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(54) **Control valve for a fuel injector**

(57) A valve arrangement (131) for use in a fuel injector of a high-pressure fuel injection system for an internal combustion engine. The valve arrangement (131) comprises a valve body (134) defining a valve seat (154) and a valve member (138) which is engageable with the valve seat (154). The valve arrangement (131) further comprises an armature (156) disposed within an armature chamber (150) and cooperable with the valve member (138), and an electromagnetic actuator (139) operable to cause movement of the valve member (138) to control the flow of fluid into the armature chamber (150) past the valve seat (154). The valve arrangement (131) is arranged to direct fluid flowing into the armature chamber (150) away from the armature (156). In particular, the valve arrangement (131) may be arranged to direct a jet of fuel away from the armature (156), so as to reduce resistance to valve closing movement that would otherwise be caused by the jet impinging on the armature (156). In this way, shot-to-shot variation of the fuel injector can be reduced.

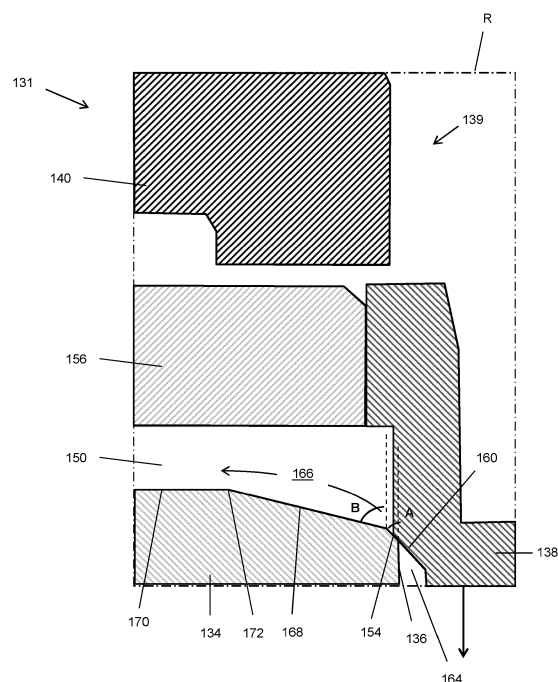


FIGURE 3

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Description

Field of the Invention

[0001] This invention relates to a control valve for use in a fuel injector, and in particular, but not exclusively, to a control valve for use in a fuel injector in a high pressure fuel injection system for an internal combustion engine.

Background to the Invention

[0002] Fuel injectors are a conventional means of delivering fuel to the combustion chambers of an internal combustion engine. In one type of conventional fuel injector, movement of a valve needle is controlled hydraulically through the balancing of pressures acting around the needle. Fuel injectors of this type typically include a nozzle control valve (NCV) which is used to control drainage of high-pressure fuel to a low-pressure drain. An example of a conventional fuel injector including such a nozzle control valve is described in the Applicant's earlier patent, EP 0 798 459 B1, and is illustrated in Figures 1a and 1b. For illustrative purposes, Figure 1a, which shows the control valve, is drawn on an enlarged scale compared to Figure 1b, which shows a nozzle of the fuel injector.

[0003] As shown in Figure 1b, a known fuel injector 8 includes a nozzle 9 having a nozzle body 10 which includes a bore 12, within which a valve needle 14 is slidably received. The valve needle 14 controls injection of fuel into an engine cylinder. The bore 12 is provided with openings (not shown) at a tip end. The openings define a fuel injector outlet. A valve needle seat 16 is disposed upstream of the outlet. The valve needle 14 engages with the valve needle seat 16 when in a closed position, in order to stop fuel flow to the outlet and prevent injection. A spring 18 biases the valve needle 14 into its closed position.

[0004] A control chamber 20 is defined by the bore 12 and an end of the valve needle 14 remote from the outlet. An annular volume 24 is defined between the bore 12 and the valve needle 14. The annular volume 24 is substantially isolated from the control chamber 20, and is arranged to deliver fuel to the tip of the bore 12. High pressure fuel is supplied to the annular volume 24 through a supply passage 26, which also supplies high pressure fuel to the control chamber 20 by way of an auxiliary passage 28. The auxiliary passage 28 has a small diameter so as to create a restriction. A drain passage or spill passage 30 in an intermediate injector part (not shown) allows fuel to drain from the control chamber 20 to a low pressure drain (not shown). Flow from the control chamber 20 to the low pressure drain is under the control of a nozzle control valve 31 (see Figure 1a), which is described further below.

[0005] As shown in Figure 1b, the valve needle 14 includes several downstream-facing thrust surfaces 32 which are angled such that fuel pressure acting on the

thrust surfaces 32 generates a force on the needle that acts in an opposite direction to the force resulting from fuel pressure acting on the end of the valve needle 14 in the control chamber 20. When the nozzle control valve 31 is closed to prevent fuel flow to drain, high pressure fuel fills both the control chamber 20 and the annular volume 24, and in this condition the net force on the valve needle 14 acts in the closing direction to keep the needle 14 in its closed position.

[0006] When fuel injection is required, the valve needle 14 is lifted from the valve needle seat 16 by opening the nozzle control valve 31 to allow fuel to flow from the control chamber 20 to the low pressure drain. As a result, the pressure in the control chamber 20 drops, and the forces acting on the thrust surfaces 32 begin to overcome the forces acting in the closing direction, and thus the valve needle 14 lifts. When the valve needle 14 is lifted away from the valve needle seat 16, fuel is injected through the fuel injector outlet. To return the valve needle 14 to its closed position, the nozzle control valve 31 is closed to cut off the flow to drain, and the control chamber 20 re-fills with high pressure fuel, and therefore the valve needle 14 returns to its closed position. When the valve needle 14 is closed, high-pressure fuel refills the annular volume 24 around the needle, such that the pressures around the valve needle 14 equalise.

[0007] As illustrated in Figure 1a, the nozzle control valve 31 includes a valve body 34 having a valve bore 36 in which a valve member 38 is slidably received. The nozzle control valve 31 further includes a solenoid actuator 39 which abuts the valve body 34 and is positioned coaxially with respect to the valve bore 36. The actuator 39 comprises a magnetic core member 40, a generally tubular magnetic sleeve 42 arranged concentrically around the core member 40, a coil 44 disposed annularly between the core member 40 and the sleeve 42, and a return spring 46.

[0008] The valve body 34 is clamped to the nozzle 9 by means of a cap nut 47. The valve body 34 includes drillings 48 which connect the spill passage 30 to the valve bore 36. An armature chamber 50 is defined by a recess in an upper end face 51 of the valve body 34. The upper end face 51 of the valve body 34 mates with the lower end face of an injector body part 52 which houses the actuator 39. The armature chamber 50 is disposed concentrically with respect to the valve bore 36, so that an upper end of the valve bore 36 opens into the armature chamber 50. The upper end of the valve bore 36 defines a frusto-conical valve seat 54.

[0009] The armature chamber 50 is in communication with the low-pressure drain (not shown). An armature 56 associated with the actuator 39 is received within the armature chamber 50. The armature 56 is coupled to the valve member 38, such that the two components move together. For example, the armature 56 may be press-fitted to the valve member 38.

[0010] The valve member 38 includes a reduced-diameter portion 58 defining a frusto-conical sealing sur-

face 60. The sealing surface 60 engages with the valve seat 54 to create a seal against high-pressure fuel. A portion of the sealing surface 60 which is exposed to fuel pressure in the valve bore 36 when the valve member 38 is closed defines an upper balance surface 61. A lower frusto-conical surface of the reduced-diameter portion 58 defines a lower balance surface 62, which opposes the upper balance surface 61. An annular working chamber 64 is defined around the reduced-diameter portion 58 between the upper and lower balance surfaces 61, 62. The drillings 48 in the valve body 34 connect the working chamber 64 to the spill passage 30.

[0011] When the nozzle control valve 31 is closed, both the upper and lower balance surfaces 61, 62 are exposed to fuel at high pressure, so the valve member 38 is substantially hydraulically balanced when in its closed position. Thus, the force required to move the valve member 38 between its open and closed positions is relatively small. This allows the size of the armature 56, the actuator 39 and the return spring 46 to be minimised, thereby affording a more compact design.

[0012] Figure 2 is an enlarged view of a portion (labelled R in Figure 1a) of the nozzle control valve 31, showing more clearly the geometry of the valve member 38 and the valve body 34 in the region of the location at which they engage. An end of the valve bore 36 that opens into the armature chamber 50 is chamfered to define the frusto-conical valve seat 54, with which the sealing surface 60 of the valve member 38 can engage to define a closed position for the nozzle control valve 31. When engaged, the valve member 38 and valve seat 54 create a seal which prevents fuel from flowing from the control chamber 20 through the drillings 48 into the armature chamber 50 and hence to the low-pressure drain.

[0013] The frusto-conical valve seat 54 typically has a cone angle of 90° , so that the valve seat 54 is inclined at an angle of 45° (labelled A in Figure 2) with respect to the axis of the valve bore 36. In an open position of the nozzle control valve 31, the valve member 38 is not engaged with the valve seat 54 so that fuel from the working chamber 64 can flow into the armature chamber 50 through a gap defined between the valve seat 54 and the valve member 38.

[0014] Referring back to Figure 1a, the return spring 46 exerts a force to urge the valve member 38 into engagement with the valve seat 54, such that the sealing surface 60 is in contact with the valve seat 54 when the coil 44 is not energised. When the coil 44 is energised, the armature 56 moves towards the core member 40, carrying the valve member 38 away from the valve seat 54 and allowing fuel to flow from the control chamber 20 to drain. In this way, fuel pressure in the control chamber 20 is reduced, which causes opening movement of the valve needle 14 of the fuel injector nozzle 9.

[0015] When the coil 44 is de-energised, the valve member 38 moves back towards the valve seat 54 under the action of the return spring 46 in a period of valve closing movement. The valve closing movement com-

pletes when the sealing surface 60 of the valve member 38 engages with the valve seat 54, such that the nozzle control valve 31 returns to the closed position. The flow to drain from the control chamber 20 is stopped, so that the pressure in the control chamber 20 rises and the needle 14 moves on to its seat, ending the injection.

[0016] A conventional fuel injector 8 such as that described above offers accurate metering of the fuel that is delivered in an injection event, which has been an important factor in providing more reliable and predictable combustion in vehicle engines and reducing emissions. The result of this is that modern engines are highly refined, and consequently produce more power whilst releasing lower emissions than engines of the past.

[0017] To optimise performance, it is desirable to minimise the variation in the quantity of fuel that is injected over successive injections into a given cylinder, against a constant injection quantity demand. This variation is known in the art as the "shot-to-shot variation" of the fuel injector. The variation is generally very small in absolute terms, but the relative impact of the shot-to-shot variation can be significant, particularly for short-duration, high-pressure injections. Accordingly, if the shot-to-shot variation of a fuel injector can be reduced, the injected quantity of fuel is more consistent, and combustion in the engine becomes more efficient. This has the effect of improving engine performance while reducing the emissions released by the engine. As emissions targets continue to be lowered in order to reduce the environmental impact of vehicles, any measures that can be taken to reduce emissions without compromising engine performance are highly important.

[0018] The quantity of fuel that is delivered in a fuel injection (or the "injection quantity") is directly related to the length of time for which the valve needle is lifted from the valve needle seat 16. Therefore, the injection quantity is indirectly related to the length of time for which the nozzle control valve is open. For this reason, the nozzle control valve has been identified as a potential cause of shot-to-shot variation. Against this background, it would be desirable to provide an improved fuel injector having a reduced shot-to-shot variation.

Summary of the Invention

[0019] According to a first aspect of the invention, there is provided a valve arrangement for use in a fuel injector of a high-pressure fuel injection system for an internal combustion engine. The valve arrangement comprises a valve body defining a valve seat and a valve member which is engageable with the valve seat. The valve arrangement further comprises an armature disposed within an armature chamber and cooperable with the valve member, and an electromagnetic actuator operable to cause movement of the valve member to control the flow of fluid into the armature chamber past the valve seat. The valve arrangement is arranged such that fluid flowing into the armature chamber is directed away from the ar-

mature.

[0020] The inventors of the present invention have determined that, by using a control valve arrangement according to the invention in a fuel injector so that the fluid flowing into the armature is directed away from the armature when the control chamber is connected to a low-pressure drain, a reduction in the shot-to-shot variation of the injector can be achieved, as will now be explained.

[0021] In a conventional nozzle control valve of the type shown in Figures 1a and 2, there can be considerable variation in the quantity of fuel that flows to drain in successive injections, even when the valve opening time is set at a constant value and the fuel is supplied to the injector at constant pressure.

[0022] It has been observed by the inventors that, in the conventional arrangement of Figures 1a and 2, when a gap defined between the sealing surface 60 of the valve member 38 and the valve seat 54 is large, for example when the nozzle control valve 31 is in the open position, or when valve closing movement has just started, fuel flows through the gap relatively unimpeded. However, towards the end of the valve closing movement, the gap becomes progressively smaller. This has the effect that the fuel which flows through the gap is formed into a jet (generally indicated by arrow 66 in Figure 2) within the armature chamber 50. In this context, the term "jet" refers to a localised efflux of fuel which is projected through the surrounding fuel in the armature chamber 50. The jet has a higher momentum than the surrounding fuel.

[0023] The jet follows a path that extends substantially in line with the valve seat 54 and is disposed conically around the valve member 38. The jet of fuel is therefore directed towards the armature 56.

[0024] When the jet impacts the armature 56, a force on the armature 56 is created. The force acts in the opening direction, and therefore acts to resist to the closing movement of the armature 56 and the valve member 38. The time taken for the valve closing movement to complete is extended, such that the nozzle control valve 31 remains open for a longer period than expected. As a result, a larger quantity of fuel is admitted to the armature chamber 50 and therefore to the low pressure drain. This has the consequence that fuel injector valve needle is open for longer than expected, meaning the actual quantity of fuel delivered in the injection is increased compared to the desired injection quantity. Furthermore, because of the turbulent nature of the jet, the behaviour of the jet and the corresponding effect on the armature 50 are not entirely predictable. Consequently, the increase in the injection quantity may not be consistent. In this way, the jet of fuel is thought to account for the higher than expected shot-to-shot variation of conventional fuel injectors, at least in part.

[0025] It will be appreciated that in the case of a hydraulically-balanced nozzle control valve, the force provided by the return spring to urge the valve member into engagement with the valve seat is relatively low. This is because the return spring does not normally have to op-

pose forces related to the pressure of the fuel, which are accounted for by the balancing of the valve member. Therefore, the force created by the jet on the armature may be of a similar scale to that provided by the return spring, and thus the effect on valve closing movement may be significant.

[0026] The problem caused by the jet is particularly pronounced when the pressure of the fuel is very high, as the force created by the jet on the armature increases with the pressure of the fuel. In addition, the problem is more noticeable for shorter injection timings, in which the period of valve closing movement is shorter, as the jet persists for a larger proportion of each injection.

[0027] Accordingly, the valve arrangement according to the present invention offers a solution to the problem of reducing shot-to-shot variation, by reducing the effect that the fluid flow behaviour within the armature chamber has on the movement of the valve member. In particular, because the valve arrangement is arranged so that fluid flowing into the armature chamber is directed away from the armature, undesirable forces that might otherwise act on the armature due to jets of fluid that form during closure of the valve member, or due to other fluid flow effects, are reduced or avoided.

[0028] In one embodiment of the invention, the valve member is moveable in a valve closing movement from an open position, in which fluid flows into the armature chamber, to a closed position, in which the valve member engages the valve seat. The valve arrangement may be arranged to direct fluid flowing into the armature chamber away from the armature during at least part of the valve closing movement. For example, the fluid may be directed away from the armature towards the end of the valve closing movement.

[0029] Fuel flowing into the armature chamber may be formed into a jet during at least part of the valve closing movement, and the valve arrangement may be arranged to direct the jet away from the armature. In this way, forces that might otherwise be imparted on the armature by the jet may be substantially avoided, therefore minimising resistance to valve closing movement.

[0030] The valve body may be shaped so as to direct the jet using the Coandă effect. This arrangement beneficially facilitates re-direction of the jet without major modification of the shape of the valve body compared to known arrangements.

[0031] The valve seat may be frusto-conical to define a first cone angle. This arrangement beneficially reduces the impact of manufacturing tolerances on the functioning of the valve arrangement.

[0032] The valve arrangement may further comprise a flow redirecting region next to the valve seat. The flow redirecting region may be shaped to direct fluid flowing into the armature chamber away from the armature. The flow redirecting region may comprise a rounded surface of the valve body. Alternatively, or in addition, the flow redirecting region may comprise a frusto-conical surface

of the valve body. The frusto-conical surface of the flow redirecting region may be directly adjacent to the valve seat.

[0033] In a preferred embodiment, the valve seat is frusto-conical to define a first cone angle, and the flow redirecting region comprises a frusto-conical surface that defines a second cone angle that is larger than the first cone angle.

[0034] The first cone angle may be between approximately 80° and approximately 100°. Preferably, the first cone angle is approximately 90°. The second cone angle may be between approximately 100° and approximately 160°. Preferably, the second cone angle is approximately 120°.

[0035] As an alternative to, or instead of, providing a flow redirecting region next to the valve seat, the valve seat itself may be shaped to direct fluid flowing into the armature chamber away from the armature. For example, the valve seat may be frusto-conical to define a cone angle equal to or greater than approximately 120°.

[0036] The valve body may include a recess which defines the armature chamber. The recess may be formed in a mating face of the valve body. The valve body may include a bore within which the valve member is slidably received, and a supply passage which opens into the bore. The actuator may comprise a magnetic core, a coil and a biasing means. The armature may be arranged to carry the valve member away from the valve seat when the actuator is energised. Said another way, the valve arrangement may be of the energise-to-open type.

[0037] The valve member may comprise a sealing surface, and at least part of the sealing surface may be arranged to engage with the valve seat to create a seal. Conveniently, the sealing surface may be frusto-conical. The valve member may comprise a further surface which opposes the sealing surface, such that the sealing surface and the further surface define a working chamber for high-pressure fluid therebetween. In this way, the valve member is substantially hydraulically balanced when in the closed position, such that fuel pressure in the working chamber does not significantly act to lift the valve member away from the valve seat. The further surface may be frusto-conical.

[0038] According to a second aspect of the invention, there is provided a fuel injector for use in a high-pressure fuel injection system for an internal combustion engine, comprising a valve arrangement according to the first aspect. The valve arrangement may be a nozzle control valve of the fuel injector.

[0039] The fuel injector may further comprise an injection nozzle including a valve needle which is engageable with a valve needle seating to control fuel delivery from the injector. A surface associated with the valve needle may be exposed to fuel pressure within a control chamber. In this embodiment, the valve arrangement is operable to connect the control chamber to a low-pressure drain to control the fuel pressure within the control chamber, and the armature chamber is in communication with

the low-pressure drain. This arrangement allows for fast and predictable movement of the valve needle, thereby providing a high level of control over injection timings.

[0040] Preferred and/or optional features of the first aspect of the invention may be used, alone or in appropriate combination, in the second aspect of the invention also.

Brief Description of the Drawings

[0041]

Figures 1a and 1b, which have already been referred to above, are schematic cross-sectional views of a nozzle control valve and a nozzle for a conventional fuel injector; and

Figure 2 is an enlarged view of a part of the nozzle control valve of Figure 1a, indicated by region R.

[0042] In order that the invention may be more readily understood, preferred non-limiting embodiments thereof will now be described with reference to the remaining accompanying drawings, in which:

Figure 3 is a cross-sectional view corresponding to region R of Figure 1a of part of a valve arrangement according to one embodiment of the invention; and

Figure 4 is a cross-sectional view corresponding to region R of Figure 1a of part of a valve arrangement for a fuel injector according to another embodiment of the invention.

Throughout this specification, terms such as 'upper', 'lower', 'downwardly' and 'side' are used with reference to the orientation of the components as shown in the accompanying drawings. It will be appreciated, however, that the components could be oriented in any suitable orientation in use.

Detailed Description of Embodiments of the Invention

[0043] Figure 3 illustrates part of a modified control valve arrangement 131 according to an embodiment of the invention. The control valve is designed to mitigate the above identified problem of the jet of fuel impacting the armature 156. Figure 3 is an enlarged view of a portion of the valve arrangement 131, which corresponds to the view of the conventional nozzle control valve 31 shown in Figure 2 (and hence region R in Figure 1a). Those components of the valve arrangement 131 that are not illustrated in Figure 3 are the same as those shown in Figure 1a.

[0044] The valve arrangement 131 includes a valve body 134, a valve member 138, an armature 156 coupled to the valve member 138, and a solenoid actuator 139

comprising a magnetic core member 140. The valve body 134 includes a valve bore 136 within which the valve member 138 is slidably received. An annular working chamber 164 is defined around a portion of the valve member 138.

[0045] An armature chamber 150 is defined by a recess in the valve body 134 which is disposed coaxially with respect to the valve bore 136, at an upper end of the valve bore 136 and adjacent to the magnetic core member 140. The armature 156 is received in the armature chamber 150. An upper end of the valve bore 136 opens into the armature chamber 150 and is shaped to form a chamfered frusto-conical surface. The frusto-conical surface defines a valve seat 154 for the valve member 138. A downwardly-directed frusto-conical sealing surface 160 of the valve member 138 engages with the valve seat 154 to create a seal, in order to prevent fuel from flowing past the valve seat 154 and into the armature chamber 150 when the valve member 138 is seated on the valve seat 154.

[0046] The valve arrangement 131 of this embodiment of the invention includes a flow redirecting region in the form of a frusto-conical redirection surface 168 on the valve body 134 which links the valve seat 154 with a planar lower surface of the armature chamber 170. The flow redirecting region redirects fuel flowing into the armature chamber 150 away from the armature 156, so as to reduce the resistance to valve closing movement. Accordingly, the valve closing movement is completed with a much smaller deviation from the desired timing than would be the case in the absence of the redirection surface 168, leading to more reliable and consistent injection quantities, and thus reducing the shot-to-shot variation of the fuel injector 8. The altered path of the jet is generally indicated in Figure 3 by arrow 166. As indicated by the arrow, the path of the jet is directed away from the armature 156, towards a side of the armature chamber 150.

[0047] As in the conventional arrangement shown in Figure 2, in the embodiment of Figure 3, the frusto-conical valve seat 154 typically has a cone angle of 90° , which in the context of this embodiment is referred to as a first cone angle. The valve seat 154 is therefore inclined at an angle of 45° (labelled A in Figure 3) with respect to the axis of the valve bore 136. The redirection surface 168 defines a second cone angle which is larger than the first cone angle, typically 120° . The redirection surface 168 is therefore inclined at an angle of 60° (labelled B in Figure 3) with respect to the axis of the valve bore 136.

[0048] In order to re-direct fuel, the second frusto-conical surface exploits the Coandeeffect, which is a phenomenon whereby a fluid jet has a tendency to be attracted to and "attach" to a nearby surface. In other words, the fluid jet remains close to the surface and follows its contours. The Coandeeffect is relatively weak, and depends upon a relatively modest change in the angle of the nearby surface relative to the direction of travel of the fluid jet. If the change in angle is too large, the attraction is too weak to have an effect, and the jet separates or "de-

taches" from the surface.

[0049] In the conventional valve arrangement 31 of Figures 1a and 2, the angle at which the valve seat 54 meets the planar lower surface of the armature chamber 70 is too large for the Coandeeffect to dominate, and therefore the jet separates from the surface of the valve body 34 where the valve seat 54 meets the planar lower surface of the armature chamber 70 (hereafter referred to as the top end of the valve seat 54). The jet then continues on its path towards the armature 56, resulting in the problem described previously.

[0050] However, in the embodiment of the invention shown in Figure 3, the redirection surface 168 adjoins the valve seat 154, so as to provide a graduated change in angle between the valve seat 154 and the lower surface 170 of the armature chamber 150. Therefore, the redirection surface 168 creates a second step in the transition between the valve seat 154 and the lower surface 170 of the armature chamber 150 such that the transition involves two step changes in angle. In contrast, in the conventional nozzle control valve 31 of Figure 2, the transition between the valve seat 54 and the lower surface 70 of the armature chamber 150 involves only one step change in angle. Therefore, in the Figure 3 embodiment of the invention, the maximum change in angle of the surface of the valve body 134 relative to the jet of fuel is reduced compared with the conventional nozzle control valve 31. Consequently, in this arrangement, the jet of fuel does not detach from the surface of the valve body 134 at the top end of the valve seat 154. Instead, the Coandeeffect causes the jet to change direction and remain close to the redirection surface 168.

[0051] In this way, the direction of travel of the jet, as indicated by arrow 166, is altered compared with the conventional valve arrangement 31, such that the path of the jet is diverted away from the armature 156. Figure 3 shows how the path of the jet follows the profile of the redirection surface 168. The second step change in angle is similar in size to the first step change in angle. Therefore, the jet may continue to follow the profile of the surface of the valve body 134 as it flows outwardly from the valve seat 154, such that the path of the jet eventually becomes substantially parallel with the lower surface of the armature chamber 170.

[0052] The jet may instead detach from the surface of the valve body 134 at an end 172 of the redirection surface 168 that is remote from the valve seat 154 (hereafter referred to as the top end 172 of the redirection surface 168). However, even if the jet does detach at the top end 172 of the redirection surface 168, the direction of travel of the jet has been altered sufficiently by that stage that the jet no longer impinges on the armature 156. Therefore, the jet applies substantially no additional force to the armature 156, or at least a significantly reduced force. This means that the effect of the jet on the valve closing movement is reduced, thereby reducing the shot-to-shot variation of the fuel injector.

[0053] It will be appreciated that the manufacture of

the redirection surface 168 is relatively straightforward. For example, the redirection surface 168 can be ground in the same manufacturing process as the valve seat 154. Therefore the embodiment of the invention presented in Figure 3 offers a convenient and relatively inexpensive solution to the above described problem found in conventional valve arrangements 31.

[0054] Figure 4 illustrates a valve arrangement 231 according to another embodiment of the invention which is similar to the embodiment of Figure 3. The valve arrangement 231 of Figure 4 includes a valve body 234 defining a valve bore 236 in which a valve member 238 is slidably received. The arrangement 231 further comprises an actuator 239 comprising a magnetic core member 240, and an armature 256 coupled to the valve member 238. The valve member 238 includes a sealing surface 260 which engages with a valve seat 254, to prevent fuel flowing from a working chamber 264 to an armature chamber 250.

[0055] The arrangement 232 of Figure 4 differs from that of Figure 3 in that, in the arrangement of Figure 4, the flow redirecting region comprises a rounded surface 274, rather than a frusto-conical surface. The rounded surface 274 creates a gradual transition between the valve seat 254 and a planar lower surface 270 of the armature chamber 250. As a result, there are no step changes in the angle of the surface near to the jet; instead, the surface near to the jet varies continuously, resulting in a smooth transition between the valve seat 254 and the lower surface 270 of the armature chamber 250. The valve arrangement 231 of Figure 4 is otherwise identical to the valve arrangement 131 of Figure 3.

[0056] The influence of the Coandeeffect is enhanced in this embodiment, as the path of the jet is diverted in a continuous and gradual manner. Because the transition between the valve seat 254 and the planar lower surface 270 of the armature chamber 250 is gradual and continuous, the change in angle is always small enough for the Coandeeffect to dominate at all positions on the surface of the valve body 234. This ensures that the jet remains attached to the surface of the valve body 234, which in turn ensures that the path of the jet, as generally indicated by arrow 266, is re-directed away from the armature 256 as much as possible. Therefore, the reduction in the shot-to-shot variation of the fuel injector as a result of diverting the jet is maximised.

[0057] The rounded surface 274 of the valve arrangement 231 of Figure 4 can be added to a conventional valve arrangement 31 without a significant development burden. Therefore, this embodiment offers an alternative convenient solution to the previously described problem, and the rounded surface 274 provides a particularly effective shape for re-directing the jet.

[0058] It will be appreciated that flow redirecting regions with different shapes could be provided to optimise performance and manufacturability. For example, the flow redirecting region may comprise both a rounded surface portion and a frusto-conical surface portion.

[0059] In a variant of the invention (not illustrated), the flow of fuel into the armature chamber is directed away from the armature by altering the cone angle of the valve seat of the conventional valve arrangement, such that the jet is directed away from the armature at the point of creation of the jet. An increase in the cone angle of the valve seat reduces the step change in angle between the top of the valve seat and the planar lower surface of the armature chamber. Depending on the angle of the valve seat, the Coandeeffect may act to re-direct the jet of fuel at the top of the valve seat, to move the jet further away from the armature. This solution offers a simpler arrangement compared with the above described embodiments, because only a single frusto-conical surface is required, without the need to provide additional surface features to direct the fluid flow away from the armature.

[0060] It is noted that all of the above described embodiments of the invention are suitable for use as nozzle control valves for controlling a conventional nozzle 9 of the type shown in Figure 1b.

[0061] It will be appreciated by a person skilled in the art that the invention could be modified to take many alternative forms to that described herein, without departing from the scope of the appended claims. It will also be appreciated that although the embodiments of the invention have been described in relation to a nozzle control valve for a fuel injector, the invention is potentially applicable to any valve that suffers from the problem of fluid flow within the valve causing resistance to valve closure.

Claims

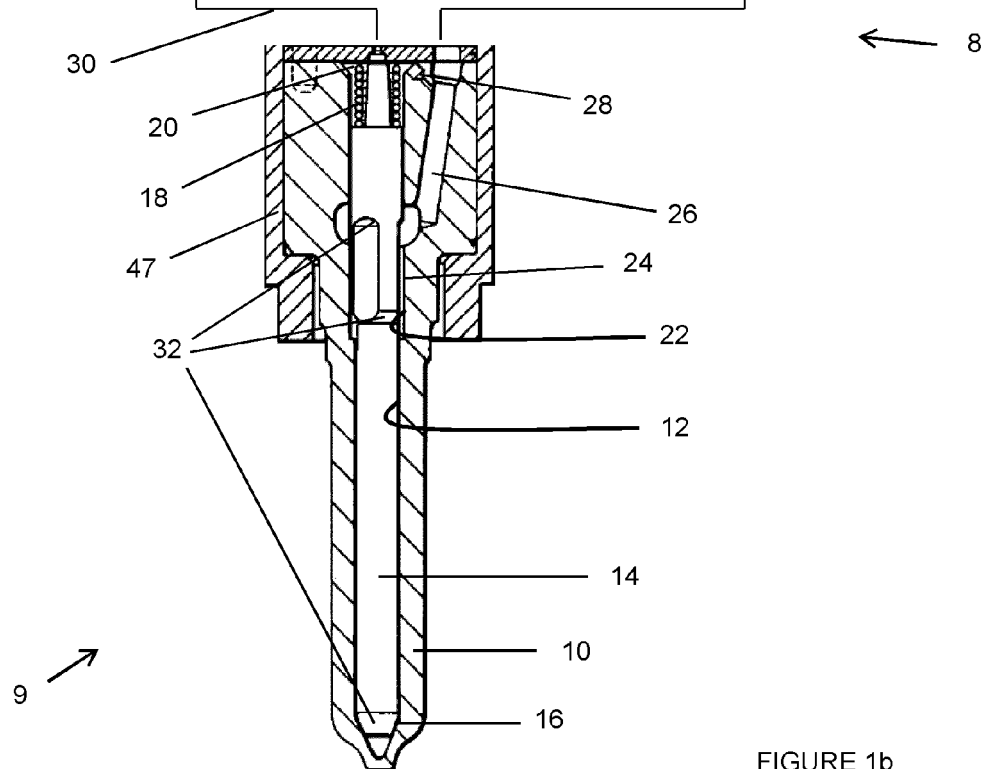
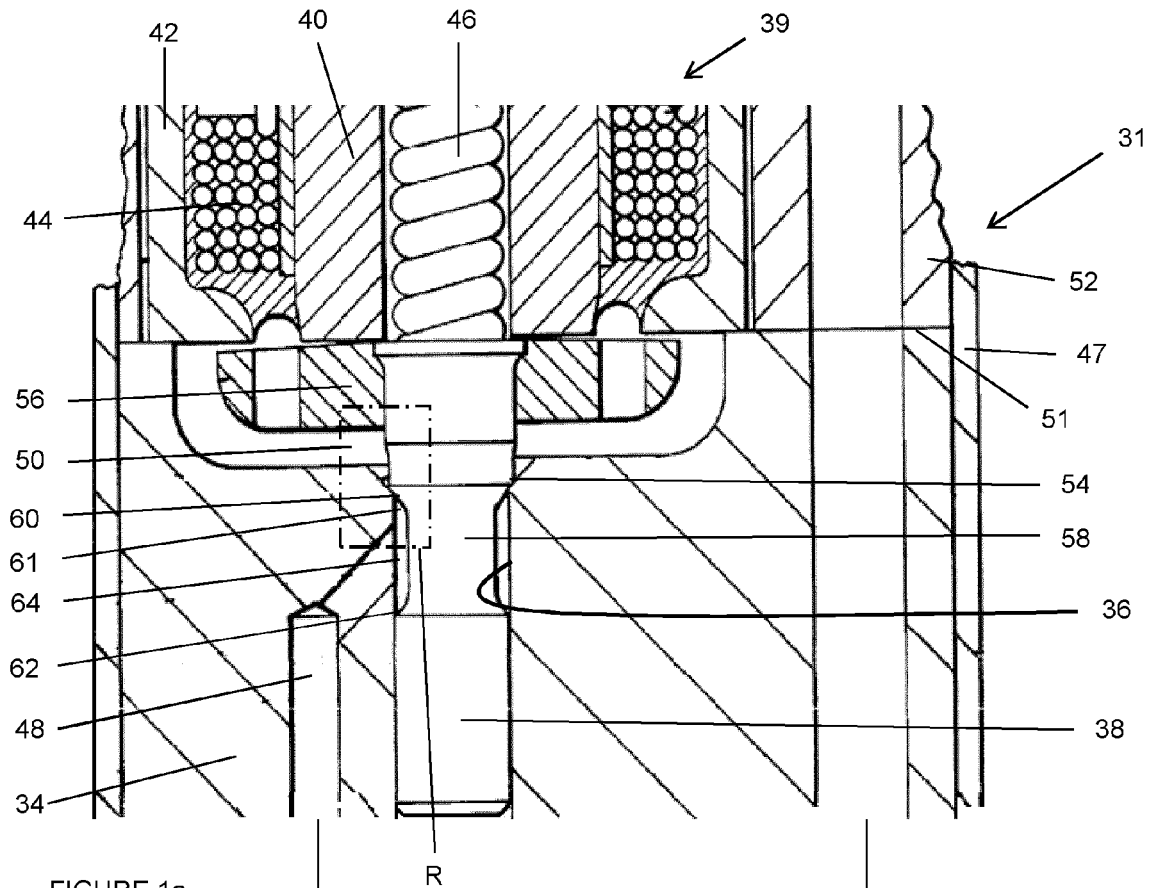
1. A valve arrangement (131, 231) for use in a fuel injector of a high-pressure fuel injection system for an internal combustion engine, the valve arrangement (131, 231) comprising:

a valve body (134, 234) defining a valve seat (154, 254);
 a valve member (138, 238) which is engageable with the valve seat (154, 254);
 an armature (156, 256) disposed within an armature chamber (150, 250) and cooperable with the valve member (138, 238); and
 an electromagnetic actuator (139, 239) operable to cause movement of the valve member (138, 238) to control the flow of fluid into the armature chamber (150, 250) past the valve seat (154, 254);

wherein the valve arrangement (131, 231) is arranged such that fluid flowing into the armature chamber (150, 250) is directed away from the armature (156, 256).

2. A valve arrangement (131, 231) according to claim 1, wherein the valve member (138, 238) is moveable

- in a valve closing movement from an open position, in which fluid flows into the armature chamber (150, 250), to a closed position, in which the valve member (138, 238) engages the valve seat (154, 254), and wherein the valve arrangement (131, 231) is arranged to direct fluid flowing into the armature chamber (150, 250) away from the armature (156, 256) during at least part of the valve closing movement.
3. A valve arrangement (131, 231) according to claim 2, wherein fuel flowing into the armature chamber (150, 250) is formed into a jet during at least part of the valve closing movement, and wherein the valve arrangement (131, 231) is arranged to direct the jet away from the armature (156, 256).
 4. A valve arrangement (131, 231) according to claim 3, wherein the valve body (134, 234) is shaped so as to direct the jet using the Coandeeffect.
 5. A valve arrangement (131, 231) according to any one of claims 1 to 4, further comprising a flow redirecting region (168, 272) adjacent to the valve seat (154, 254), wherein the flow redirecting region (168, 272) is shaped to direct fluid flowing into the armature chamber (150, 250) away from the armature (156, 256).
 6. A valve arrangement (231) according to claim 5, wherein the flow redirecting region comprises a rounded surface (274) of the valve body (234).
 7. A valve arrangement (131) according to claim 5 or claim 6, wherein the flow redirecting region comprises a frusto-conical surface (168) of the valve body (134).
 8. A valve arrangement (131) according to claim 7, wherein the valve seat (154) is frusto-conical to define a first cone angle, and wherein the frusto-conical surface of the flow redirecting region defines a second cone angle that is larger than the first cone angle.
 9. A valve arrangement (131, 231) according to any one of claims 1 to 8, wherein the valve body (134, 234) includes a recess which defines the armature chamber (150, 250), a bore (136, 236) within which the valve member (138, 238) is slidably received, and an inlet passage which opens into the bore (136, 236).
 10. A valve arrangement (131, 231) according to any one of claims 1 to 9, wherein the armature (156, 256) carries the valve member (138, 238) away from the valve seat (154, 254) when the actuator (139, 239) is energised.
 11. A valve arrangement (131, 231) according to any one of claims 1 to 10, wherein the valve member (138, 238) comprises a sealing surface (160, 260), wherein at least part of the sealing surface (160, 260) is arranged to engage with the valve seat (154, 254) to create a seal.
 12. A valve arrangement (131, 231) according to claim 11, wherein the sealing surface (160, 260) is frusto-conical.
 13. A valve arrangement (131, 231) according to claim 11 or claim 12, wherein the valve member (138, 238) comprises a further surface (62) which opposes the sealing surface (160, 260), and wherein the sealing surface (160, 260) and the further surface define a working chamber (164, 264) for high-pressure fluid therebetween.
 14. A fuel injector for use in a high-pressure fuel injection system for an internal combustion engine, comprising a valve arrangement (131, 231) according to any one of claims 1 to 13.
 15. A fuel injector according to claim 14, further comprising an injection nozzle (9) including a valve needle (14) which is engageable with a valve needle seating (16) to control fuel delivery from the injector, a surface associated with the valve needle (14) being exposed to fuel pressure within a control chamber (20); wherein the valve arrangement (131, 231) is operable to connect the control chamber (20) to a low-pressure drain to control the fuel pressure within the control chamber (20); and wherein the armature chamber (150, 250) is in communication with the low-pressure drain.



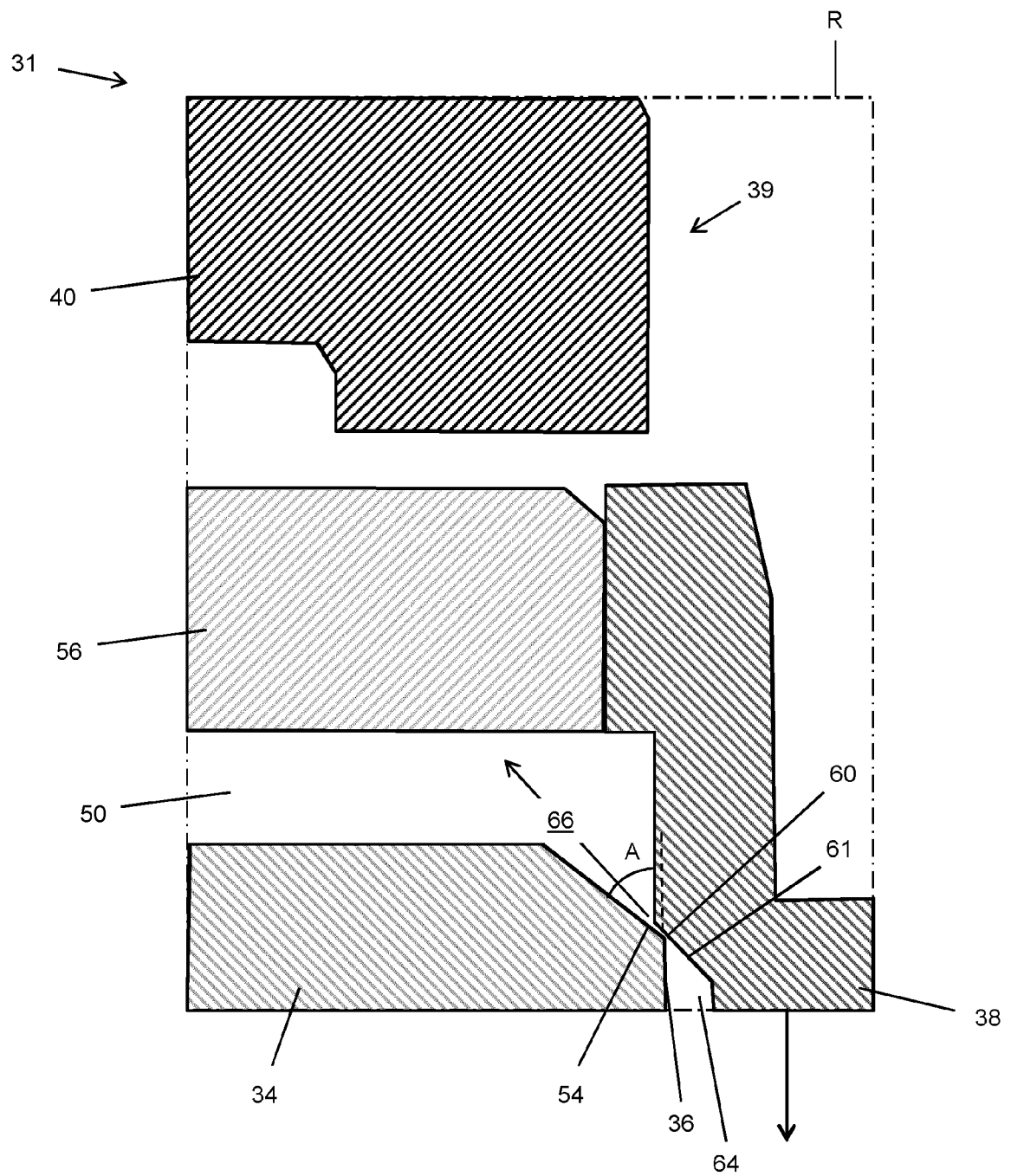


FIGURE 2

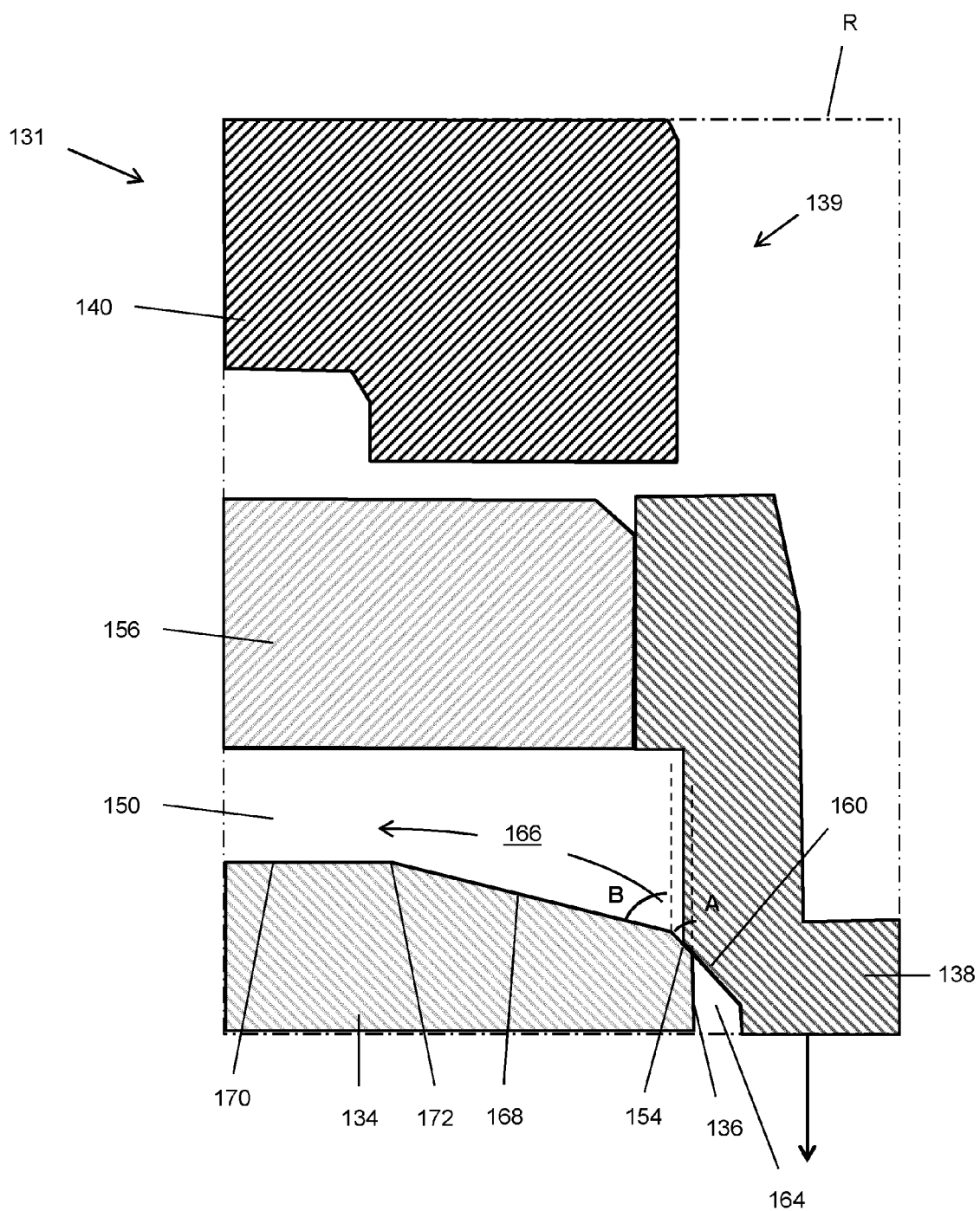


FIGURE 3

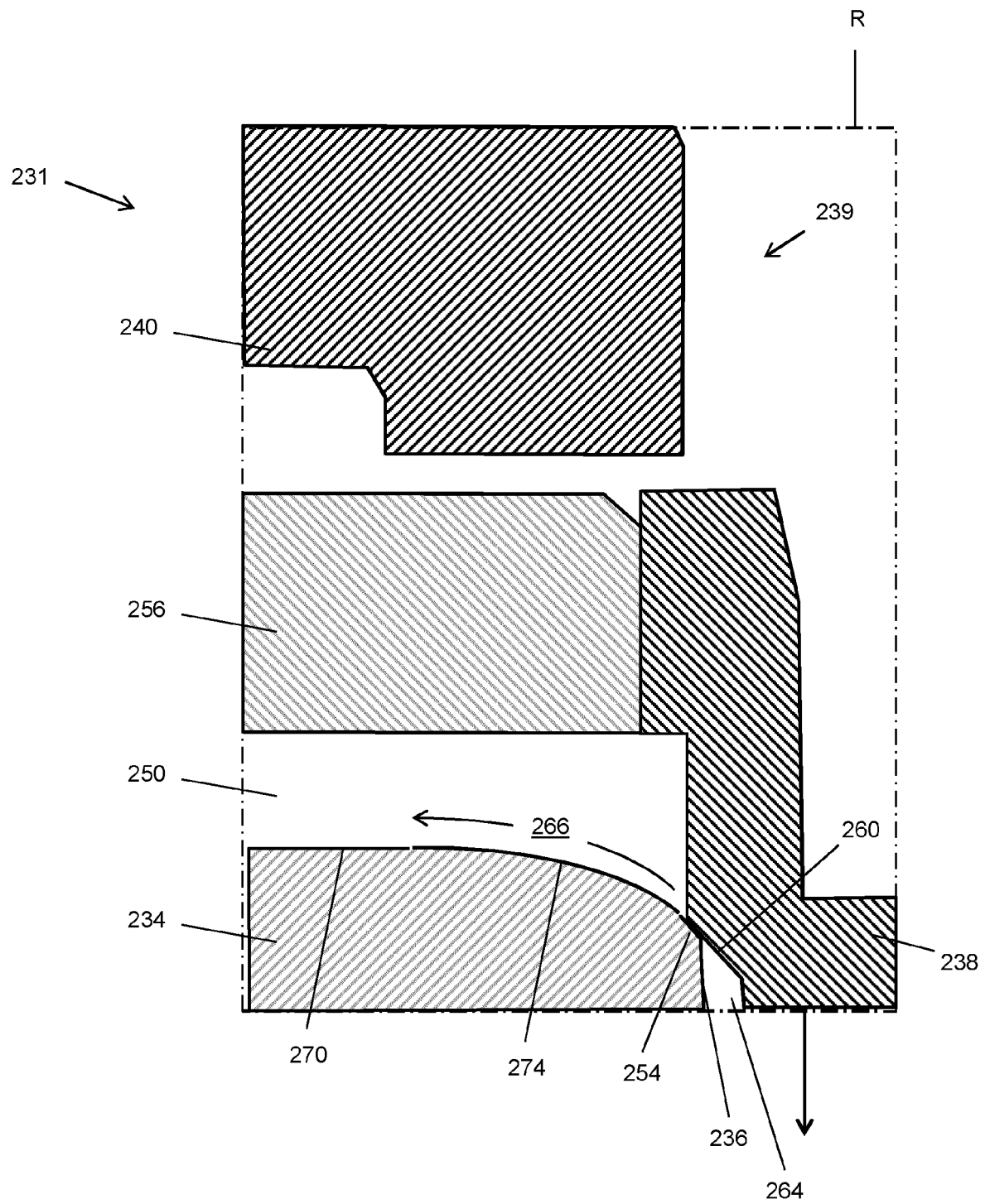


FIGURE 4



EUROPEAN SEARCH REPORT

Application Number
EP 13 16 9876

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			F02M
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		27 August 2013	Hermens, Sjoerd
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27-08-2013

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