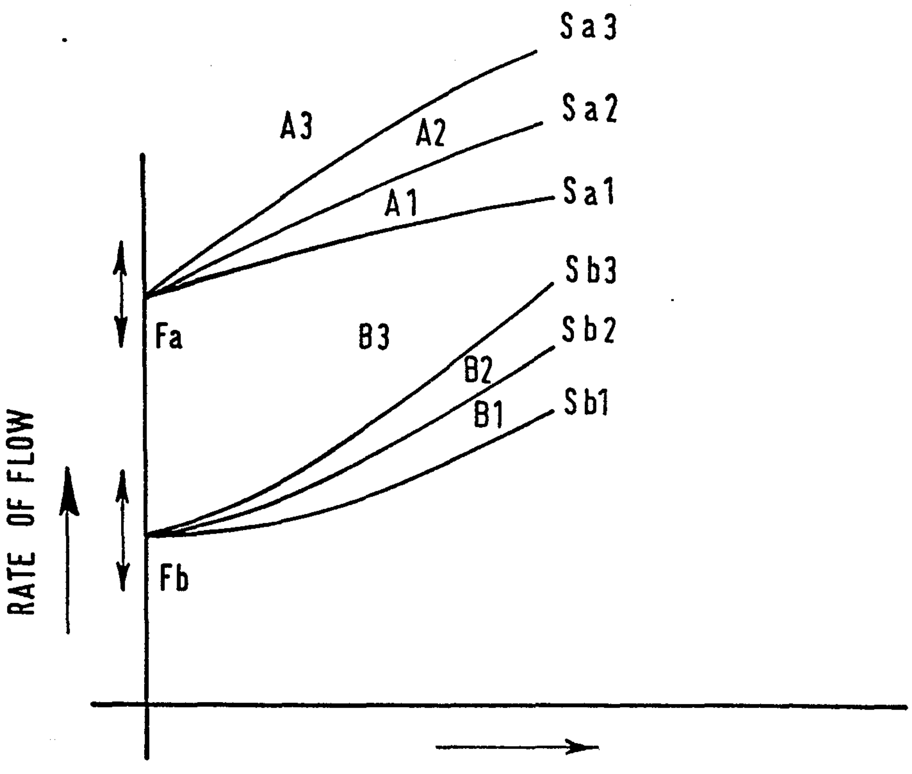
Sa3
A3
A2
Sa2
A1
Sa1
Sb3
Fa
B3
Sb2
B2
B1
Sb1
RATE OF FLOW
Fb
DISPLACEMENT OF INPUT ELEMENT

FIG 6

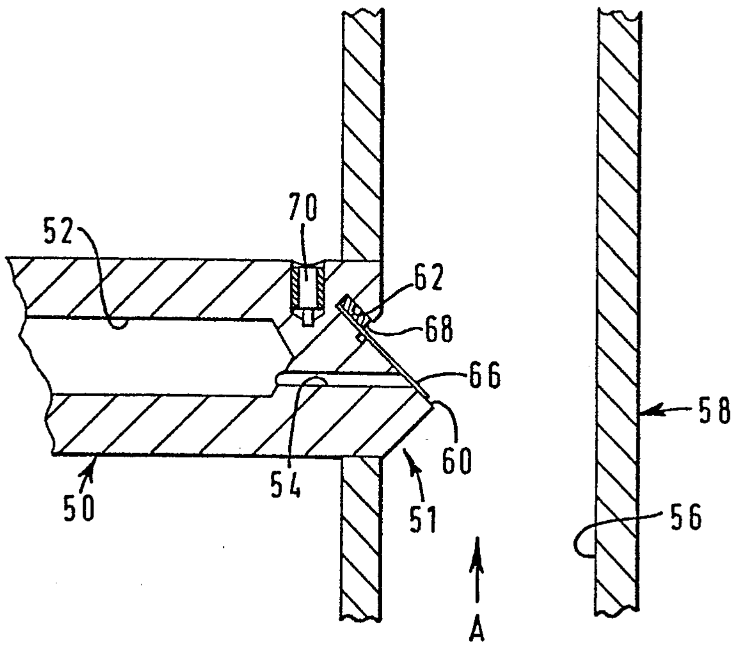

FIG 7

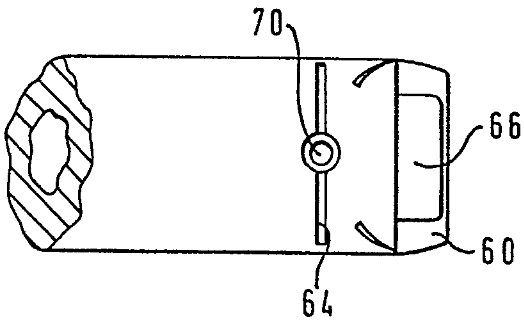

FIG 8

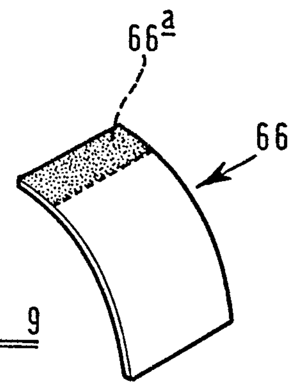

FIG 9

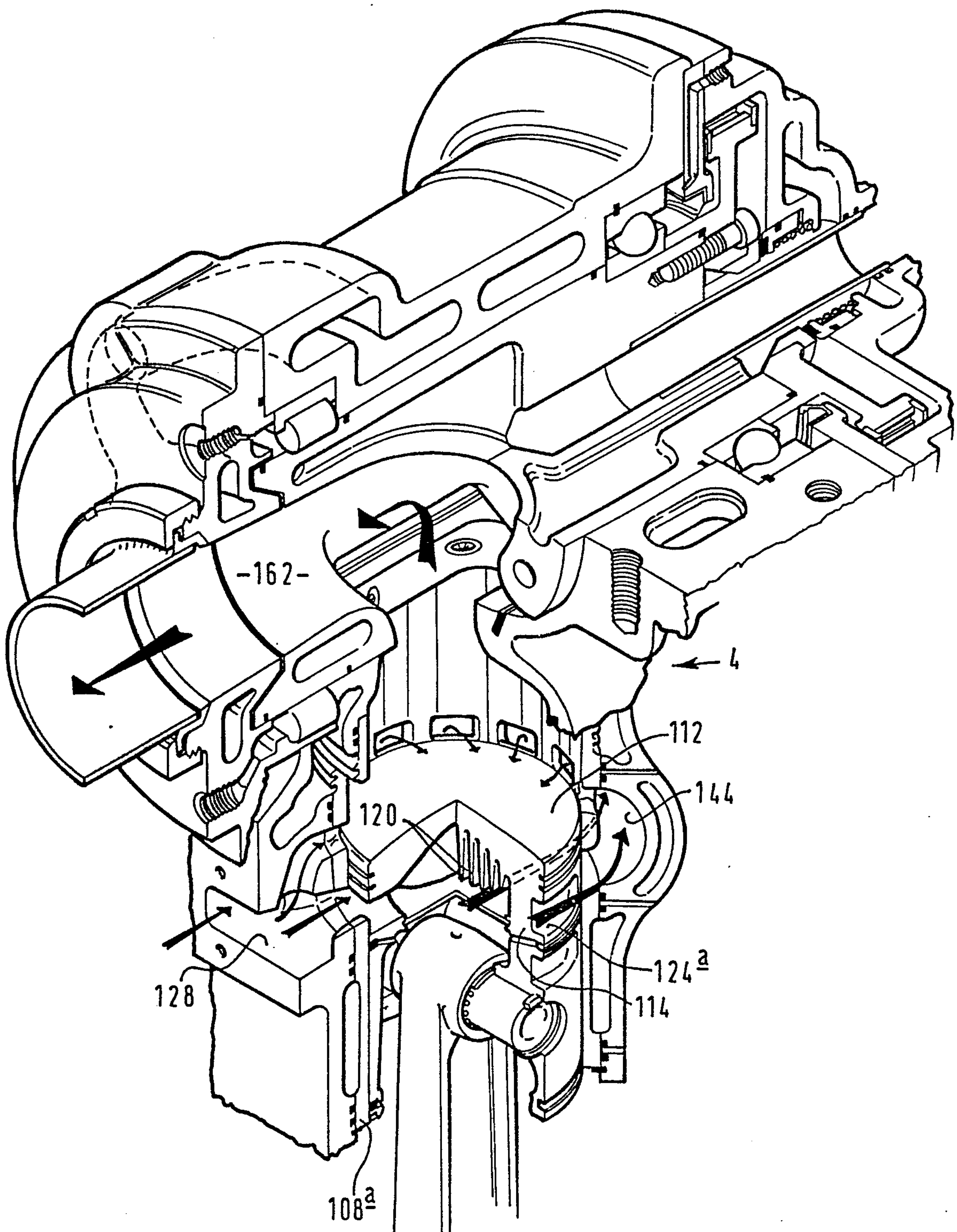

FIG 10

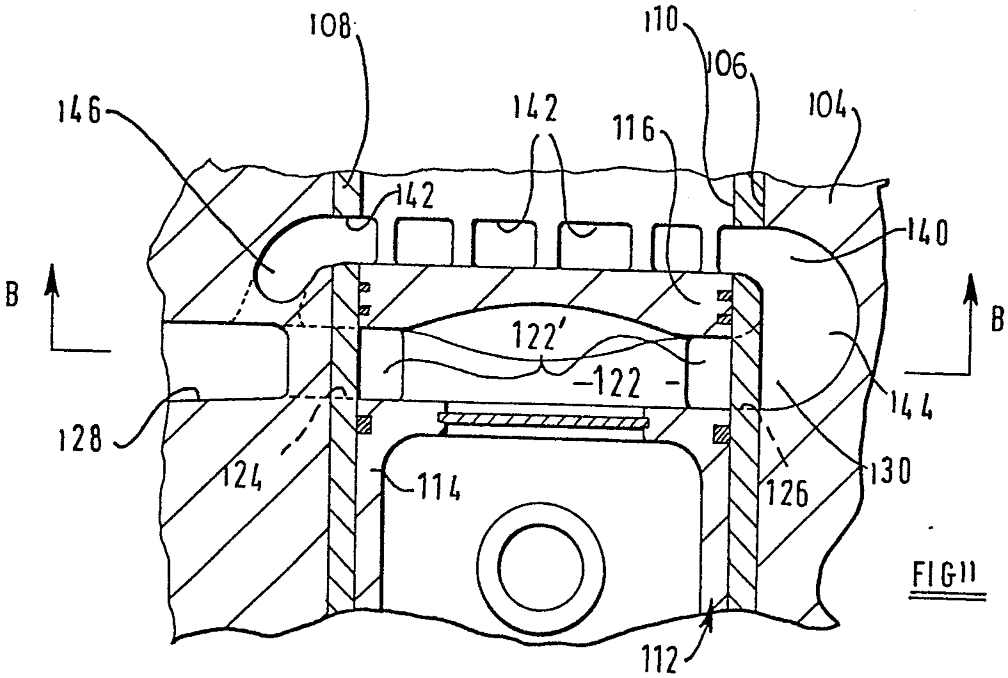
108
110
106
104
146
142
116
142
140
B
B
122'
122
144
128
124
114
126
130
112

FIG11

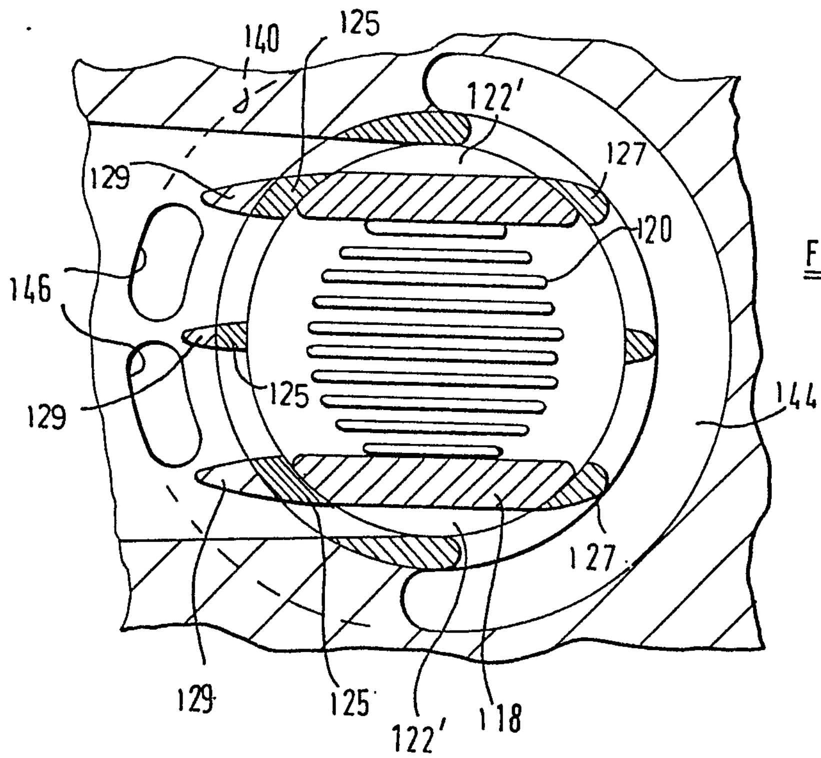
140
125
122'
127
129
120
146
125
144
129
127
129
125
122'
118

FIG13

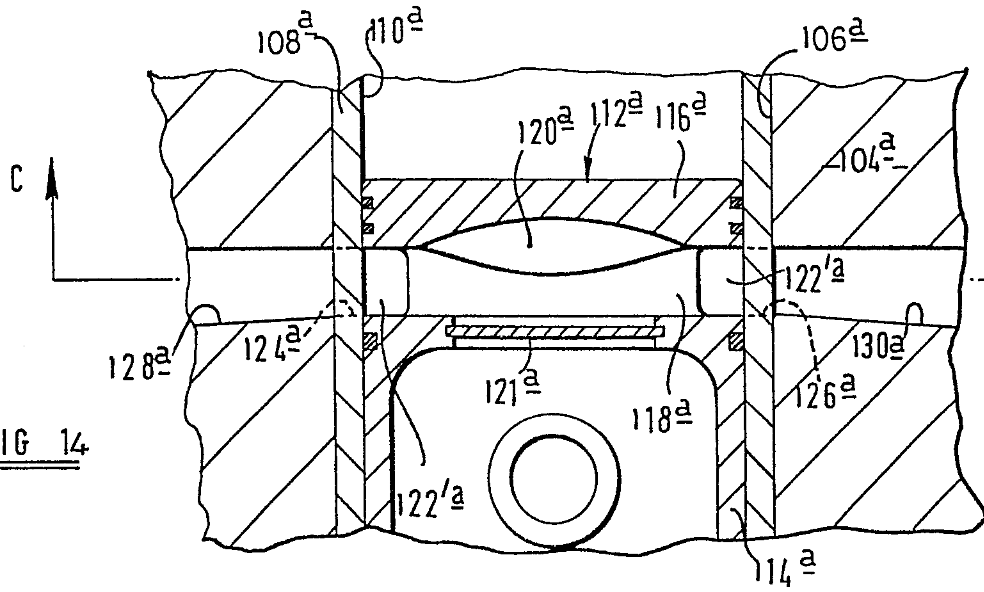

FIG 14

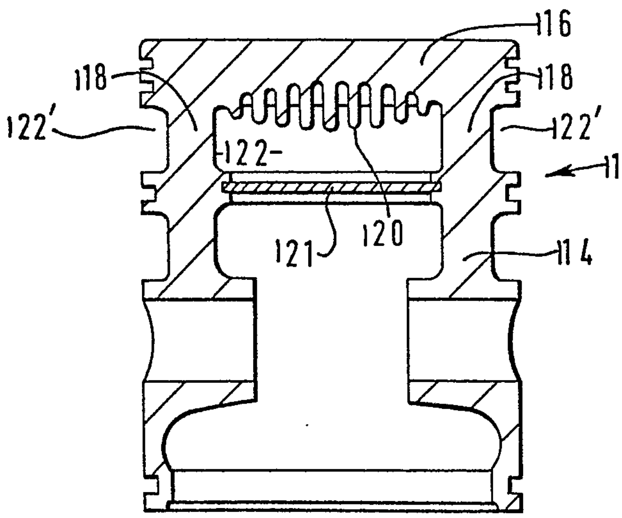

FIG 12

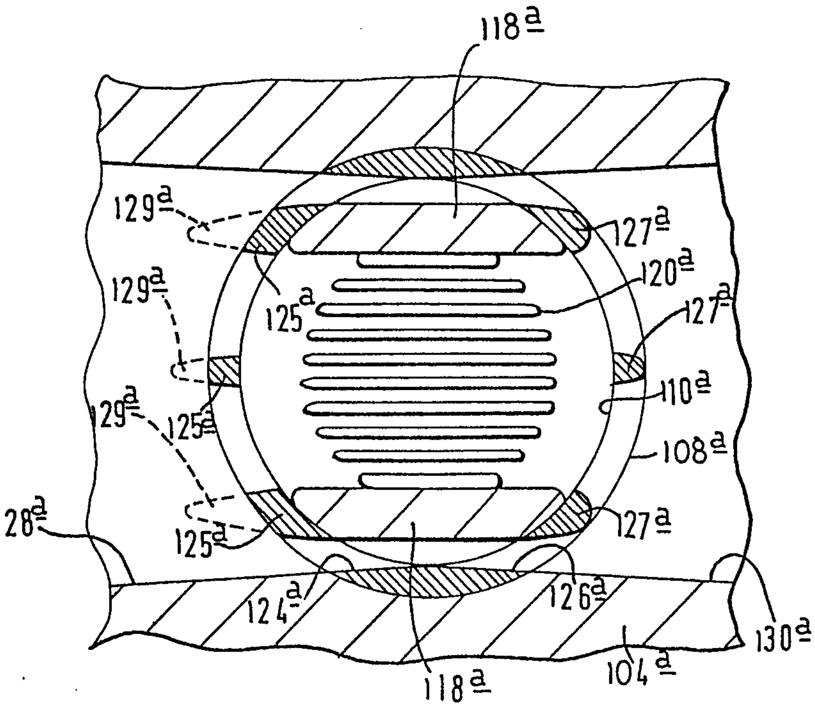

FIG 15