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Amended claims in accordance with Rule 86 (2) EPC.

(54) **Fuel injection nozzle and method of producing a fuel injection nozzle**

(57) An injection nozzle (10) for use in a fuel injector for an internal combustion engine having a combustion space, the injection nozzle (10) includes a first valve needle (16) which is engageable with a first valve needle seating (34) to control fuel delivery through one or more first outlets (36) provided in a nozzle body (12). The or each first outlet (36) defines a first cross sectional flow area for fuel. The nozzle further comprises a second valve needle (22), coaxial with the first valve needle and engageable with a second valve needle seating (40) to control fuel delivery through a plurality of second outlets

(38) provided in the nozzle body (10). The plurality of second outlets are arranged in one or more localised groups (38) of second outlets (38a,38b,38c), with each of the second outlets (38) having a cross sectional flow area equal to the first cross sectional flow area of the first outlet (36). The nozzle is of the two-stage lift type to provide a variable fuel injection rate depending on whether one of the valve needles (16,22) is moved alone to open one of the outlets or localised groups of outlets only to provide a relatively low injection rate, or whether the other of the valve needles is moved also to provide an increased injection rate.

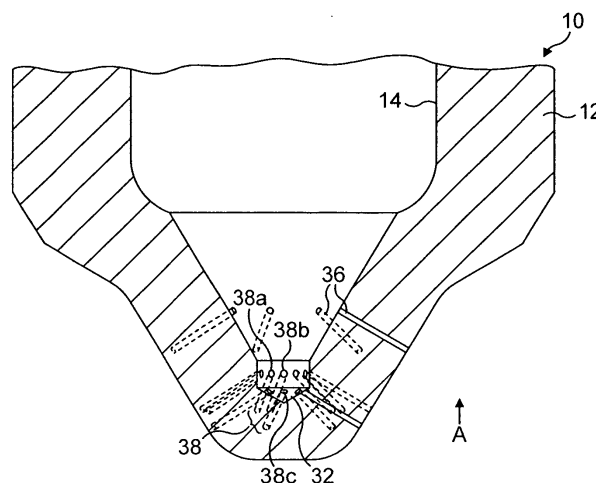


FIG. 7

Description

[0001] The present invention relates to fuel injection nozzle including an inner valve needle and an outer valve needle, each of which controls the delivery of fuel into the combustion chamber of an internal combustion engine. In particular, the invention relates to an injection nozzle in which the outer valve needle is co-operable with one outlet to control fuel delivery and an inner valve needle cooperates with another outlet to control fuel delivery. The invention also relates to a method of producing an injection nozzle of the aforementioned type.

[0002] In a known injection nozzle, commonly referred to as a variable orifice nozzle (VON), a nozzle body is provided with a blind bore within which a first, outer valve needle is movable under the control of an actuator. The outer valve needle is provided with a further bore within which a second, inner valve needle is able to move. The outer valve needle is engageable with a seating defined by the first bore to control fuel delivery through a first outlet or set of outlets. The inner valve needle projects through the open end of the further bore in the outer valve needle and is engageable with an additional seating defined by the nozzle body bore to control fuel delivery through a second set of outlets. The outer valve needle and the inner valve needle are co-operable with one another so that when the outer valve needle is caused to move away from its seating beyond a predetermined amount, a force is transmitted to the inner valve needle to cause it to lift away from its seating also. During this stage of operation, both the first and second outlets are opened. If the outer valve needle is only caused to move away from the seating by an amount less than the predetermined amount, the inner valve needle remains seated, so that injection only occurs through the first outlet or set of outlets.

[0003] Variable orifice nozzles provide particular advantages for diesel engines, in that they provide the flexibility to inject fuel into the combustion chamber either through the first set of outlets on its own or through both the first and second outlets together. This enables selection of a larger total fuel delivery area for high engine power modes or a smaller total fuel delivery area for lower engine power modes.

[0004] It has been found previously that further advantages are obtained if the number of outlets in the second set (being those controlled by the inner valve needle) is the same as the number of outlets in the first set (being those outlets controlled by the outer valve needle). It has also been found to be desirable for the outlets in each set to be aligned in the same direction, so that the fuel sprays emerging from each set combine in the combustion chamber to give a similar effect to a single set of outlets, with a total flow area equal to the sum of the areas of the first and second outlets. An injection nozzle of this type is described in further detail in the applicants co-pending European patent application EP 0967382 A. Conventionally, electric discharge machining (EDM) or

laser drilling techniques are implemented to cut the outlets through the nozzle body.

[0005] The inventors have recognised that existing variable orifice nozzle designs can pose undesirable limitations on the range of flow delivery rates available, especially for high engine power modes. At present there is no convenient solution to the problem of increasing the range of available flow delivery rates which is compatible with the requirements of the manufacturing methods used to create the outlets in the nozzle body.

[0006] It is with a view to addressing the aforementioned problem that an improved injection nozzle, and method of producing an injection nozzle, is provided.

[0007] According to the present invention, there is provided an injection nozzle for use in a fuel injector for an internal combustion engine having a combustion chamber, the injection nozzle comprising a first valve needle which is engageable with a first valve needle seating to control fuel delivery through one or more first outlets provided in a nozzle body, wherein the or each first outlet defines a first cross sectional flow area for fuel, the injection nozzle further comprising a second valve needle which is coaxial with the first valve needle and engageable with a second valve needle seating to control fuel delivery through a plurality of second outlets provided in the nozzle body, wherein the plurality of second outlets are arranged to form one or more localised groups of second outlets, with each of the second outlets having a cross sectional flow area substantially equal to the first cross sectional flow area.

[0008] The injection nozzle is of the variable orifice nozzle type, providing a wide range of fuel delivery rates through selective injection through either the first outlet and/or the plurality of second outlets. As each of the outlets (i.e. a first outlet or a second outlet of a localised group) has the same cross sectional flow area, it is possible to form all of the outlets using the same machining tool during electric discharge machining. As the second outlets formed a localised group, an increased flow area is provided by opening the second valve needle to inject through the localised group, compared to that available by opening only the first valve needle to inject through the first outlet.

[0009] It is one advantage of machining all outlets with the same machining tool, so as to have the same size, that the flow characteristics of each will be substantially similar. Following the initial machining process, the outlets will all respond to subsequent manufacturing operations in a similar manner. Consistency of flow balance between the first and second outlets is thus likely to be improved.

[0010] In one embodiment, the first valve needle is an outer valve needle and the second valve needle is an inner valve needle being received at least partially within the outer valve needle. The outer valve needle therefore controls fuel delivery through the first outlet and the inner valve needle therefore controls fuel delivery through the second outlets. Alternatively, the first valve needle is an

inner valve needle and the second valve needle is an outer valve needle so that the inner valve needle controls fuel delivery through the first outlet and the outer valve needle controls fuel delivery through the second outlets.

[0011] In a preferred embodiment, the injection nozzle comprises a plurality of localised groups of second outlets and a plurality of first outlets, each of the groups of second outlets being associated with a respective one of the first outlets.

[0012] In one embodiment, each localised group of second outlets includes at least one pair of second outlets, wherein the first outlet lies in a first vertical plane and the second outlets of the associated localised group also lie in the first vertical plane.

[0013] In another embodiment, each localised group of second outlets includes at least one pair of second outlets, each of the second outlets of the pair lying in a vertical plane offset from the first vertical plane of the associated first outlet.

[0014] For example, one of the second outlets of the pair may lie in a vertical plane offset on one side of the first vertical plane of the associated first outlet and the other of the second outlets of the pair may lie in a vertical plane offset on the other side of the first vertical plane of the associated first outlet.

[0015] By way of further example, the second outlets of the pair may lie in different horizontal planes. In this arrangement, the second outlets form a staggered-like configuration.

[0016] In another embodiment, the associated localised group of second outlets may include a further second outlet arranged to lie in the first vertical plane of the associated first outlet.

[0017] For example, the second outlets of the pair are arranged in a horizontal plane offset from a horizontal plane of the further second outlet.

[0018] In another embodiment, each of the localised groups further comprises at least one additional pair of second outlets and wherein each of the second outlets of a localised group lies in a different horizontal plane and in a different vertical plane to the other second outlets of the localised group so that the second outlets form a staggered-like configuration.

[0019] In one type of nozzle, second outlets of the localised group and the associated first outlet are inclined relative to one another through the nozzle body so as to provide a combined fuel spray within the combustion chamber as a result of merging fuel sprays from the first and second outlets, with the combined fuel spray being as if it had emerged from a single outlet.

[0020] Alternatively, second outlets of a localised group and the associated first outlet are aligned in parallel within the nozzle body so as to provide substantially parallel aligned fuel sprays within the combustion chamber.

[0021] In one embodiment, the first valve needle is co-operable with the second valve needle so that the second valve needle is caused to move away from the second valve needle seating in circumstances in which

the first valve needle moves away from the first valve seating beyond a threshold amount, and wherein the first valve needle is actuatable so as to move alone, without moving the second valve needle, when moved through an amount less than the threshold amount (i.e. leaving the second valve needle seated). Alternatively, the needle arrangement may be such that the first valve needle is caused to move away from the first valve needle seating in circumstances in which the second valve needle moves away from the second valve seating beyond a threshold amount, and wherein the second valve needle is actuatable so as to move alone, without moving the first valve needle, when moved through an amount less than the threshold amount (i.e. leaving the first valve needle seated).

[0022] According to a second aspect of the present invention, there is provided a fuel injector for use in an internal combustion engine, wherein the fuel injector includes an injection nozzle in accordance with the first aspect of the invention, and wherein at least one of the valve needles is movable by means of an actuator. Preferably, the actuator is one of a piezoelectric actuator or an electromagnetic actuator.

[0023] According to a third aspect of the present invention there is provided a method of producing an injection nozzle having a first valve needle and a second valve needle, the method comprising:

providing a nozzle body,

providing an electric discharge machining tool having a machining tool size,

using the electric discharge machining tool to form one or more first outlets through the nozzle body such that the or each of the first outlets provides a first cross sectional area for fuel flow which is determined by the electric discharge machining tool size, and

using the same electric discharge machining tool to form a localised group of a plurality of second outlets through the nozzle body, wherein each of the second outlets provides a cross sectional area for fuel flow that is substantially equal to the first cross sectional flow area.

[0024] In one embodiment, the machining tool used to form the one or more first outlets and the plurality of second outlets is an electric discharge machining tool. The method provides the advantage that only one electric discharge machining tool is required to form all of the outlets in the nozzle body. By grouping the second outlets in one or more localised groups, the nozzle can facilitate a higher flow rate into the engine through the localised group(s) so as to achieve a variable injection rate.

[0025] Alternatively, the machining tool may be a laser machining tool.

[0026] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic view of a lower part of an injection nozzle of a first embodiment of the invention,

Figure 2 is an end view, along direction A, of the injection nozzle in Figure 1;

Figure 3 is a schematic view of a lower part of an injection nozzle of a second embodiment of the invention;

Figure 4 is an end view, along direction A, of the injection nozzle in Figure 3;

Figure 5 is a schematic view of a lower part of an injection nozzle of a third embodiment of the invention;

Figure 6 is an end view, along direction A, of the injection nozzle in Figure 5;

Figure 7 is a schematic view of a lower part of an injection nozzle of a fourth embodiment of the invention;

Figure 8 is an end view, along direction A, of the injection nozzle in Figure 7;

Figure 9 is a schematic view of a lower part of an injection nozzle of a fifth embodiment of the invention; and

Figure 10 is an end view, along direction A, of the injection nozzle in Figure 9.

[0027] Referring to Figure 1, a variable orifice injection nozzle, referred to generally as 10, forms part of a fuel injector for use in a compression ignition internal combustion engine. The injection nozzle 10 includes a nozzle body 12 provided with a blind bore 14, within which is received a first, outer valve needle 16. Figure 1 shows the lower end of the injection nozzle 10 only. The bore 14 defines, together with an outer surface of the first valve needle 16, a delivery chamber 18 for receiving fuel at an injectable pressure level from a fuel source of the associated engine. Typically, the fuel source takes the form of a common rail for supplying pressurised fuel to a plurality of other injectors of the engine also.

[0028] The outer valve needle 16 is provided with an axially extending bore 20 within which is received at least a part of a second, inner valve needle 22 having a valve needle tip 24, so that the first and second valve needles 16, 22 are coaxial. Only a lower part of the inner valve needle 22 is visible in Figure 1. The outer valve needle

16 is also provided with a plurality of radial cross drillings or bores 26. The drillings 26 permit fuel within the delivery chamber 18 to flow into a flow path 28 defined by the axial bore 20 in the outer valve needle 16 and, hence, into a delivery volume 30 for fuel located just beneath the seated outer valve needle 16. The blind end of the bore, located just beneath the tip 24 of the seated inner valve needle 22, defines a nozzle sac volume 32.

[0029] The outer valve needle 16 is engageable with an outer valve needle seating 34 defined by a surface of the nozzle body bore 14. Movement of the outer valve needle 16 towards and away from its seating 34 controls fuel delivery through a set of first outlets 36 (only one outlet of the set is shown in Figure 1) provided in the nozzle body 12. The outer valve needle seating 34 is comprised of two seats; a first, upper seat 34a located upstream of the first outlets 36 and a second, lower seat 34b located downstream of the first outlets 36. The provision of a twin-valve seat 34a, 34b for a variable orifice injection nozzle is described in the Applicant's co-pending European patent application 04250132.0, and will be discussed in further detail below. Each of the first outlets 36 of the set has an inlet end which opens into and communicates with the bore 14 in the nozzle body 12, and an outlet end which communicates with a combustion chamber of the engine.

[0030] The nozzle body 12 is also provided with a set of second outlets comprising a plurality of localised groups of outlets (only one group 38 is visible in Figure 1). Each of the localised groups 38 of second outlets is considered to be associated with one of the first outlets 36, for reasons which will become apparent from the following description. Each group 38 of the second set of outlets includes a pair of individual outlets 38a, 38b. Inlet ends of the second outlets 38a, 38b communicate with the nozzle sac volume 32 and outlet ends of the second outlets 38a, 38b communicate with the combustion chamber.

[0031] The inner valve needle 22 is engageable with an inner valve needle seating 40, of annular form, to control fuel delivery through the groups 38 of second outlets. The second outlets 38a, 38b of each group are axially aligned with one another so that fuel sprays emerging from the outlets 38a, 38b will follow substantially parallel flow paths into the combustion chamber. The first outlets 36 are also arranged to be in axial alignment with the associated group of second outlets 38a, 38b so that the fuel sprays emerging from related ones of the outlets 36, 38a, 38b follow substantially parallel flow paths.

[0032] Figure 2 illustrates the arrangement of the first and second outlets 36, 38a, 38b more clearly. It can be seen that the first set of outlets comprises seven outlets 36 (only two of which are numbered), equi-angularly spaced around the circumference of the nozzle body 12. Seven groups 38 of second outlets (only two of which are numbered) are also provided. Each of the groups 38 is formed of a pair of outlets 38a, 38b, with the outlets of each pair being located in close proximity to one another

and each pair being associated with a different one of the first outlets 36.

[0033] The outlets 38a, 38b of each pair are located at different axial positions along the length of the nozzle body 12 and such that the inlet end of one outlet 38a of a pair lies in the same vertical plane (identified as X-X) as the inlet end of the other outlet 38b of the pair. Reference to inlet ends of the outlets being in the same vertical plane equates to the inlet ends of the outlets having the same angular location on the internal circumference of the bore 14 in the nozzle body 12.

[0034] The inlet end of each of the second outlets 38a, 38b is also aligned in the same vertical plane X-X as the inlet end of its associated first outlet 36. The second outlets 38a, 38b are located so that their inlet ends communicate with the nozzle body bore 14 at positions radially inward of the point of communication between the inlet end of the associated first outlet 36 and the nozzle body bore 14. The outlets 36 of the first set are equal in size to the outlets 38a, 38b of the second set so that the cross sectional flow area presented by each of the outlets 36, 38a, 38b is substantially identical. As the outlets 36, 38a, 38b are arranged substantially in parallel with one another (as shown in Figure 1) to provide emerging fuel sprays in parallel, the outlets lie in the same vertical plane along their entire lengths.

[0035] In use, when it is required to inject through the first set of outlets 36, the outer valve needle 16 is actuated to move away from the outer valve needle seating 34 by a first, relatively small amount. Fuel within the delivery chamber 18 is thus able to flow past the upper seat 34a of the outer valve needle seating 34 and through the first set of outlets 36 into the combustion chamber. Fuel flowing through the radial cross drillings 26 flows into the flow path 28 defined within the outer valve needle 16 and, hence, into the delivery volume 30. As the outer valve needle 16 is unseated, fuel within the delivery volume 30 is also able to flow past the lower seat 34b of the outer valve needle seating 34 to the first outlets 36. The flow of fuel through the first outlets 36 therefore flows from the delivery chamber 18 through two different routes; either directly past the upper seat 34a or indirectly via the flow path 28 through the outer valve needle 16 and past the lower seat 34b.

[0036] In circumstances such as those described above, in which the outer valve needle 16 is lifted away from the outer valve needle seating 34 by only a relatively small amount (less than a threshold amount), the inner valve needle 22 remains seated. The second outlets 38 therefore remain closed, so that the overall flow rate into the engine is relatively low and is governed by the cross sectional flow area of the first outlets 36 only. This mode of operation is suitable for lower engine power modes.

[0037] If it is required to inject at a higher rate, the outer valve needle 16 is moved further away from the outer valve seating 34, beyond the threshold amount, under the control of the actuator. The outer valve needle 16 and the inner valve needle 22 are arranged so that as the

outer valve needle 16 is moved further away from the outer valve seating 34, movement is transmitted to the inner valve needle 22, thus causing the inner valve needle 22 to lift away from the inner valve needle seating 40. With the inner valve needle 22 lifted away from its seating 40, the second outlets 38 are opened to allow fuel to flow into the combustion chamber through these outlets also. With both needles 16, 22 lifted, the flow rate to the engine is thus significantly increased. This mode of operation is therefore suitable for higher engine power modes.

[0038] The coupling mechanism between the inner and outer needles 22, 16 may take one of several forms. For example, the inner valve needle and the outer valve needle may be coupled mechanically by providing the inner valve needle with an enlarged head at its upper end, with which a stepped surface in the bore of the outer valve needle 16 is engaged when it has lifted through the threshold amount.

[0039] In order to terminate injection into the engine, the actuator is de-actuated so as to cause the outer valve needle 16, and hence the inner valve needle 22, to return to engage with their respective seatings 34, 40, thus closing the sets of first and second outlets 36, 38.

[0040] It is one benefit of the injection nozzle of the present invention that a wide range of fuel delivery rates is possible so as to satisfy all engine power modes. Furthermore, as all of the outlets 36, 38a, 38b are formed with the same size (i.e. each presents the same flow area to fuel during injection) it is convenient to use only one machining tool to form them all, without the requirement to change any tooling parts. By way of example, the machining tool may be an electric discharge machining apparatus or a laser machining apparatus. As the same machining tool can be used to form both sets of outlets 36, 38, flow balance between them will be consistent. Furthermore, as the outlets 36, 38a, 38b are substantially identical, processing and flow measuring techniques employed during manufacture can be used to measure the flow through all of the outlets together, rather than having to treat the first and second sets independently. This provides for a convenient and more efficient manufacturing process.

[0041] In the embodiment illustrated in Figure 1, the outlets 36, 38a, 38b of the first and second sets are in axial alignment with one another so that, when both the inner and outer valve needles 22, 16 are lifted, the emerging sprays follow substantially parallel flow paths into the combustion chamber. In an alternative embodiment, the outlets 36, 38a, 38b of the first and second sets may be shaped so that their emerging sprays converge so as to merge with one another, at some point within the combustion chamber. This provides a combined fuel spray having the characteristics of a spray having emerged from a single outlet.

[0042] In a further alternative embodiment, the second outlets 38a, 38b of a localised group only may be oriented, aligned or otherwise arranged so that the emerging fuel sprays converge to merge with one another (i.e.

sprays from second outlets 38a, 38b only are caused to combine).

[0043] In a further variation, the actuation mechanism for the inner and outer valve needles 22, 16 may be such that it is possible to inject through only the set of second outlets 38, and not the first. For example, the injector may be provided with separate actuators for independent control of the inner and outer valve needles 22, 16.

[0044] Figures 3 and 4 show an alternative embodiment of the invention in which similar parts to those shown in Figures 1 and 2 have been identified with like reference numerals. In this embodiment, each outlet 38a, 38b of a pair forming a localised group 38 of second outlets is located at the same axial position along the length of the nozzle body 12 as the other outlet of the pair, but is angularly spaced from its neighbour by a small amount. Each outlet of a localised group of second outlets 38a, 38b is positioned in a vertical plane offset from the vertical plane of the associated first outlet 36 (plane X-X identified in Figure 4), with one of the second outlets 38a being located on each side of the first vertical plane X-X. The first and second outlets 36, 38a, 38b extend substantially in parallel through the nozzle body 12 so that the emerging fuel sprays from the outlets 36, 38a, 38b maintain substantially parallel flow paths in the combustion chamber.

[0045] As described previously, the outlets 36, 38a, 38b of each of the first and second sets are of the same size, and hence each provides the same cross sectional flow area to fuel. Therefore, opening of the outer valve needle 16 only provides a relatively low flow rate into the combustion chamber, whereas opening both the inner and the outer valve needles 22, 16 together provides an increased flow area to the combustion chamber.

[0046] In an alternative version of the nozzle to that shown in Figures 3 and 4, associated ones of the first and second outlets 36, 38a, 38b are inclined relative to one another, so that emerging fuel sprays from the outlets 36, 38a, 38b merge within the combustion chamber to form a combined spray as if they had emerged from a single outlet. In this modification, references to an outlet being in 'a vertical plane' should be taken to be a reference to the vertical plane of the inlet end of the outlet.

[0047] In another modification, only the second outlets 38a, 38b of a localised group are inclined relative to one another so that the emergent sprays from this group only merge to form a combined fuel spray within the combustion chamber.

[0048] Figures 5 and 6 show a further alternative embodiment of the invention in which similar parts to those shown in Figures 1 to 4 have been identified with like reference numerals. In this embodiment, the second outlets 38a, 38b of each of the localised groups are offset from the associated one of the first outlets 36 in both horizontal and vertical planes. The outlets 36, 38a, 38b therefore adopt a staggered-like configuration. The first and second outlets 36, 38a, 38b are aligned substantially in parallel (as in Figure 1) so that the fuel sprays from

each are substantially parallel as they emerge into the combustion chamber. As described previously, the outlets 36, 38a, 38b of each of the first and second sets are of the same size, and hence each provides the same cross sectional flow area to fuel.

[0049] The embodiment of Figures 5 and 6 provides a particular advantage in that there is a maximum separation between the second outlets 38a, 38b formed in the part of the nozzle body 12 defining the sac volume 32. As the wall section separating the outlets 38a, 38b of the second set is maximised, stresses in the nozzle body 12 are minimised. This also allows additional outlets to be provided in each localised group without compromising stresses in the nozzle body 12. Flow efficiency may also be improved, as any one of the second outlets 38a, 38b has an increased (maximised) fuel volume from which fuel is drawn for injection when the inner valve needle 22 is lifted away from its seating 40.

[0050] In an alternative version of the nozzle to that shown in Figures 5 and 6, associated ones of the first and second outlets 36, 38a, 38b are inclined relative to one another, so that emerging fuel sprays from the outlets 36, 38a, 38b merge within the combustion chamber to form a combined spray as if they had emerged from a single outlet. In this modification, reference to an outlet being in 'a vertical plane' should be taken to be a reference to the vertical plane of the inlet end of the outlet, as the remainder of the length of the outlet may be out of plane to ensure fuel sprays are combined.

[0051] In another modification, only the second outlets 38a, 38b of a localised group are inclined relative to one another so that the emergent sprays from this group only merge to form a combined spray.

[0052] Figures 7 and 8 show another embodiment of the invention which provides for a further increased injection rate in circumstances in which both the inner and outer valve needles 22, 16 are lifted away from their respective seatings 40, 34. In this embodiment, each of the localised groups 38 of second outlets includes three outlets 38a, 38b, 38c. A first one of the second outlets 38c of each group is aligned in the same vertical plane as the associated one of the first outlets 36 (i.e. outlets are aligned in a 'first vertical plane'). Second and third ones of the outlets 38a, 38b of each group are aligned in a vertical plane offset from the first vertical plane, with one of the second and third outlets 38a being located in a vertical plane to one side of the first vertical plane and the other of the second and third outlets 38b being located in a vertical plane to the other side of the first vertical plane. Again, each outlet 38a, 38b, 38c of the second set 38 has a size which is the same as that of each outlet 36 of the first set, thus allowing the same machining tool to be used to form all outlets of the nozzle 10. The outlets 36, 38a, 38b, 38c of the first and second sets are aligned in parallel with one another so that emerging fuel sprays follow substantially parallel flow paths as they emerge into the combustion chamber.

[0053] In an alternative version of the nozzle to that

shown in Figures 7 and 8, associated ones of the first and second outlets 36, 38a, 38b, 38c may be inclined relative to one another, so that emerging fuel sprays from the outlets 36, 38a, 38b, 38c merge within the combustion chamber to form a combined spray as if they had emerged from a single outlet. In this modification, reference to an outlet being in 'a vertical plane' should be taken to be a reference to the vertical plane of the inlet end of the outlet.

[0054] In another modification, only the second outlets 38a, 38b, 38c of a localised group 38 are inclined relative to one another so that the emergent sprays from this group only merge to form a combined spray.

[0055] Figures 9 and 10 show a further alternative embodiment in which each localised group of second outlets includes two pairs of second outlets, 38a, 38b and 38c, 38d. The outlets 38a-38d of any one group are spaced in close proximity with one another. The embodiment of Figures 9 and 10 is a variation of the embodiment in Figures 5 and 6, in which the second outlets of each localised group 38 are arranged in a staggered-like formation so as to maximise the wall separation between them. In other words, a first, "upper" pair of outlets 38a, 38b in each group is arranged so that each outlet 38a, 38b thereof lies in a different vertical and horizontal plane compared to that of the associated first outlet 36. Each outlet 38a, 38b of the upper pair also lies in a different vertical and horizontal plane compared to those of the outlets 38c, 38d of a second, "lower" pair of outlets of the same group 38. The embodiment of Figures 9 and 10 provides for a further increased flow rate during injection when both the inner and outer valve needles 22, 16 are spaced from their respective seatings due to their being four flow outlets in each group.

[0056] In an alternative version of the nozzle to that shown in Figures 9 and 10, associated ones of the first and second outlets 36, 38a-38d may be inclined relative to one another, so that emerging fuel sprays combine within the combustion chamber to form a combined spray as if they had emerged from a single outlet. In this modification, reference to an outlet being in 'a vertical plane' should be taken to be a reference to the vertical plane of the inlet end of the outlet.

[0057] In another modification, only the second outlets 38a-38d of a localised group are inclined relative to one another so that the emergent sprays from this group 38 only merge to form a combined spray.

[0058] All of the aforementioned embodiments provide the advantage that the same machining tool can be used to form both the first 36 and second outlets 38, thus ensuring each provides closely matched flow characteristics. In addition, each outlet is likely to respond to further processing stages, such as abrasive honing for rounding of the outlets at their inlet ends, in a similar manner. As flow balance between the outlets of the first set and those of the second set is likely to be consistent, advantages are also achieved during subsequent nozzle processing and measuring stages of manufacture. This would not

be the case were the second set of outlets formed with an increased size to provide an increased flow area required for higher injection rates.

[0059] It will be appreciated that the embodiments described are given by way of example only, and that other embodiments which retain the aforementioned advantages are also envisaged. For example, each localised group 38 of the second outlets may include a greater number of outlets than those shown in Figures 1 to 10. The sets of outlets 36, 38 need not include seven separately spaced outlets/outlet groups, but may provide a greater or lesser number of outlets/outlet groups.

[0060] In a further alternative embodiment, the number of outlets of the first set need not be equal to the number of groups of outlets of the second set. It is also envisaged that the outlets of the first set may be bunched in localised groups also.

[0061] In the previous discussion, it has been assumed that the outer valve needle is caused to lift to initially to allow a relatively low fuel flow rate into the engine, and that the inner valve needle is caused to lift when the outer valve needle has moved beyond a certain threshold amount to allow a higher rate of fuel flow to the engine. The invention is equally applicable, however, to an injection nozzle in which the inner valve needle is caused to move first to give a relatively low fuel flow, followed by opening of the outer valve needle to provide a higher fuel flow rate.

Claims

1. An injection nozzle (10) for use in a fuel injector for an internal combustion engine having a combustion chamber, the injection nozzle (10) comprising:

a first needle (16) which is engageable with a first valve needle seating (34) to control fuel delivery through one or more first outlets (36) provided in a nozzle body (12), wherein the or each first outlet (36) defines a first cross sectional flow area for fuel, and

a second valve needle (22) which is engageable with a second valve needle seating (40) to control fuel delivery through a plurality of second outlets (38) provided in the nozzle body (10), the second valve needle (22) being coaxial with the first valve needle (16),

wherein the plurality of second outlets are arranged in one or more localised groups (38) of second outlets, with each of the second outlets (38) having a cross sectional flow area substantially equal to the first cross sectional flow area.

2. The injection nozzle as claimed in claim 1, wherein the first valve needle is an outer valve needle (16), the inner valve needle (22) being received at least

partially within the outer valve needle (16).

3. The injection nozzle as claimed in claim 1 or claim 2, comprising a plurality of localised groups (38) of second outlets and a plurality of first outlets (36), each of the groups (38) of second outlets being associated with a respective one of the first outlets (36). 5
4. The injection nozzle as claimed in claim 3, wherein each of the first outlets (36) lies in a first vertical plane and the associated localised group (38) includes a pair of second outlets (38a, 38b), wherein the second outlets of the localised group (38) lie in the first vertical plane (X-X). 10
5. The injection nozzle as claimed in claim 3, wherein each of the first outlets (36) lies in a first vertical plane (X-X) and wherein the associated group (38) of second outlets includes a pair of second outlets (38a, 38b; 38a-38c; 38a-38d), wherein the second outlets of the pair lie in a vertical plane offset from the first vertical plane. 15
6. The injection nozzle as claimed in claim 5, wherein one of the second outlets (38a) of the pair lies in a vertical plane offset on one side of the first vertical plane (X-X) of the associated first outlet (36) and the other of the second outlets (38b) of the pair lies in a vertical plane offset on the other side of the first vertical plane (X-X) of the associated first outlet (36). 20
7. The injection nozzle as claimed in claim 6, wherein each of the second outlets (38a, 38b) of the pair lies in a different horizontal plane to the other second outlet of the pair. 25
8. The injection nozzle as claimed in claim 6, wherein the localised group (38) includes a further second outlet (38c) arranged to lie in the first vertical plane (X-X). 30
9. The injection nozzle as claimed in claim 8, wherein the second outlets (38a, 38b) of the pair are arranged in a horizontal plane offset from a horizontal plane of the further second outlet (38c). 35
10. The injection nozzle as claimed in claim 7, wherein the or each of the localised groups (38) further comprises at least one additional pair of second outlets (38c, 38d), and wherein all of the second outlets (38a-38d) of a localised group (38) lie in different horizontal planes and in different vertical planes. 40
11. The injection nozzle as claimed in any one of claims 1 to 10, wherein the first outlet (36) and the associated localised group (38) of second outlets (38a, 38b; 38a-38c; 38a-38d) are oriented to provide a combined fuel spray within the combustion chamber as 45

a result of merging fuel sprays from the first and second outlets.

12. The injection nozzle as claimed in any one of claims 1 to 10, wherein the first outlet (36) and the associated localised group (38) of second outlets (38a, 38b; 38a-38c; 38a-38d) are aligned within the nozzle body so as to provide substantially parallel aligned fuel sprays which emerge into the combustion chamber. 50
13. The injection nozzle as claimed in any one of claims 1 to 12, wherein the first valve needle (16) is co-operable with the second valve needle (22) so that the second valve needle (22) is caused to move away from the second valve needle seating (40) in circumstances in which the first valve needle (16) moves away from the first valve seating (34) beyond a threshold amount, and wherein the first valve needle (16) is actuatable so as to move alone when moved through an amount less than the threshold amount. 55
14. The injection nozzle as claimed in any one of claims 1 to 12, wherein the first valve needle (16) is co-operable with the second valve needle (22) so that the first valve needle (16) is caused to move away from the first valve needle seating (34) in circumstances in which the second valve needle (22) moves away from the second valve seating (40) beyond a threshold amount, and wherein the second valve needle (22) is actuatable so as to move alone when moved through an amount less than the threshold amount.
15. A fuel injector for use in an internal combustion engine, the fuel injector including an injection nozzle (10) as claimed in any one of claims 1 to 14, wherein at least one of the first or second valve needles (16, 22) is movable by means of an actuator.
16. The fuel injector as claimed in claim 15, wherein the actuator is one of a piezoelectric actuator or an electromagnetic actuator.
17. A machining method for producing an injection nozzle (10) having a first valve needle (16) and a second valve needle (22), the method comprising:
 - providing a nozzle body (12),
 - providing a machining tool having a machining tool size,
 - using the machining tool to form one or more first outlets (36) through the nozzle body (10) such that the or each of the first outlets (36) provides a first cross sectional area for fuel flow which is determined by the machining tool size, and
 - using the same machining tool to form a localised group (38) of a plurality of second outlets (38a, 38b; 38a-38c; 38a-38d) through the nozzle

body (10), wherein each of the second outlets provides a cross sectional flow area for fuel that is substantially equal to the first cross sectional flow area.

18. The method as claimed in claim 17, wherein the machining tool for forming the one or more first outlets and the plurality of second outlets is an electric discharge machining tool.

19. The method as claimed in claim 17, wherein the machining tool for forming the one or more first outlets and the plurality of second outlets is a laser machining tool.

Amended claims in accordance with Rule 86(2) EPC.

1. An injection nozzle (10) for use in a fuel injector for an internal combustion engine having a combustion chamber, the injection nozzle (10) comprising:

a first needle (16) which is engageable with a first valve needle seating (34) to control fuel delivery through one or more first outlets (36) provided in a nozzle body (12), wherein the or each first outlet (36) defines a first cross sectional flow area for fuel, and

a second valve needle (22) which is engageable with a second valve needle seating (40) to control fuel delivery through a plurality of second outlets (38) provided in the nozzle body (10), the second valve needle (22) being coaxial with the first valve needle (16),

wherein the plurality of second outlets are arranged in one or more localised groups (38) of second outlets, with each of the second outlets (38) having a cross sectional flow area substantially equal to the first cross sectional flow area.

2. The injection nozzle as claimed in claim 1, wherein the first valve needle is an outer valve needle (16), the inner valve needle (22) being received at least partially within the outer valve needle (16).

3. An injection nozzle as claimed in claim 1 or claim 2, wherein each localised group of second outlets is associated with a first outlet or group of first outlets.

4. The injection nozzle as claimed in any of claims 1 to 3, comprising a plurality of localised groups (38) of second outlets and a plurality of first outlets (36), each of the groups (38) of second outlets being associated with a respective one of the first outlets (36).

5. The injection nozzle as claimed in claim 4, wherein each of the first outlets (36) lies in a first vertical plane and the associated localised group (38) includes a

pair of second outlets (38a, 38b), wherein the second outlets of the localised group (38) lie in the first vertical plane (X-X).

6. The injection nozzle as claimed in claim 4, wherein each of the first outlets (36) lies in a first vertical plane (X-X) and wherein the associated group (38) of second outlets includes a pair of second outlets (38a, 38b; 38a-38c; 38a-38d), wherein the second outlets of the pair lie in a vertical plane offset from the first vertical plane.

7. The injection nozzle as claimed in claim 6, wherein one of the second outlets (38a) of the pair lies in a vertical plane offset on one side of the first vertical plane (X-X) of the associated first outlet (36) and the other of the second outlets (38b) of the pair lies in a vertical plane offset on the other side of the first vertical plane (X-X) of the associated first outlet (36).

8. The injection nozzle as claimed in claim 7, wherein each of the second outlets (38a, 38b) of the pair lies in a different horizontal plane to the other second outlet of the pair.

9. The injection nozzle as claimed in claim 7, wherein the localised group (38) includes a further second outlet (38c) arranged to lie in the first vertical plane (X-X).

10. The injection nozzle as claimed in claim 9, wherein the second outlets (38a, 38b) of the pair are arranged in a horizontal plane offset from a horizontal plane of the further second outlet (38c).

11. The injection nozzle as claimed in claim 8, wherein the or each of the localised groups (38) further comprises at least one additional pair of second outlets (38c, 38d), and wherein all of the second outlets (38a-38d) of a localised group (38) lie in different horizontal planes and in different vertical planes.

12. The injection nozzle as claimed in any one of claims 1 to 11, wherein the first outlet (36) and the associated localised group (38) of second outlets (38a, 38b; 38a-38c; 38a-38d) are oriented to provide a combined fuel spray within the combustion chamber as a result of merging fuel sprays from the first and second outlets.

13. The injection nozzle as claimed in any one of claims 1 to 11, wherein the first outlet (36) and the associated localised group (38) of second outlets (38a, 38b; 38a-38c; 38a-38d) are aligned within the nozzle body so as to provide substantially parallel aligned fuel sprays which emerge into the combustion chamber.

14. The injection nozzle as claimed in any one of claims 1 to 13, wherein the first valve needle (16) is co-operable with the second valve needle (22) so that the second valve needle (22) is caused to move away from the second valve needle seating (40) in circumstances in which the first valve needle (16) moves away from the first valve seating (34) beyond a threshold amount, and wherein the first valve needle (16) is actuable so as to move alone when moved through an amount less than the threshold amount.

15. The injection nozzle as claimed in any one of claims 1 to 13, wherein the first valve needle (16) is co-operable with the second valve needle (22) so that the first valve needle (16) is caused to move away from the first valve needle seating (34) in circumstances in which the second valve needle (22) moves away from the second valve seating (40) beyond a threshold amount, and wherein the second valve needle (22) is actuable so as to move alone when moved through an amount less than the threshold amount.

16. A fuel injector for use in an internal combustion engine, the fuel injector including an injection nozzle (10) as claimed in any one of claims 1 to 15, wherein at least one of the first or second valve needles (16, 22) is movable by means of an actuator.

17. The fuel injector as claimed in claim 16, wherein the actuator is one of a piezoelectric actuator or an electromagnetic actuator.

18. A machining method for producing an injection nozzle (10) having a first valve needle (16) and a second valve needle (22), the method comprising:

providing a nozzle body (12),
 providing a machining tool having a machining tool size,
 using the machining tool to form one or more first outlets (36) through the nozzle body (10) such that the or each of the first outlets (36) provides a first cross sectional area for fuel flow which is determined by the machining tool size,
 and
 using the same machining tool to form a localised group (38) of a plurality of second outlets (38a, 38b; 38a-38c; 38a-38d) through the nozzle body (10),

wherein each of the second outlets provides a cross sectional flow area for fuel that is substantially equal to the first cross sectional flow area.

19. The method as claimed in claim 18, wherein the machining tool for forming the one or more first outlets and the plurality of second outlets is an electric

discharge machining tool.

20. The method as claimed in claim 18, wherein the machining tool for forming the one or more first outlets and the plurality of second outlets is a laser machining tool.

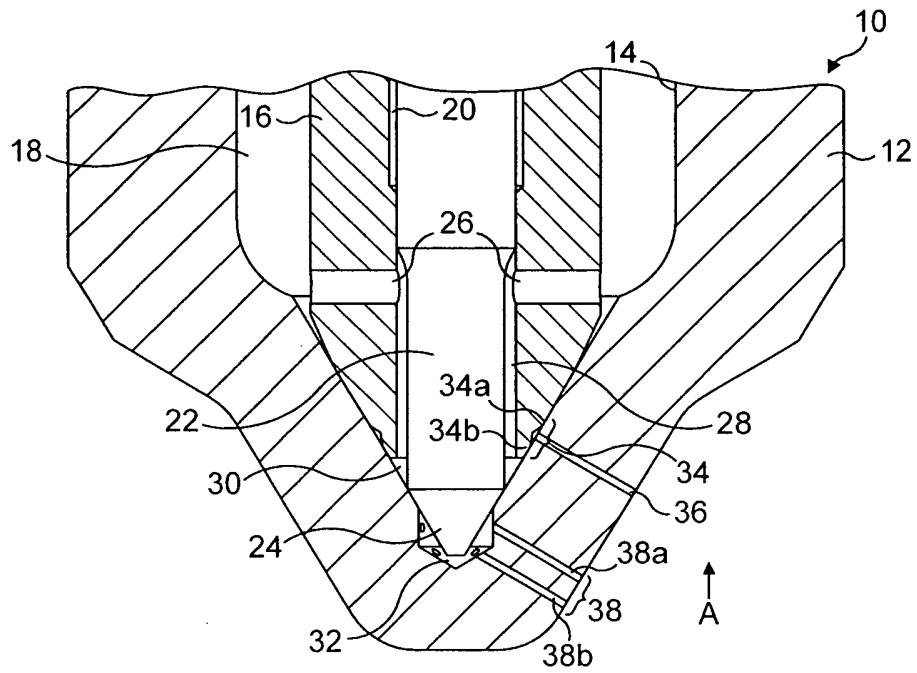


FIG. 1

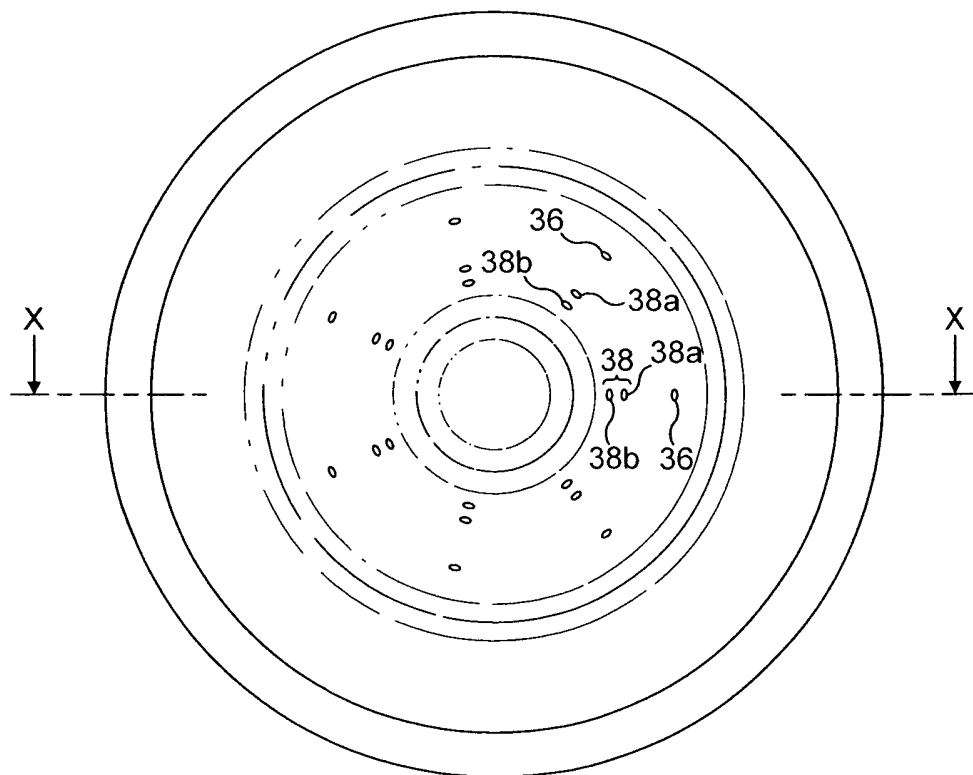


FIG. 2

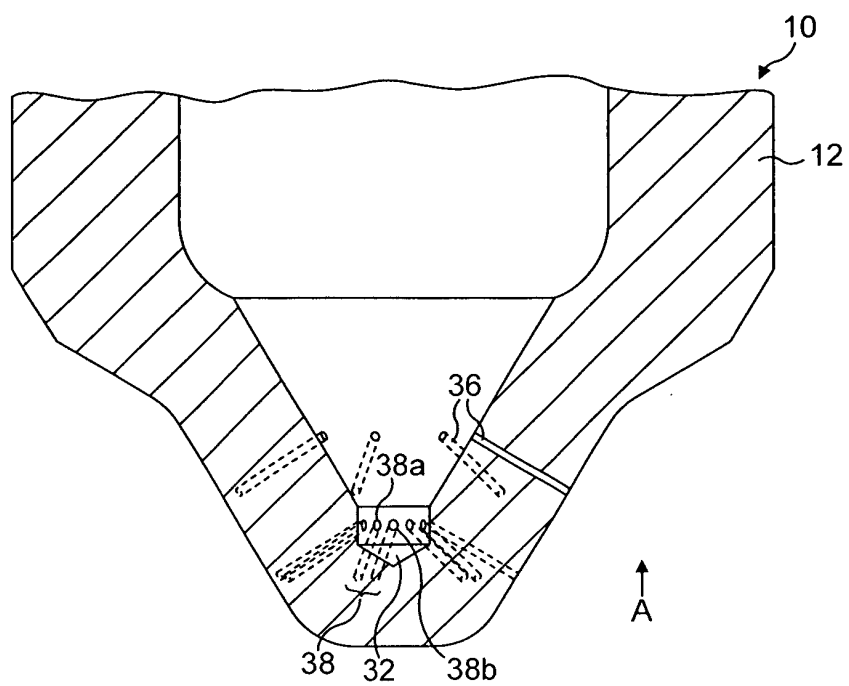


FIG. 3

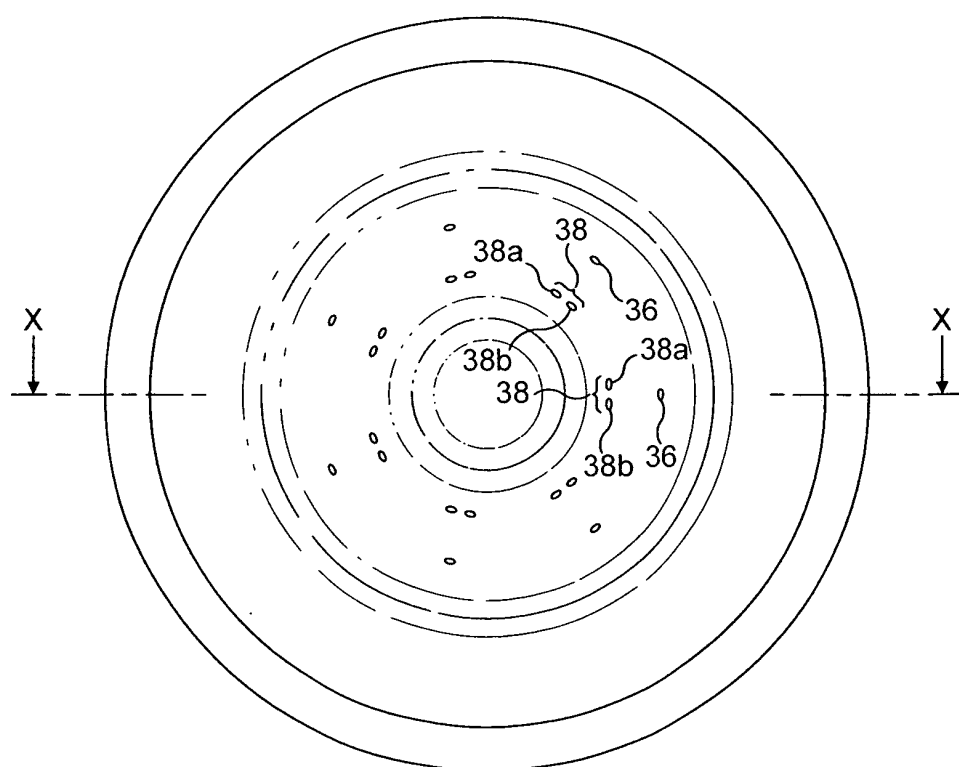


FIG. 4

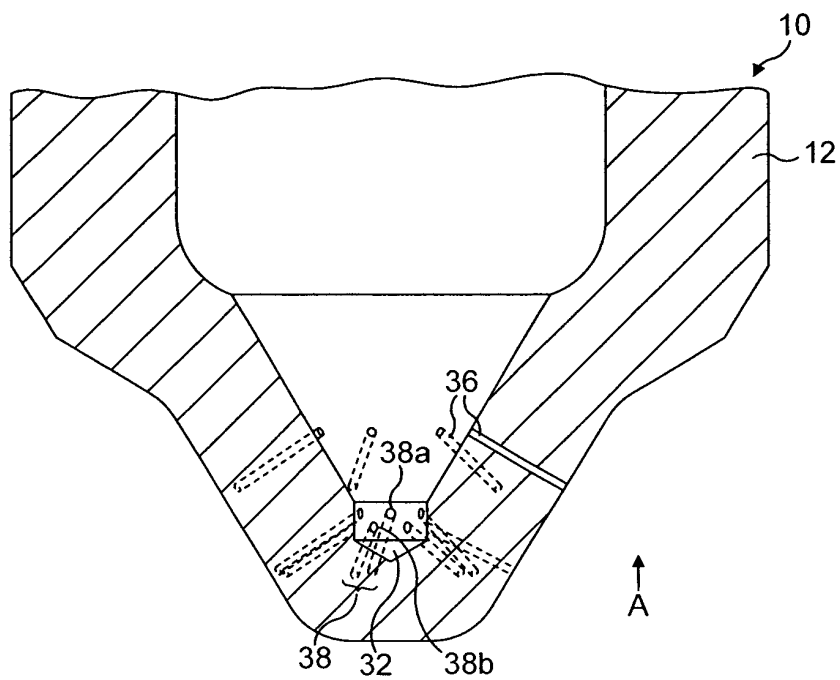


FIG. 5

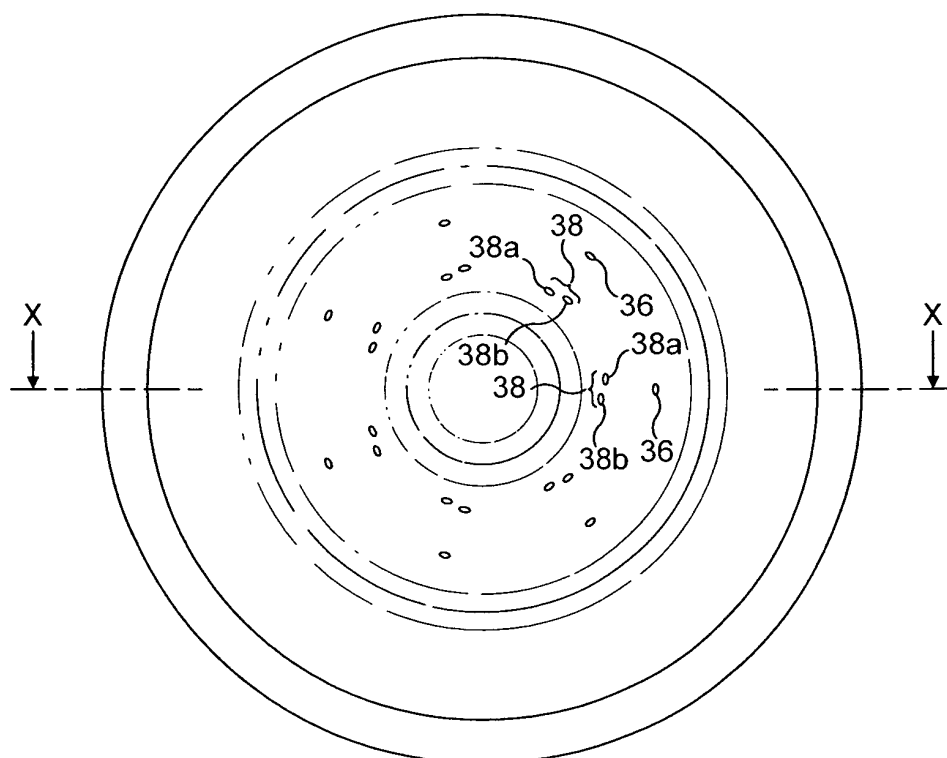


FIG. 6

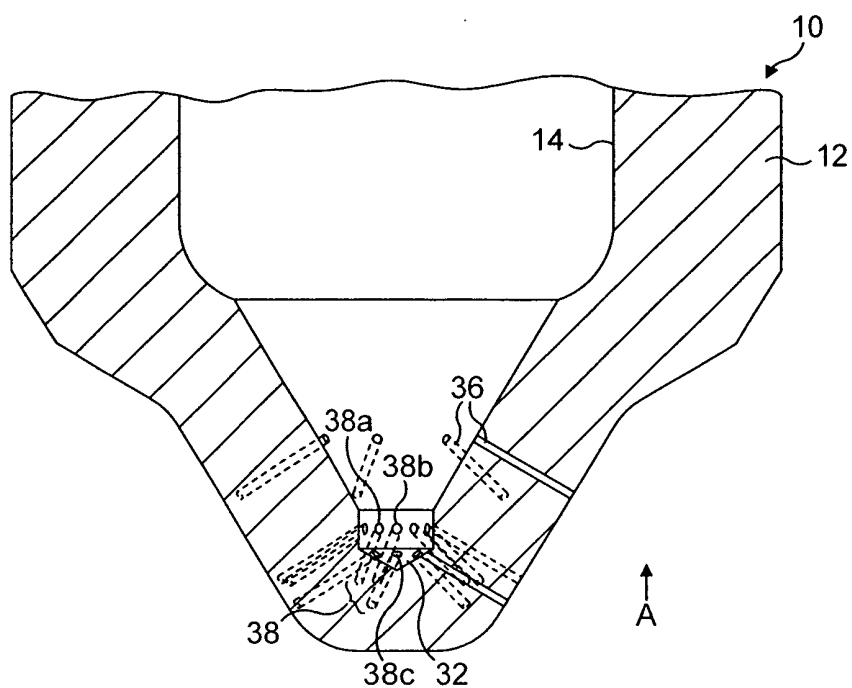


FIG. 7

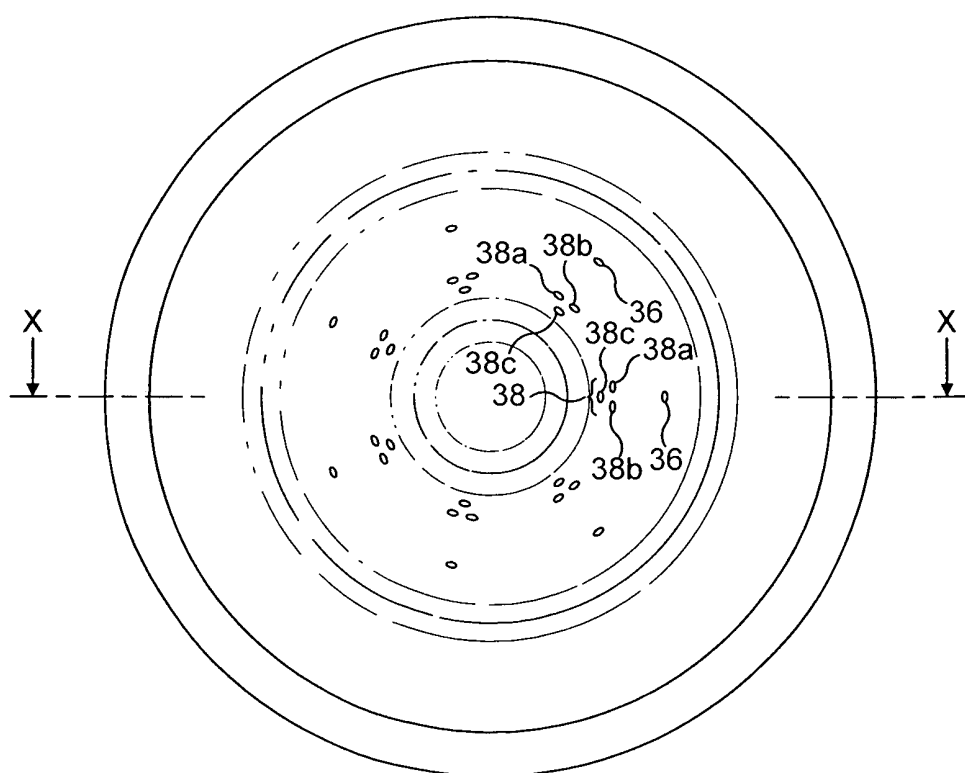


FIG. 8

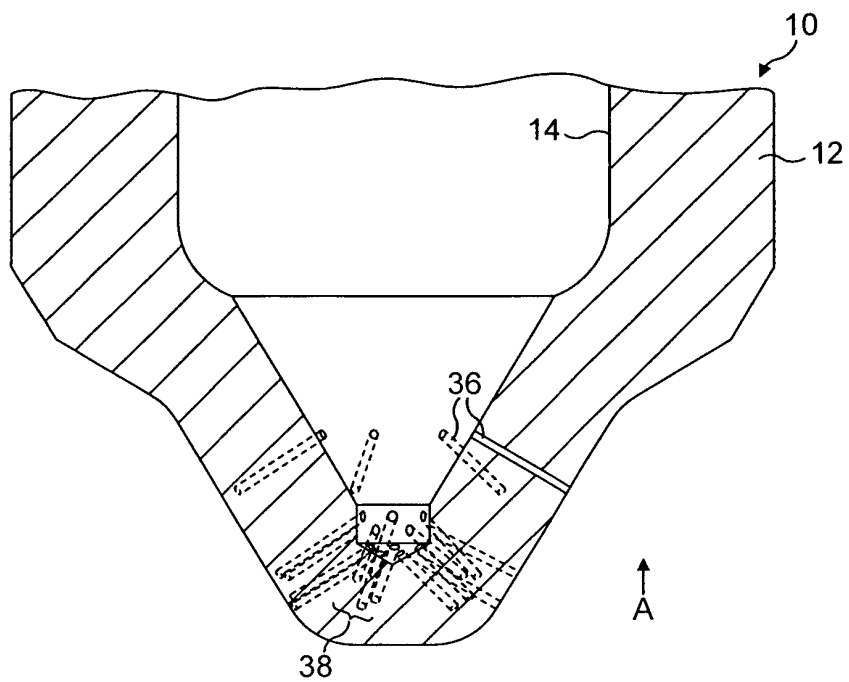


FIG. 9

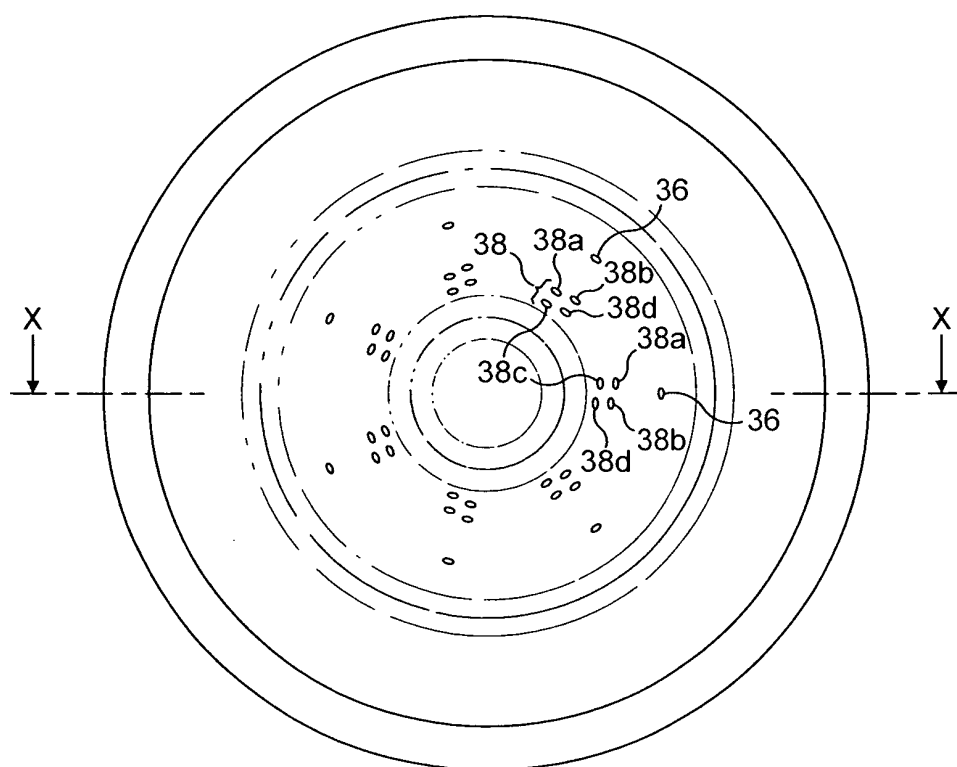


FIG. 10



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 25 5676

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 2004/055562 A1 (STEWART CHRIS ET AL) 25 March 2004 (2004-03-25)	1-6,8, 11-16	F02M45/08 F02M61/16
Y	* paragraph [0038]; figures 2-8 *	17-19	
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 25 February 2005	Examiner Morales, M
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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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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25-02-2005

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