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(54) **Pump head for fuel pump assembly**

(57) A pump head for a fuel pump assembly is described. The pump head (120, 120a) comprises a tappet (134) and a pump head main body (122). The tappet (134) has an internal volume and a tappet base (176). The tappet base (176) is adapted to be co-operable with an engine driven cam so as to, in use, impart drive to the tappet (134). The pump head main body (122) comprises

an inlet means for admitting fuel at relatively low pressure and an outlet means for expelling pressurised fuel at relatively high pressure. The tappet (134) is adapted to reciprocate with respect to the pump head main body (122). The internal volume of the tappet (134) forms at least a part of a pump chamber (130) for pressurising fuel to be expelled through the outlet means.

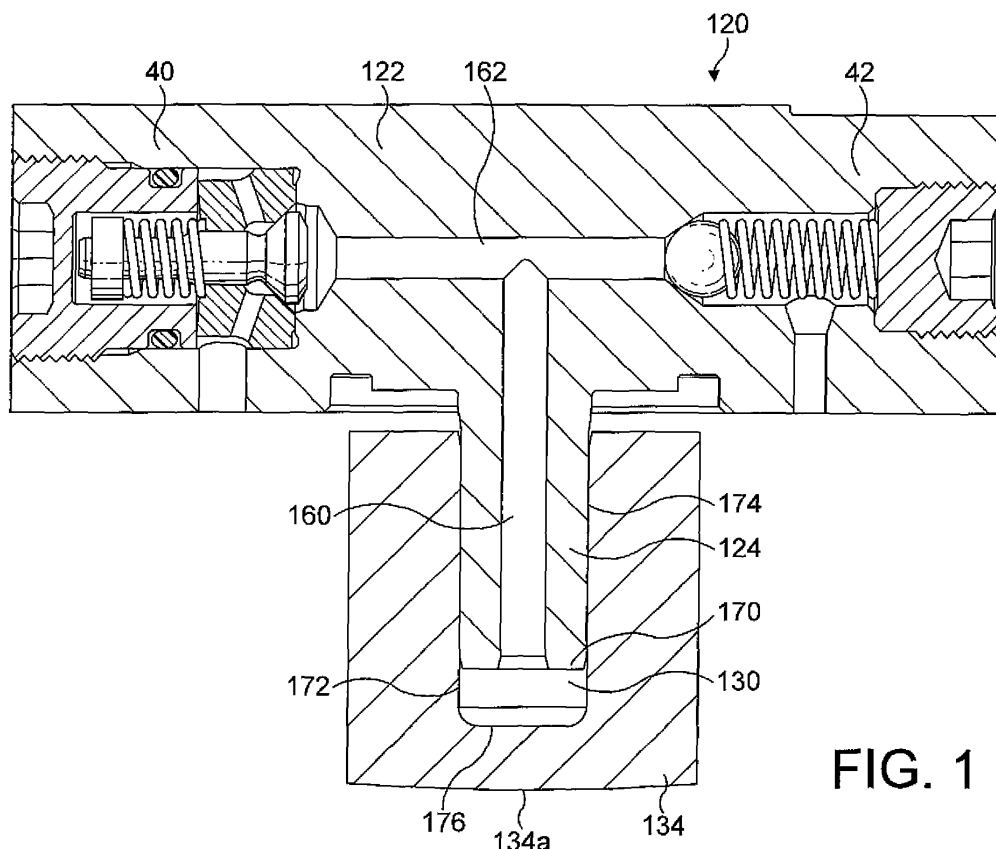


FIG. 1

Description

TECHNICAL FIELD

[0001] The invention relates to a pump head for a fuel pump assembly. Embodiments of the pump head and fuel pump assembly described are particularly suitable for use in a common rail fuel injection system for supplying high pressure fuel to a compression ignition internal combustion engine. In particular, the invention has application in a pump assembly of the type in which an engine driven cam imparts reciprocating, pumping, motion on an intermediate drive member.

BACKGROUND TO THE INVENTION

[0002] Fuel pumps are employed in a variety of engine systems. Common rail fuel injection systems for compression ignition (diesel) internal combustion engines provide excellent control of all aspects of engine operation and require a pump to act as a source of high pressure fuel.

[0003] One known common rail fuel pump is of radial pump design and includes three pumping plungers arranged at equi-angularly spaced locations around an engine driven cam - such a pump is described in, for example, WO 2004/104409. In this pump, each plunger is mounted within a plunger bore provided in a pump head mounted to a main pump housing. As the cam is driven in use, the plungers are caused to reciprocate within their bores in a phased, cyclical manner. As the plungers reciprocate, each causes pressurisation of fuel within a pump chamber defined at one end of the associated plunger bore in the pump head. Fuel that is pressurised within the pump chambers is delivered to a common high pressure supply line and, from there, is supplied to a common rail or other accumulator volume, for delivery to the downstream injectors of the common rail fuel system.

[0004] The fuel pump has an inlet valve for admitting fuel under low pressure and an outlet valve for letting out the pressurised fuel. Both inlet and outlet valves are non-return valves - each have a valve member which is a moving element biased to close a valve aperture.

[0005] In this pump assembly, the cam carries a cam rider that extends co-axially with the drive shaft for the cam. The cam rider is provided with a plurality of flat surfaces ("flats"), one for each of the plungers. An intermediate drive member in the form of a tappet co-operates with the flat on the cam rider and couples to the plunger so that, as the tappet is driven upon rotation of the cam, drive is imparted to the plunger.

SUMMARY OF THE INVENTION

[0006] According to the present invention, there is provided a pump head for a fuel pump assembly, the pump head comprising: a tappet having an internal volume and a tappet base, wherein the tappet base is adapted to be

co-operable with an engine driven cam so as to, in use, impart drive to the tappet; a pump head main body comprising an inlet means for admitting fuel at relatively low pressure and an outlet means for expelling pressurised fuel at relatively high pressure; wherein the tappet is adapted to reciprocate with respect to the pump head main body; and wherein the internal volume of the tappet forms at least a part of a pump chamber for pressurising fuel to be expelled through the outlet means.

[0007] Such an arrangement reduces the number of parts compared to prior art pump heads: the tappet takes the function of both the tappet and plunger in systems such as that disclosed in WO 2004/104409. This arrangement also requires no cross drillings into the main pump chamber, which reduces stresses.

[0008] Advantageously, the pump head main body comprises an extension, the extension having an extension bore therethrough, wherein the extension bore is in communication with an inlet valve of the inlet means and an outlet valve of the outlet means, the extension bore passing through an end face of the extension. Preferably, the main body comprises a main bore extending between the inlet valve and the outlet valve, wherein the extension bore is in communication with the main bore. This arrangement requires limited machining. It also allows the space between the inlet valve and the outlet valve to be reduced when compared to prior art designs, enabling the overall size of the pump head to be reduced.

[0009] Advantageously, the tappet has opposed side-walls forming a central bore which defines, together with the tappet base, the internal volume of the tappet; and whereby the tappet is mounted on the extension and is adapted to reciprocate along it; and wherein the pump chamber is formed between the central bore of the tappet, the tappet base, and the end face of the extension.

[0010] In one arrangement, the invention provides a pump assembly comprising two or more pump heads, each pump head being as described above, wherein a first pump head has a first tappet and a second pump head has a second tappet, the pump assembly further comprising an engine driven cam, wherein the engine driven cam is co-operable with each tappet so as to impart drive to and thereby reciprocate each tappet with respect to the main body of each pump head, wherein the pump assembly further comprises a linking component to couple the first tappet and the second tappet to form a desmodromic pump assembly.

[0011] In an alternative arrangement, the pump head comprises a return spring to bias the tappet to move away from the main body. In one form of this arrangement, the return spring is a cylindrical spring mounted around the tappet and in abutment against a seat in the main body. In another form of this arrangement, the return spring is a conical spring mounted to abut an end face of the tappet and in abutment against a seat in the main body. In another aspect, the invention provides a pump assembly as described above and an engine driven cam, wherein the engine driven cam is co-operable with the tappet so

as to impart drive to it and reciprocate the tappet with respect to the extension to the main body of the pump head.

[0012] Such a pump assembly can advantageously be used in a common rail fuel injection system for a compression ignition (diesel) internal combustion engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The invention will now be described, by way of example only, by reference to the following drawings in which:

Figure 1 is a cut-away view of the pump head of a first embodiment of the present invention;

Figure 2 is a cut-away view of the pump head of a second embodiment of the present invention; and

Figure 3 is a cut-away view of a prior art pump assembly in which the pump heads described may be replaced by pump heads according to embodiments of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0014] The pump assembly of Figure 3 will be described first. This pump assembly is in the prior art, and is described more fully in WO 2004/104409. The pump heads illustrated in Figures 1 and 2 and comprised in embodiments of the present invention will then be described in the context of their use in a pump assembly of the type shown in Figure 3.

[0015] Referring to Figure 3, a pump assembly includes a first housing part in the form of a main pump housing 10 provided with an axially extending opening 17. A cam shaft drive is mounted within, and extends through, the axially extending opening 17 when the assembly is installed in the engine within which it is to be used. The central axis 13 of the drive shaft is shown, although the drive shaft itself is not illustrated.

[0016] The drive shaft co-operates with a cam arrangement including an eccentrically-mounted cam 11. The main pump housing 10 projects, at its front end, to accommodate the near full length of the drive shaft. The assembly is closed at its back end by a rear closure plate 15 having three ears or flanges 16, each provided with a respective opening for receiving a suitable fixing for mounting the pump assembly to the engine. The front closure plate 15 has a rearwardly directed nose (not visible) which projects into the main pump housing 10.

[0017] The main pump housing 10 is typically formed from cast iron and is provided with first, second and third radially extending openings or through bores 18a, 18b, 18c respectively, each of which communicates, at a radially inner end thereof, with the axially extending opening 17 through the housing 10. A radially outer end of

each opening 18a, 18b, 18c receives a pump head, first, second and third ones of which are identified by numerals 20a, 20b and 20c respectively. Each pump head 20a, 20b, 20c is substantially identical to the others and so only the first pump head 20a will be described in detail below.

[0018] The first pump head 20a includes a head portion 22 and a downwardly extending extension 24 (in the orientation shown) which projects into a radially outer end of the opening 18a in the main pump housing 10. The extension 24 is provided with a plunger bore 26 within which a pumping plunger 28 is received. A blind end of the plunger bore 26 is located within the head portion 22 of the first pump head 20a. The blind end of the plunger bore 26 defines, together with a radially outer end face of the plunger 28, a pump chamber 30 to which fuel at relatively low pressure is delivered and within which pressurisation of fuel to a relatively high level suitable for injection takes place as the plunger 28 is driven to perform a pumping stroke, in use, upon rotation of the drive shaft.

[0019] A radially inner end of the radially extending opening 18a receives an intermediate drive member for the plunger 28 in the form of a tappet 34. The tappet is cup or bucket shaped, having first and second opposing sidewalls interconnected by a tappet base. Because of its construction, the tappet may be referred to as a "bucket tappet". The tappet 34 locates within a radially inner end of the opening 18a so that an internal surface of the opening 18a serves to guide axial movement of the tappet 34, in use. It is therefore the main pump housing 10 which defines the guide surface for axial tappet motion and which constrains lateral tappet motion across the cam rider 38.

[0020] The bucket tappet 34 is coupled to the plunger 28 by means of a circlip 29, as shown in Figure 3. In practice, other coupling means may be provided for connecting the tappet 34 and the plunger 28 together, providing that the coupling is such that motion of one (e.g. the tappet) results in motion of the other (e.g. the plunger) during at least a part of the plunger's stroke. For example, the tappet 34 and the plunger 28 may be coupled together so that a degree of relative movement between them, along the main plunger axis, is permitted. One suitable arrangement is for a spring seat to be formed on the plunger 28 (for example, by a press fit), and for the preloading of the plunger return spring 36 (described below) to hold the parts together.

[0021] The upper surface of the tappet base is provided with a recess for locating one end of a plunger return spring 36. The spring 36 is mounted concentrically with both the plunger 28 and the extension 24 and occupies a clearance region or chamber defined between the internal surface of the opening 18a and the extension 24. The other end of the plunger return spring 36 abuts the head portion 22 of the first pump head 20a so that the spring 36 serves to apply a return biasing force to the plunger 28, and hence to the tappet 34, to drive a plunger return stroke.

[0022] The drive shaft 12 co-operates with the cam 11 which, in turn, is co-operable with a generally tubular cam rider member 38 which extends co-axially with the shaft 12. On its outer surface the cam rider 38 is provided with first, second and third flattened surfaces 38a, 38b, 38c, referred to as flats. Each one of the flats 38a, 38b, 38c co-operates with the base surface of the tappet 34 for a respective one of the plungers 28. For example, the tappet 34 for the plunger 28 of the first pump head 20a co-operates with the first flat 38a on the cam rider 38. As the tappet 34 is coupled to the plunger 28, rotation of the shaft 12 causes the cam rider 38 to ride over the surface of the cam 11, thereby imparting drive to both the tappet 34 and the plunger 28. As the tappet 34 is driven, a degree of lateral sliding movement is permitted between the lower surface of the tappet base and the first flat 38a of the rider 38 as the cam rider 38 is able to translate relative to the axially guided tappet 34. A lubricating fluid, such as fuel, is provided between these sliding surfaces to limit wear due to friction.

[0023] As the cam 11 is driven, the tappet 34 is caused to reciprocate within the opening 18a and the plunger 28 is caused to reciprocate within the plunger bore 26. The tappet 34 and the pumping plunger 28 are therefore driven together causing the plunger 28 to perform a pumping cycle including a pumping stroke, during which the tappet 34 and the plunger 28 are driven radially outward from the shaft (i.e. for the first pump head 20a, vertically upwards in Figure 3) to reduce the volume of the pump chamber 30. During this pumping stroke the pumping plunger 28 is driven inwardly within its plunger bore 26 and fuel within the pump chamber 30 is pressurised to a relatively high level in a manner which would be familiar to those skilled in this technology field.

[0024] During a subsequent plunger return stroke, the tappet 34 and the plunger 28 are urged in a radially inward direction (i.e. for the first pump head 20a, vertically downwards in Figure 3) to increase the volume of the pump chamber 30. During the return stroke of the plunger 28 and its tappet 34, the plunger 28 is urged outwardly from the plunger bore 26 and fuel at relatively low pressure fills the associated pump chamber 30.

[0025] The provision of the plunger return spring 36 serves to urge the plunger 28 to perform its return stroke and additionally ensures contact is maintained between the tappet 34 and the flat 38a of the rider 38 at all times throughout the pumping cycle.

[0026] The tappet 34 and the plunger 28 perform cyclical sinusoidal motion and are driven at a maximum frequency of about 120 Hz. The tappet 34 typically has a range of travel, between bottom-dead-centre and top-dead-centre, of around 10 millimetres.

[0027] The main pump housing 10 is machined so as to minimise geometric deviations which would affect the ability of the flat 'sliding' surface of the tappet base to be properly in contact with the corresponding flat 38a on the cam rider 38. The main pump housing 10 also supports the shaft bearings as precisely as is practical. The rear

bearing is fitted directly into the main housing 10, while the front bearing is in the front closure plate 15. The main pump housing 10 locates the front closure plate 15 so that the front and rear bearings are substantially concentric. Having the critical features mostly in a single part (i.e. the main pump housing 10) enables errors to be minimised by machining dependent features so that the predominant feature is used as a datum or reference.

[0028] Figure 1 shows a pump head according to an embodiment of the invention and suitable for use in a pump assembly as shown in Figure 3 in place of the pump heads 20a, 20b and 20c shown in Figure 3. Where elements shown are essentially unchanged in the embodiment of Figure 1, the same reference numbers are used in each Figure.

[0029] The pump head 120 shown in Figure 1 performs the same function as that of the pump heads 20a, 20b and 20c in Figure 3. Fuel is admitted at lower pressure through inlet valve 40 and, after pressurisation in a pump chamber 130, let out through outlet valve 42 (not shown in Figure 3). The description of the pumping cycle given for Figure 3 is broadly applicable to the arrangement of Figure 1. The two differ in that the pumping chamber 130 shown in Figure 1 is defined differently from the pump chamber 30 shown in Figure 3.

[0030] In Figure 1, the pump chamber 130 is formed between an inner surface of the tappet 134 (the inner surface being formed by the inner face of the tappet base 176 and a part of the central bore 172 of the tappet) and an end face 170 of an extension 124 of the main body 122 of the pump head 120. The extension 124 and its end face 170 in effect act as a plunger within the central bore 172 formed by the opposing sidewalls of the tappet 134, though the "plunger" is stationary while the tappet 134 reciprocates along it. An extension bore 160 provides fuel to the pump chamber 130 from the inlet valve 40 and provides fuel from the pump chamber 130 to the outlet valve 42.

[0031] The design of the inlet valve 40 is not critical to the invention and may be as described in WO 2004/104409. The same applies to the outlet valve 42. In each case, the valve is a non-return valve biased to close unless a threshold pressure is exceeded in the flow direction. For the inlet valve 40 this pressure is relatively low, and allows fuel at relatively low pressure, or unpressurised fuel, to fill an expanded empty pump chamber 130. For the outlet valve 42 this pressure is typically higher, and sets the pressure at which pressurised fuel is allowed to escape from the pump chamber 130. A typical threshold pressure may be 1.5 bar for the inlet valve 40, and 6 bar for the outlet valve 42.

[0032] As stated above, the pumping cycle is broadly as described above for Figure 3. Drive may be provided to the tappet 134 in exactly the same manner as for the tappet 34 in the arrangement of Figure 3 - the cam-facing face of the tappet 134 can be of exactly the same form as the equivalent face of the tappet 34. As the cam is driven, the tappet 134 is caused to reciprocate along the

extension 124. The inner face of the tappet end 176 and the end face 176 of the extension 124 are therefore driven together causing the performance of a pumping cycle. The pumping cycle includes a pumping stroke during which the inner face of the tappet end 176 is driven radially outward from the shaft (for the pump head 120, vertically upwards in Figure 1), towards the end face 176 of the extension 124, to reduce the volume of the pump chamber 130. During this pumping stroke fuel within the pump chamber 130 is pressurised to a relatively high level in a manner which would be familiar to those skilled in this technology field. During a subsequent return stroke, the tappet 134 is urged in a radially inward direction (i.e. for the pump head 120, vertically downwards in Figure 1) to increase the volume of the pump chamber 130. During the return stroke of the tappet 134, fuel at relatively low pressure fills the associated pump chamber 130.

[0033] The extension 124 needs sufficient structural strength to sustain the mechanical loading that it receives from its role in the cam-follower function demonstrated in this arrangement (it sees loading that extension 24 in the arrangement of Figure 3 does not).

[0034] As in the Figure 3 arrangement, a means to ensure that the tappet 134 is properly located with respect to the cam drive is required. As in the Figure 3 arrangement, this may be a return spring. Figures 4 and 5 show alternative arrangements involving a return spring 136, 136a between the tappet 134 and the main body 122 of the pump head 120. In the Figure 4 arrangement, a constant diameter helical spring 136 is seated at one end on a ridge 135 around the tappet 134 and at the other end in a groove 137 in the main body 122. This arrangement is broadly similar to that of Figure 3, but the return spring 136 needs to be provided outside the tappet 134 in the light of the different functional arrangement within the tappet. Figure 5 shows an arrangement with a conical spring 136a, the spring at one end abutting the tappet 134 at an upper face facing the main body 122 and surrounding the extension 124, the spring at the other end being located in an annular groove 137 located in the main body 122 of the pump head 120. As in the Figure 3 arrangement, these return springs serve to urge the tappet 134 to perform its return stroke and ensure contact between the tappet 134 and the cam follower.

[0035] An alternative to use of a return spring is shown in the arrangement of Figure 6. In this arrangement, a two plunger pump is shown with pump heads 220 and 220a, which are both of the type shown in Figure 1. Cam 211 rotates about cam axis 213 and has a cam follower 238 which engages with the bases of tappets 234, 234a. A linking component 280 couples together the first tappet 234 and the second tappet 234a to form a desmodromic valve arrangement. When, as shown here, the first tappet 224 is at top dead centre and has moved as close as it can to the main body 222 of the first pump head 220, the second tappet 224a is at bottom dead centre and at its maximum distance from the main body 222a of the sec-

ond pump head 220a. With this arrangement, the tappets are moved positively in both directions and no return spring is required. While a two valve arrangement is shown here, multiple valve arrangements could be formed with appropriate linkage structures.

[0036] The arrangement shown in Figure 1 has several advantageous features. It requires fewer parts than are required in the arrangement of Figure 3, as the functions of tappet 34 and plunger 28 in the arrangement shown in Figure 3 are combined into the tappet 134 in the arrangement shown in Figure 1. In machining the parts forming the pump chamber 30 of Figure 3, it is necessary for cross drillings to be made to provide connections to at least one of the inlet valve 40 and the outlet valve. This is not required in machining the parts forming the pump chamber 130 of Figure 1 - the only fluid connection to the pump chamber 130 is through the extension bore 160. The extension bore 160 communicates with a main body bore 162 which connects the inlet valve 40 and the outlet valve 42. The extension 124 is effective to guide the reciprocating tappet 134, and provides a significant sealing length between the two, serving to reduce high pressure fuel leakage from the pump chamber 130.

[0037] The arrangement shown in Figure 1 does have a lower compression ratio than that shown in Figure 3, in that the extension bore 160 and the main body bore 162 do not form part of the working volume of the pump chamber 130, but are in communication with it during the compression part of the pumping cycle. This lower compression ratio is not especially significant if the working volume of the pump chamber 130 is relatively large. However, this dead volume can be reduced in the arrangement shown in Figure 2, in which the main body bore 162a is significantly shorter. This brings inlet valve 40 and outlet valve 42 much closer to each other. In addition to improving the compression ratio of the pump, the arrangement of Figure 2 has the further advantage of reducing the overall size of the pump head 120a.

[0038] As discussed above, the pump heads 120, 120a can be used directly in the pump assembly of Figure 3, but can also be used in other pump assemblies interacting with a pump head in the same or similar ways. Such a pump assembly, and hence such pump heads, are particularly suitable for use in common rail fuel injection systems for compression ignition internal combustion engines. Such pump heads and pump assemblies can however be used in any other context in which the pump properties described are of use.

Claims

1. A pump head for a fuel pump assembly, the pump head (120,120a) comprising:

a tappet (134) having an internal volume and a tappet base (176), wherein the tappet base (176) is adapted to be co-operable with an en-

- gine driven cam so as to, in use, impart drive to the tappet (134);
 a pump head main body (122) comprising an inlet means for admitting fuel at relatively low pressure and an outlet means for expelling pressurised fuel at relatively high pressure;
 wherein the tappet (134) is adapted to reciprocate with respect to the pump head main body (122); and wherein
 the internal volume of the tappet (134) forms at least a part of a pump chamber (130) for pressurising fuel to be expelled through the outlet means.
2. A pump head as claimed in claim 1, wherein the pump head main body (122) comprises an extension (124), the extension (124) having an extension bore (160) therethrough, wherein the extension bore (160) is in communication with an inlet valve (40) of the inlet means and an outlet valve (42) of the outlet means, the extension bore (160) passing through an end face (170) of the extension (124).
 3. A pump head as claimed in claim 2, wherein the main body (122) comprises a main bore (162) extending between the inlet valve (40) and the outlet valve (42), wherein the extension bore (160) is in communication with the main bore (162).
 4. A pump head as claimed in claim 2 or claim 3, wherein the tappet (134) has opposed sidewalls forming a central bore (172) which defines, together with the tappet base (176), the internal volume of the tappet (134); and whereby the tappet (134) is mounted on the extension (124) and is adapted to reciprocate along it; and wherein the pump chamber (130) is formed between the central bore (172) of the tappet (134), the tappet base (176), and the end face (170) of the extension (124).
 5. A pump head as claimed in any of claims 1 to 4, further comprising a return spring (136, 136a) to bias the tappet (134) to move away from the main body (122).
 6. A pump head as claimed in claim 5, wherein the return spring (136) is a cylindrical spring mounted around the tappet (134) and in abutment against a seat (137) in the main body (122).
 7. A pump head as claimed in claim 5, wherein the return spring (136a) is a conical spring mounted to abut an end face of the tappet (134a) and in abutment against a seat (137a) in the main body (122).
 8. A pump assembly comprising a pump head (120, 120a) as claimed in any of claims 1 to 7 and an engine driven cam (11), wherein the engine driven cam (11) is co-operable with the tappet (134) so as to impart drive to and thereby reciprocate the tappet (134) with respect to the pump head main body (122).
 9. A pump assembly comprising two or more pump heads, each pump head (220, 220a) being as claimed in any of claims 1 to 4, wherein a first pump head (220) has a first tappet (234) and a second pump head (220a) has a second tappet (234a), the pump assembly further comprising an engine driven cam (211), wherein the engine driven cam (211) is co-operable with each tappet (234, 234a) so as to impart drive to and thereby reciprocate each tappet (234, 234a) with respect to the main body (222, 222a) of each pump head (220, 220a), wherein the pump assembly further comprises a linking component (280) to couple the first tappet (234) and the second tappet (234a) to form a desmodromic pump assembly.

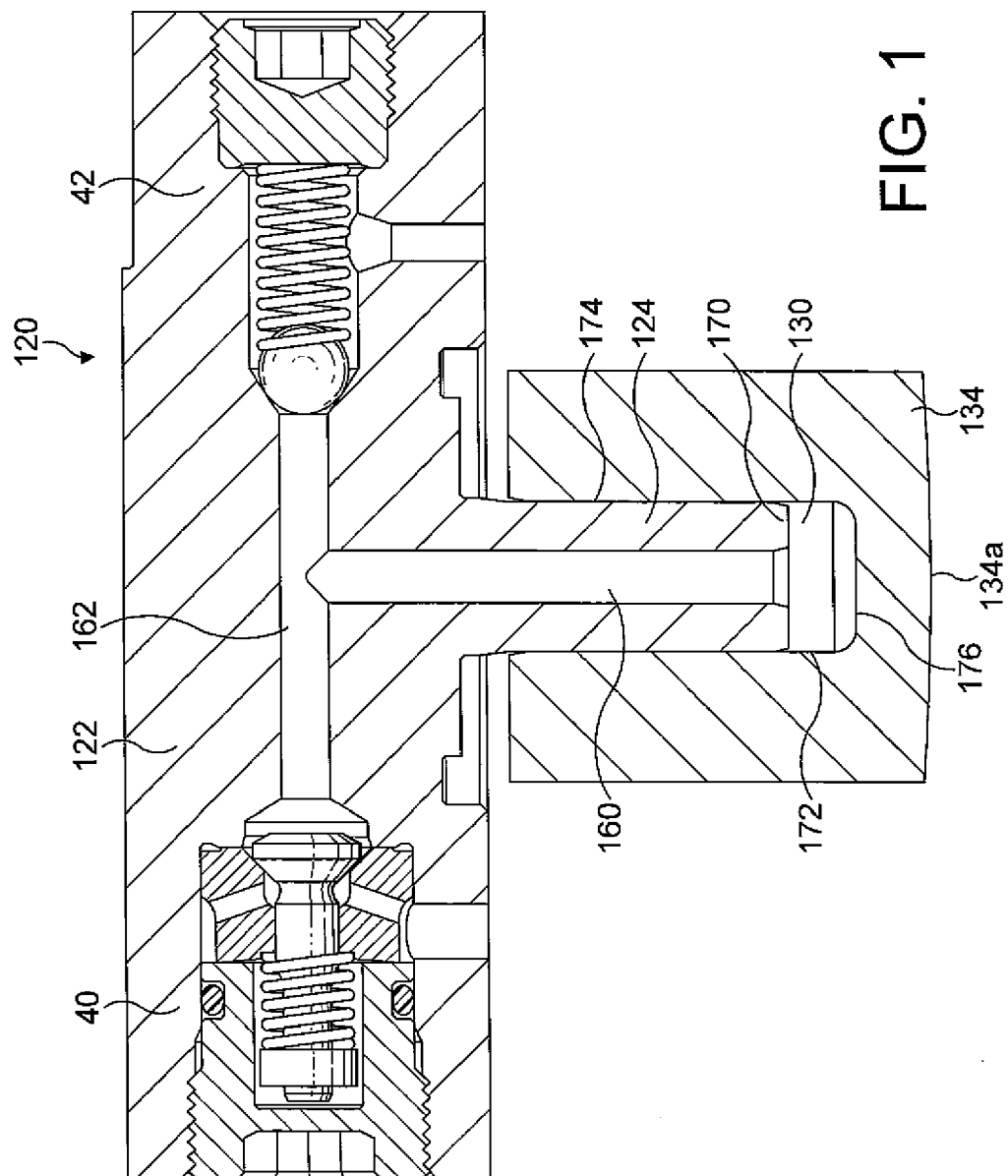


FIG. 1

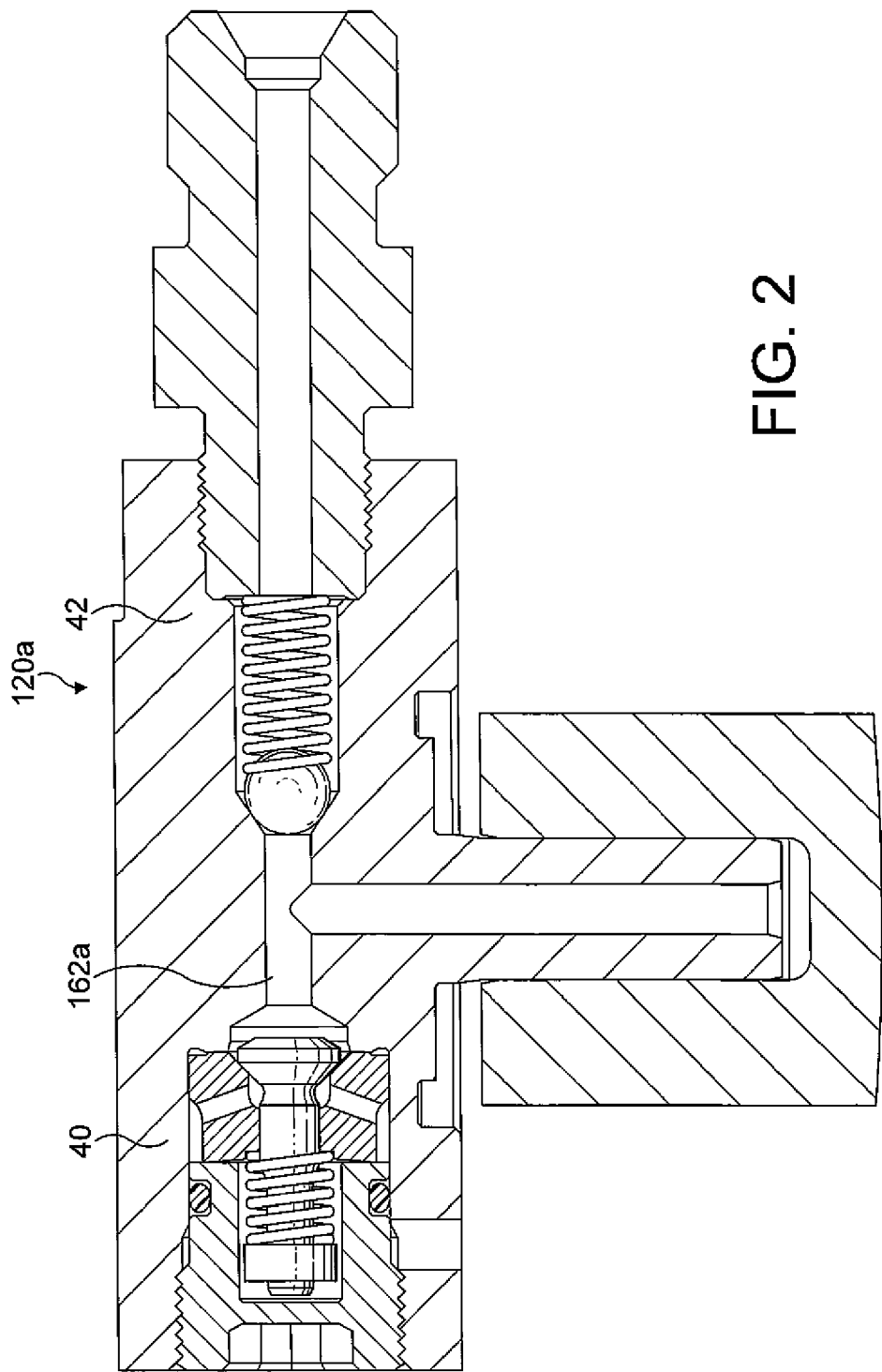


FIG. 2

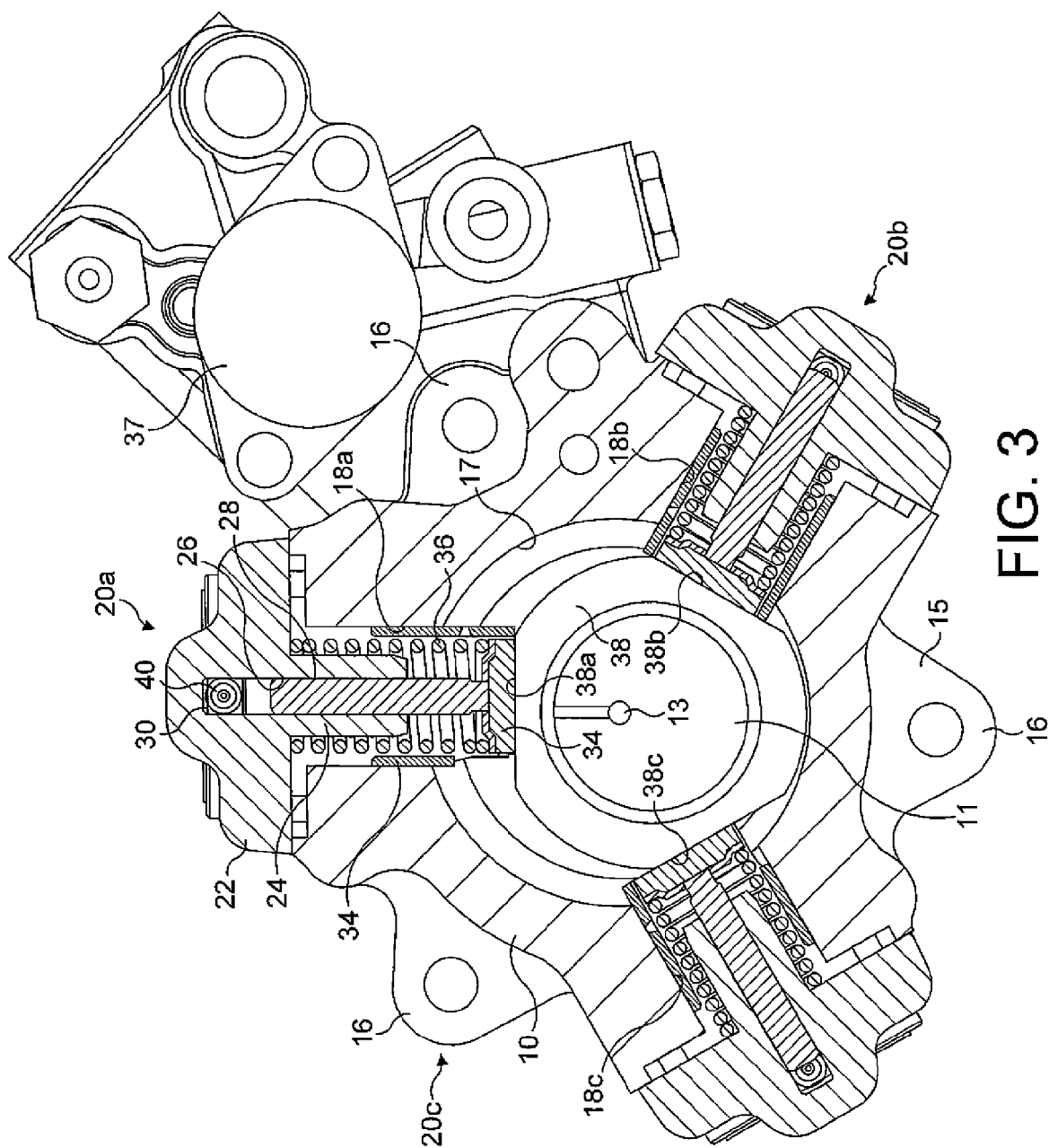


FIG. 3

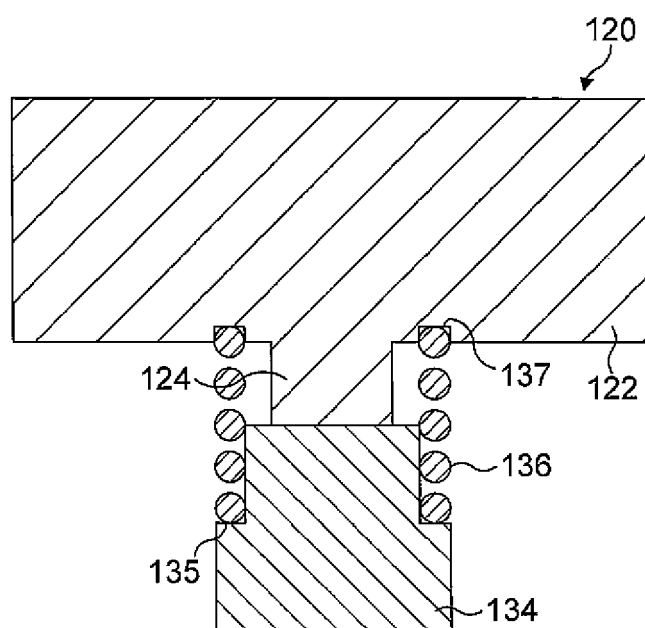


FIG. 4

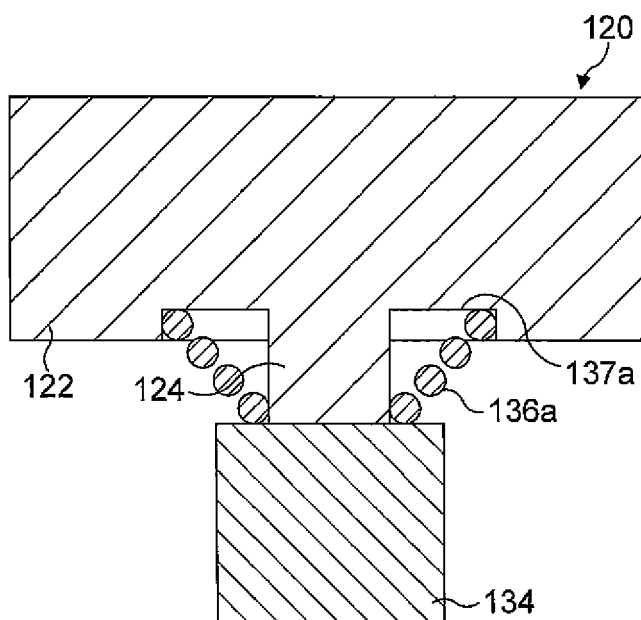
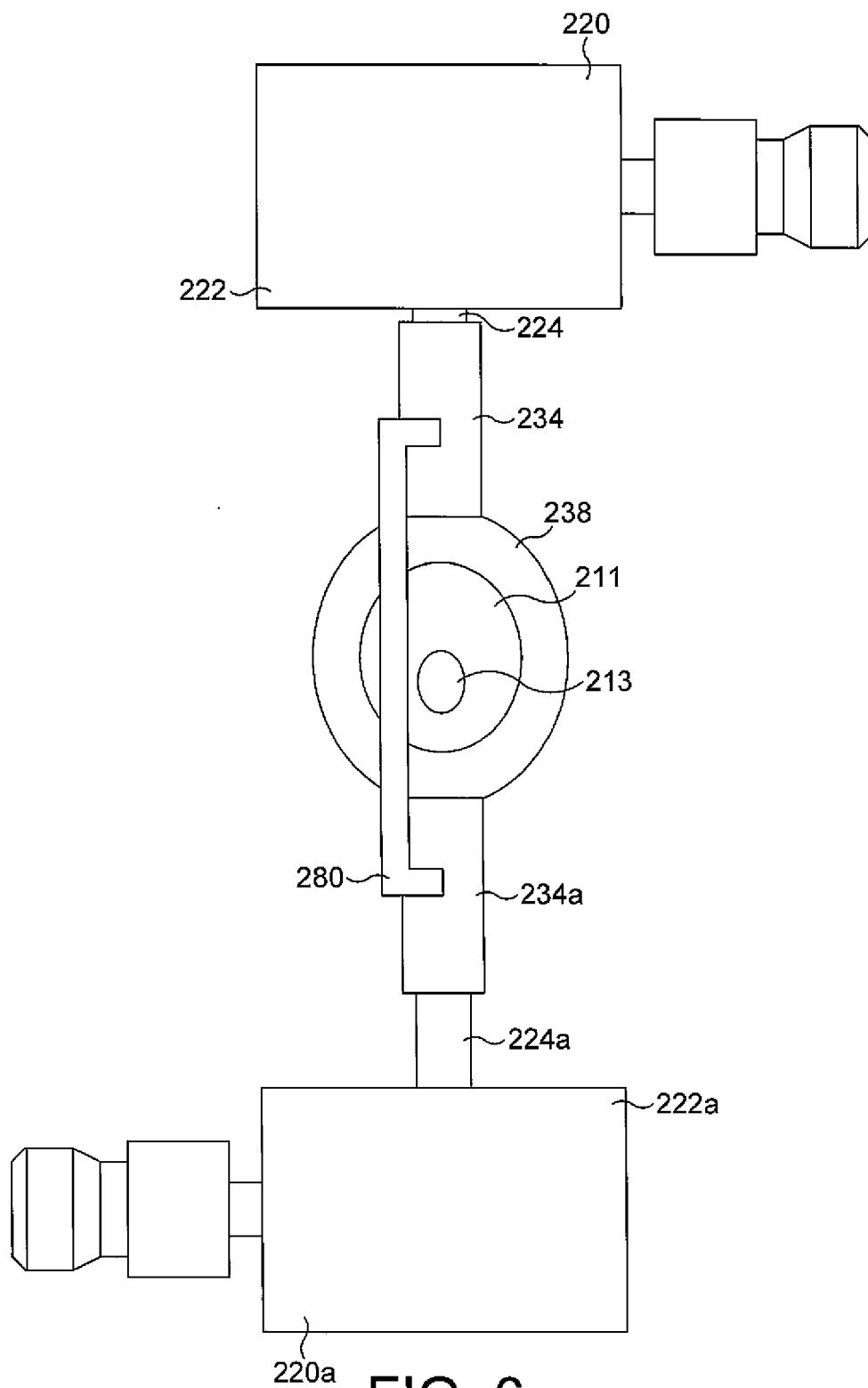


FIG. 5





EUROPEAN SEARCH REPORT

Application Number
EP 08 16 8618

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	US 6 109 894 A (CHATELAIN MICHEL [FR]) 29 August 2000 (2000-08-29) * column 2, line 22 - line 35; figure 5 *	9	
			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 8 April 2009	Examiner Kolland, Ulrich
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (F04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 08 16 8618

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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