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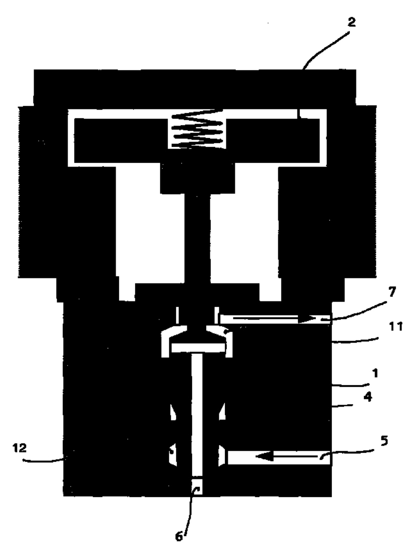
(54) **Improved injection device in diesel engines of the common-rail type**

(57) Fuel injector for an internal combustion engine, comprising a valve body provided with an inner housing, a therein sliding plunger, in which there are arranged at least a first and a second chamber, three distinct conduits adapted to convey a flow of fuel from a high-pressure source to one of said chambers and a flow of fuel from one of said chambers to the needle valve, in which the outer walls of the plunger are slidably adhering to inner walls of said housing so as to prevent fuel from anyhow leaking or seeping between said two chambers through passages between the plunger and said walls.

The outflow section connecting said first conduit with said third conduit within the second chamber is of the same order of magnitude as the outflow section of said needle valve and is further significantly smaller than the outflow section connecting said second conduit within the first chamber.

FIG. 2



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Description

[0001] The present invention refers to a fuel injection device adapted to inject precise amounts of highly pressurized fuel into the cylinder of a two-stroke or four-stoke diesel engine.

[0002] Conventional injection systems make use of a plunger pump to pressurize the fuel circuit and inject the same fuel at a sufficiently high pressure in the cylinder of the engine. In the most common one of these systems, the pump, which is operated by a cam driven by the same engine, pressurizes the injection circuit up to such an extent as to cause the spring-loaded needle of the nozzle to open, thereby starting the phase in which fuel is injected in the combustion chamber. Relieving the pressure onto the pump causes the circuit to decompress and this in turn causes the needle to close and the injection phase to terminate.

[0003] Various systems are used to control the beginning and the end of the pumping action. In the most commonly used types of pumps, it is the pump plunger itself that controls these phases by stopping and clearing, during its stroke, corresponding ports provided in the pumping element guide; in other systems, such an action can be performed by mechanically or electronically controlled valves. In this latter case, through an appropriate action of the control organs of the valves it is possible for both the starting instant of the pumping action with respect to the engine cycle and the duration of the injection, and therefore the amount of fuel injected, to be modified. Owing to the pumping element being operated by a cam, the closing phase of the valve(s), ie. the beginning of the pumping action, will take place at different speeds of the pumping element and will therefore affect the characteristics of the injection cycle.

[0004] In all of the above described systems, the injection (phase and duration) control action is performed by the pump which must be appropriately synchronized with the engine. The injector itself has on the contrary a passive role from a control point of view and, through the motion of the needle of the nozzle brought about by the pressure waves generated by the pump, ensures that the injection starts and ends at well-defined pressure levels.

[0005] In another type of operation, a mechanically actuated and mechanically or electronically controlled pump pressurizes a manifold system, or common rail, with an action that is totally independent of the actual injection action which is on the contrary controlled by preferably electronically controlled injectors. No correlation exists in this case between the timing of the pump and the timing of the engine, while the pump itself can be operated in an asynchronous manner independently of the engine. The injection control action, both in terms of timing thereof and duration or injected amount, is entirely performed by the injectors through the action of suitable electronically controlled valves that are an integral part of the injectors themselves.

[0006] The usual injection systems have an injection pressure that follows an almost triangular law versus time. The initial and, above all, the final phase of the injection take therefore place at relatively low pressures and this causes the fuel to be atomized in a certainly not optimum manner in view of both the efficiency of the engine and the formation of polluting compounds. The injection pump which, as already stated, is the actual regulation organ of these apparatuses, is driven by the engine and, therefore, its performance is strongly affected by the operating conditions, in particular the running speed thereof. The performance that can actually be obtained from the injection apparatus will therefore be strongly influenced by the rotating speed and the power output of the engine.

[0007] A one of the targets which engineers concerned with the development of injection systems are constantly aiming at is the possibility for the whole amount of fuel to be injected under optimum atomization conditions by implementing and performing injection cycles that are characterized by rapid pressure rises and falls in the initial and terminal parts of the cycle. On the other hand, excessive values of these parameters tend to bring about negative effects, so that the need arises for the injection law that is actually capable of favouring the best possible combustion, in terms of both engine efficiency and formation of polluting compounds, to be found out for each engine and operating condition thereof.

[0008] The fuel injection systems for diesel engine of the so-called common-rail type are constituted by a pressure accumulator or manifold, which is kept at a constant pressure by means of a pump, and one or more injectors connected thereto through proper tubings. A properly controlled organ, which may be constituted by a valve or the same needle of the nozzle according to the various cases, regulates the fuel flow from said manifold to the nozzle and, therefore, the combustion chamber.

[0009] Accordingly, the operating principle of these injection apparatuses is very simple if compared with most currently used apparatuses. However, it is just this seeming simplicity where most of the practical implementation difficulties lie which have precluded any concrete development thereof until most recently. In fact, the amount of fuel that is injected in each cycle depends exclusively on the response times of the control organs of the outflow coefficients of the flow governing organs (ie. valve, needle, nozzle), further to the rail pressure. There is no self-adjusting capability as in traditional apparatuses relying on a control on the pump so that the dosing function of the same pump tends to "dampen" the dispersion introduced by the other organs of the apparatus.

[0010] The operating time and the hydraulic characteristics of the control organ determine both the phase, or timing, and the amount of fuel injected. The characteristic parameters of the injection, therefore, are not determined by the pump, as this on the contrary occurs in traditional apparatuses, but solely by the motion of the flow control organ. This of course makes injection fully independent of the manner in which the engine operates, owing to the regulation parameters being fully disengaged from both the rotation speed and the load of the engine.

[0011] The inherent flexibility of the system in terms of injection pressure, timing and shape of the injection law, can only be used to any actual advantage if use is made of an electronic control of the control organ: as a matter of fact, the development of this type of apparatuses has been tightly tied to, ie. strongly affected by the availability of electronically controlled actuators featuring suitable characteristics.

[0012] There are two basic categories of apparatuses that achieve such a principle. The first one uses, as a control organ, the same needle of the nozzle and, therefore, fuel under pressure is constantly available upstream of the nozzle itself. In this case, the needle is constantly unbalanced as far as hydraulic forces are concerned, so that remarkable forces are required in view of obtaining the desired response times. The needle is therefore always operated by means of a system of pilot valves which are in turn actuated by an electric actuator.

[0013] The second category, which the device being described here actually belongs to, makes use of a valve arranged between the rail and the nozzle, which is therefore only subject to the injection pressure during the active injection period, similarly to what actually occurs in traditional apparatuses with pump-connected control. The motion of the needle of the nozzle is controlled by the course of the injection pressure in the same manner as it occurs in traditional apparatuses.

[0014] In this second case it is possible for valves to be provided which are balanced with respect to the injection pressure and can be controlled directly by the electric actuator. Those skilled in the art are generally well aware of the fact that the used of balanced valves offers considerable advantages not only from an operating point of view, but also in terms of performance, reliability and wide choice of valve types to ideally comply with any definite application requirements.

[0015] The valves themselves can be either of the two-way or the three-way type. In the first case the valve is constituted by a simple shutter, or plunger, which is adapted to shut and to open the passage from the rail to the nozzle; in the second case, which the present invention refers to, there is also a third port connecting the nozzle to a discharge circuit when the plunger is not activated. The two-way plunger solution has a major drawback in that it brings about the pressure drop on the nozzle at the end of the injection solely by means of the flow on the same nozzle. The terminal phase of the injection turns therefore out to be inherently less rapid and stable with respect to the case in which the decompression of the volume between valve and nozzle occurs through the action of the plunger itself.

[0016] Three-way valves must have following characteristics:

- high response speed,
- high repeatability and constancy in the long run, even in the presence of weardown and settling-down or adjustment occurrences of the component parts thereof,
- tight sealing capability when in closed state.
- reduced actuation forces so as to be able to be directly connected to electric actuators,
- fuel passage cross-sections that are in good proportion with the outflow sections of the nozzle.

[0017] There are various possible solutions in this connection, some of which have already been proposed and experimented. These can essentially be brought down to the schematics appearing in Figure 1, in which the balancing effect is obtained through a symmetrical construction of the inlet and discharge seats. If implemented in an appropriate manner, such a geometry is capable of meeting all of the afore mentioned requirements, except for the last one since, owing to construction-related reasons, it is not possible for the diameters of the seats to be reduced arbitrarily. This is the reason why the outflow section of the valve turns in all cases out to be considerably larger than the section existing in correspondence of the needle and the nozzle.

[0018] Owing to the symmetry of the outflow sections of the seats, the pressure wave that causes the needle of the nozzle to open is generated by the motion of the valve much in advance of the moment in which the discharge port is fully closed. This contributes to the control of the injection being made precarious, in particular in the presence of short injection durations, ie. in the order of the response times of the actuator.

[0019] The disproportion between the outflow section of the valve and the one of the nozzle causes a considerable amount of fuel to be lost by leaking through the discharge seat during the motion of the valve, thereby lowering the overall efficiency of the injection apparatus owing to a non-negligible proportion of the pump flow rate being so discharged during these phases.

[0020] Furthermore, the drawbacks of a non-optimum combustion in terms of polluting effect by the exhaust fumes are well-known

[0021] Such a solution, although effective, widely proven and based on readily available techniques free of any particular risks from a technical point of view, has therefore a drawback that is increasingly objected as the search is intensified for increasingly efficient and "clean" injection and combustion technologies.

[0022] The above discussions and issues are generally well-known to those skilled in the art and have only been set forth here to favour a better understanding of the scope of the present invention.

[0023] It therefore is a purpose of the present invention to provide an injection device for diesel engines of the common-rail type that is capable of doing way with the above mentioned drawbacks in terms of both fuel usage and polluting effects, and is further capable of being manufactured in a low-cost, reliable manner through the use of readily available techniques and materials.

[0024] The features and advantages of the invention will anyway be more readily understood from the description which is given below by way of non-limiting example with reference to the accompanying drawing, in which:

- Figure 1 is a simplified schematical view of a valve for an injection device adapted for use in connection with the common-rail technology, according to the prior art;

- Figure 2 is a simplified schematical view of a valve for an injection device adapted for use in connection with the common-rail technology, according to the present invention;

- Figure 3 is a schematical view of the most significant component parts and assemblies of an injector according to the present invention, as correctly assembled together in their normal operation state;

- Figure 4 is a schematical view of the valve body of the valve shown in Figure 2, in the closed state thereof;

- Figure 5 is a schematacal view of the valve body of the valve shown in Figure 2, in the open state thereof;

- Figure 6 is a magnified view of a critical detail of Figure 5;

- Figures 7, 8 and 9 are respective views of three distinct variants in the embodiment of the valve according to the present invention;

- Figure 10 is a simplified schematical view of a longitudinal median section of a valve for an injection device adapted for use in connection with the common-rail technology, in the closed state thereof according to an embodiment of the present invention;

- Figure 11 is a schematical view of the same item illustrated in Figure 10, however with the valve in its open state;

- Figure 11A is a view of a variant of the valve illustrated in Figure 11;

- Figure 12 is a simplified schematical view of a longitudinal median section of a valve for an injection device adapted for use in connection with the common-rail technology, in the closed state thereof, according to a second embodiment of the present invention;

- Figure 13 is a schematical view of the same item illustrated in Figure 12, however with the valve in its open state;

- Figure 14 is a view of a variant of a valve according to the present invention.

[0025] The term "fuel' will be used without distinction throughout the following description to mean each and any of the various liquid fuels suitable for the diesel cycle. Such a simplification will however by no means affect the clearness of what is being set forth therein, owing to the context in which such a term is used, as anyone skilled in the art is capable of readily understanding.

[0026] Referring to Figure 2, which illustrates a preferred embodiment, a solution according to the present invention is described below, along with the related operating principle.

[0027] In particular, the valve body 1 can be noticed to be provided with an inner housing in which there are arranged;

- some conduits communicating with the outside,
- further cavities or seats and
- a plunger 4,
  all these above cited elements being described in greater detail further on.

[0028] Further illustrated in such a Figure is the actuator 2 that is adapted to actuate, in generally known manners, said plunger 4 so as to vary the position thereof within said valve body 1.

[0029] The upper portion of said inner housing is occupied by a typically annular chamber 11, while the central portion is occupied by said plunger 4. The lower portion of said inner housing is in turn occupied by a chamber 12, which is also typically annular.

[0030] The outer walls of said plunger are closely adhering, albeit slidably, to the corresponding portion of the inner walls of said housing, so that no fuel is practically allowed to seep between said two chambers 11 and 12 through passageways or gaps that may be present between said plunger and the inner walls of said housing.

[0031] A discharge conduit 7 enters said chamber 11, while the injection conduit 6 leading to the needle valve or nozzle 51 is arranged to enter said chamber 12 along with the feeding conduit 5 from the high-pressure fuel source.

[0032] For construction-related reasons, said injection

6 may be extended through the use of an extension conduit 61 before it reaches the nozzle 51.

[0033] As at can be more clearly noticed in Figures 4 and 5, the plunger 4 is adapted to move into two extreme positions; in the first one of these positions, ie. the resting one illustrated in Figure 4, the plunger is lowered and in such a position it is adapted to close the passage between the conduit 5 and the conduit 6, while the passage that is also known under the denomination of discharge valve, and whose section is generally indicated at A in the Figure, is open between said chamber 11 and a wall thereof that constitutes the seat 3, which will be defined further on as the seat 3 of the discharge valve, onto which the upper portion of the plunger comes to lie, thereby closing also the passage from the chamber 11 to the discharge conduit 7.

[0034] In this condition, there is no passage or injection of fuel towards the conduit 6.

[0035] In the opposite situation, ie. the one illustrated in Figure 5, the plunger is actuated upwards and this causes a passage, generally indicated at B in the Figure, to be opened between the conduit 5 and the conduit 6, while the above mentioned passage A is at the same time closed.

[0036] In this condition, the same injection pressure prevailing in the common rail, and passing through said open passage B, comes to prevail in the conduit 6.

[0037] Since the generally acknowledged drawback lies in the wide difference existing between the minimum fuel outflow sections at the outlet of the nozzle 51 and the minimum outflow sections of both the fuel feeding conduit 5 and the discharge conduit 7, the devised solution is essentially based on a reduction of such a difference between said minimum sections. In particular, the outflow section B of the injection conduit 6 can be made as small as considered appropriate, albeit within determined construction-related limits, and be situated in front of a conduit 10 of equivalent diameter provided inside said plunger.

[0038] Such a conduit 10 extends along a good portion of the body of said plunger to resurface therefrom into the chamber 11 comprised between said plunger and said seat 3 of the discharge valve.

[0039] In an advantageous manner, the outflow port 5a between the conduit 5 and said chamber 12 and the inflow port 6a of the conduit 6 are arranged as close as possible to each other so that the two conduits are capable of being completely connected to each other even with a minimum stroke of the plunger. This reduces the connection times and the separation time of these conduits with respect to each other.

[0040] Such a circumstance, along with the fact that the inner conduit 10 can be provided with a large discharge section A, enables a pressure drop to be brought about very swiftly in the conduit 10 and, therefore, the therewith connected conduit 6.

[0041] The minimum outflow sections at the inlet passage B and discharge passage A are determined by the inside diameters of the respective seats (D0 for the inlet seat, D2 for the discharge seat), the angle of the respective sealing cones, and the maximum lift of the plunger, which is obviously the same for both seats.

[0042] The condition of a balanced hydraulic load on said plunger requires on the contrary that the upward thrust surface be equal to the downward thrust surface. This is obtained by making the outside sealing diameter of the inlet seat D1 equal to the inside diameter of the discharge seat D2 and selecting the diameter D3 of the plunger in correspondence of the discharge seat in such a manner that the surface area of the circular crown comprised between D3 and D2 is equal to the surface area of the circle having the diameter D1. The balance condition is therefore independent of the control diameter of the outflow section of the inlet seat D0, which can therefore be selected solely on the basis of fluid-dynamic considerations. The possibility for the sealing angles of the two seats to be so differentiated offers the additional possibility for the respective outflow sections thereof to be made different.

[0043] The operating principle is as follows:

[0044] When the plunger is in its resting position, the feeding conduit 5 is kept closed by the action of the contrasting spring or similar action of the actuator. In such a position, the nozzle is communicating with the discharge through the discharge port or passage A that is open, so that only the pressure of the discarge conduit 7 acts on the nozzle.

[0045] When the actuator is energized, it causes the plunger to move upwards, thereby opening the inlet port B and closing the discharge port A. When the plunger eventually reaches its end-of-stroke point, which is represented by the contact being established by the same plunger with the seat of the discharge port, the nozzle is fully connected with the feeding conduit, whereas the discharge conduit is fully closed. The pressure rise that in this way is brought about upstream of the needle of the nozzle causes the latter to open, in a much similar manner in which this occurs in conventional injection devices.

[0046] When the actuator is then de-energized, the plunger, under the closing force generated by either the return spring or the actuator itself, moves back into its resting position, thereby opening the discharge port and closing the inlet one. Such an opening of the discharge port brings about an abrupt pressure fall on the nozzle which in turn causes the needle to immediately close owing to the action of the return spring thereof, thereby reaching the aim of the present invention.

[0047] While fully preserving a perfect balance of the hydraulic forces, as this is absolutely necessary in view of enabling a direct control by an electric actuator, the invention is based on the marked dissymetry of the outflow sections of the two discharge and inlet ports A and B.

[0048] Referring again to Figures 4 and 5, it can be noticed that the outline inside the box 20 represents the development of the frustum of cone relating to the outflow section A and, in particular, the area of said section corresponds to the hatched zone; similarly, the drawing or outline inside the box 21 in Figure 5 represents the development of the frustum of cone relating to the outflow section of the inlet port B, while the area of such a section corresponds even in this case to the hatched zone.

[0049] From a comparison of said two hatched zones with each other, the difference clearly emerges which exists between said outflow zones as far as the area thereof is concerned.

[0050] The connection of the two ports with each other can be brought about either inside the valve, as this is schematically illustrated in Figure 2, or along the plunger body. The choice between such two solutions will be dictated only by the size of the plunger rod and the passage sections.

[0051] The main advantages deriving from this solution are:

- the outflow section of the inlet port B is not conditioned by the construction-related need for the two seats to be coupled to each other symmetrically, so that it can be selected to be as small as appropriate or convenient on the basis of the sole injection control requirements; this also contributes to an increased efficiency of the system by reducing the flow discharged during the displacement of the plunger;

- the section of the discharge port is sensibly larger than the one of the inlet port. The beginning and the end of the injection are therefore controlled to a much greater extent by the closure of the discharge port than by the opening of the inlet port. This makes it possible for very short injections to be obtained even without the use of or having to rely upon very fast actuators; furthermore, the plunger is able to carry out its complete stroke even in the case of very short injection durations, thereby definitely increasing the repeatability of the process.

[0052] The valve body 1 of the discharge valve is floating with respect to the carrying structure of the valve and is kept on its guide by the plunger. This considerably facilitates the construction of the plunger-to-valve body 1 coupling and the seal of the discharge seat.

[0053] Given the minimum tolerances required, it turns out to be particularly advantageous if it is the plunger that positions the valve body 1 and not the other way round. This in fact makes it possible for a consistent, very accurate machining operation to be carried out between saiod plunger and valve body, regardless of the machining precision of the valve body around there.

[0054] The invention allows for a number of constructional variants, which are symbolically represented in Figures 8 and 9 and do not actually need much explanation, since they are fully within the capability of understanding of those skilled in the art.

[0055] Figure 7 illustrates the technical solution that appears also in the preceding Figures, whereas Figure 8 emphasizes how the connection between the conduit 6 and the chamber 11 can be carried out outside the plunger, namely through an appropriate fixed conduit 21A contained in the valve body 1. Figure 9 on the contrary illustrates a further variant, in which the conduit 10 splits out, inside the plunger 4, into two symmetrical offshoots 10a and 10b that reach the chamber 11.

[0056] To the mere purpose of better introducing the improvements illustrated further on in this description, mention is made here of the fact that three-way valves must have following characteristics:

- high response speed,
- high repeatability and constancy in the long run, even in the presence of weardown and settling-down or adjustment occurrences of the component parts thereof,
- tight sealing capability when in closed state.
- reduced actuation forces so as to be able to be directly connected to electric actuators,
- fuel passage cross-sections that are in good proportion with the outflow sections of the nozzle.

[0057] In the course of functional tests carried out on a number of samples of injectors having the characteristics according to the above description, it has however been found that some residual problems tend to anyway come afloat in connection with the closure of the conduit and the balancing of the plunger, so as to partly limit the above cited characteristics.

[0058] One of the so identified problems depends on the fact that the closure of the fist chamner 11 is obtained through an intermittent circular contact brought about by the contact between two surfaces that are frusto-conical both of them; it has been experimented, and it is on the other hand easily understandable, that such a type of contact is rather uncertain and scarcely controllable, since the slightest deviation in the geometry of the parts involved tends to cause the sealing, ie. shutting elements to become uncoupled and, as a result, the sealing effect itself to become less effective.

[0059] A further drawback, which again depends on the type of coupling between frusto-conical surfaces, is ascribable to the weardown effect that takes place between the frusto-conical surface of the plunger 4 and the circular edge which, generally indicated at D2 in the Figure, delimitates the passage of the fuel from the chamber 11 to the discharge conduit 7.

[0060] Owing to the operation of the injector, the weardown of the circular edge D2 tends to cause the contact and, therefore, sealing surface to be shifted outwards. This again tends to modify the thrust surface onto which the injection pressure comes to act when the valve is fully open and, as a result, to change the valve balancing conditions.

[0061] A further drawback tends to occur under following condition: when the outflow section B is closed, the pressure at the inlet of the discharge conduit 7 tends to increase very swiftly, thereby bringing about, on the walls 20 of the plunger in Figure 5, a corresponding pressure increase that tends to throw out of balance the pressures that act on the same plunger altogether. In particular, such an increase in the pressure on said walls 20 acts in the sense that it decreases the pressure with which the plunger closes onto the outflow section B and, as a result, it favours the occurrence of circumstances that may allow or cause the plunger to be raised, thereby opening said outflow section B.

[0062] Such a condition, however, has the effect of making the operation of the whole injector more critical, since it is required, for safety reasons in the case of a malfunctioning, that the plunger be capable of automatically moving into the position in which it closes said outflow section B. The potential riskiness of such a solution comes therefore fully to light if only, for some reason whatsoever, an uncontrollable unbalance condition occurs in the pressures in the various conduits and chambers of the injectors.

[0063] Referring now to Figures 10 et seq., which illustrate some improvements of the invention, said first chamber 11, in view of bestowing greater clearness to the description, is subdivided into two different contiguous and alternately connecting chambers, ie.:

- a compensating chamber 11A, witch is formed by the portion of said housing that is defined as the separate hollow portion permanently communicating with the conduit 7 when said plunger is in its closing position, and

- the actual first chamber 11 comprised in the hollow portion of said housing surrounding said plunger and delimited, towards said discharge conduit 7, by said plunger closing against the corresponding portion of said valve body 1.

[0064] Mention is made here of the fact that, in the prior art, the outflow section B connecting, inside said second chamber 12, said first conduit 5 to said third conduit 6 is generally in the same order of magnitude as the outflow section of said final injection members, as well as markedly smaller than the outflow section A connecting said discharge conduit 7 to said compensating chamber 11A.

[0065] According to the related descriptions, said first chamber is provided with a portion 20 adapted to engage the upper portion 21 of said plunger in order to close said discharge conduit 7. As shown in Figures 10 and 11, said portion 20 has a frusto-conical contour against witch said upper portion 21 of the plunger is able to abut.

[0066] According to an improvement of the present invention, also the upper portion 21 of said plunger has a frusto-conical contour that is coaxial with said frusto-conical portion 20 of said first chamber.

[0067] In view of eliminating the first above cited drawback, the angle X at the base of said frusto-conical portion 21 of said plunger is suitably smaller than the angle Y at the base of the frusto-conical contour of said portion 20 of said first chamber.

[0068] Such a geometry causes the contact between the two surfaces to take place along the outside diameter of the cylindrical body of the plunger. The angle X might also be nil, as shown in Figure 11A, and in this case also the angle Y would be brought down to zero (zero divergence on a plane seal).

[0069] Going back to the general case in which the angles X and Y are not nil, the line of abutment between the plunger and said first chamber becomes a circumference, of which the two intersecting points 45 and 46 with the section plane are indicated, and which is situated along the upper edge of the cylindrical body of the plunger.

[0070] A further advantage of the cone-cylinder type of seal lies in the fact that the seal diameter is not altered in the case of weardown effects. To state it more precisely, in the case of weardown or settling-down effects it is the contact between the two portions extending inwards that is modified within the chamber 11A, ie. where the pressure is the discharge one and not the injection one, so that the resulting effect on the overall balance condition is much lower. Furthermore, the closure of the passage towards said discharge conduit causes the flow of fuel through said conduit 10, which may or may not extend through the body of the plunger, to be interrupted.

[0071] In an advantageous manner, when said plunger terminates its upward stroke to abut against said first chamber, said outflow section B opens, thereby allowing said first conduit 5 to directly communicate with said third conduit 6.

[0072] Such a situation is favoured by the fact that, when the injector is open, a connection is established, through said conduit 10, between the first chamber 11 and said first conduit 5, so that said first chamber is pressurized and such a pressure, owing to its acting transitorily also on the surface of said frusto-conical portion 21 of said plunger 4, tends to push the latter downwards and, therefore, to close it, in contrast with the desired opening condition

[0073] Conditions may however arise so that the pressure in the chambers 11 and 11A is excessive and, therefore, the resulting force acting on said frusto-conical portion is such as to hinder the plunger from duly opening under the corresponding action of the opening members.

[0074] In order to do away with this problem, a type of valve as illustrated in Figures 12 and 13 is therefore provided, in which the upper portion 47 of the plunger is provided, on the side thereof facing said compensating chamber 11A, with two enlarging shoulders 48; furthermore said upper portion 47 is required to have a larger section than strictly necessary, as this clearly emerges from a comparison between the corresponding Figures 11 and 13. In this manner, in fact, the pressure in the compensating chamber 11A acts also on said shoulders 48 of the upper portion 47 of the plunger.

[0075] It can therefore be readily appreciated that the presence of the above mentioned shoulders is instrumental in generating an upward thrust, and therefore contrasting the above cited thrust that tends to balance the plunger.

[0076] The advantage as compared to the initial solution derives from the fact that the thrusts, or pushing effects, are due to the discharge pressure, and not the injection one, said two pressure being in a ratio of approx. two orders of magnitude.

[0077] By appropriately modifying the diameter of the portion 47 of the plunger it is possible for said thrust or pushing effect to be regulated so as to obtain the desired closing force for the particular operating condition.

[0078] Those skilled in the art are generally well aware of the fact that a very important factor as far as the safety and stability of the injector are concerned is connected to the plunger tending to spontaneously move into its lowered, ie. closing position if conditions prevail in which plunger position control is not fully assured. An injector must therefore be so designed and constructed as to ensure such balance conditions as to make it possible for the valve, when it is fully open, to be effectively and readily closed without any difficulty.

[0079] However, owing to the uncertainties on the actual section of the terminal portion 21 of the plunger when the valve is fully open, mainly due to the wear-down of the seats involved, it has been observed that, in this situation, the valve shows a certain resistance to its being closed. This resistance is due to the pressure of the fuel coming from the injection conduit 5, which presses against the entire area of the lower section of the plunger, said section being symbolically indicated at D1 in Figure 13.

[0080] To do away with such a drawback, the present invention teaches to make said plunger so that it actually comprises two coaxial cylindrical bodies 50, 51 firmly joined with each other, of which the first body 50 comprises the afore cited and illustrated frusto-conical portion 21 adapted to move into abutment against an outer wall of said first chamber, while the second body 51 has a diameter that is larger than the diameter of said first body, and is arranged in a position below said first body facing said second chamber 12.

[0081] Both said bodies and the housing are so sized and shaped as to enable said bodies to freely slide within said housing and, as far as said second body 51 is concerned, without any gap or side clearance.

[0082] According to the present invention, the transition portion from said first body to said second body is formed by an annular step-like configuration 60 that may have any inclination whatsoever, ie. with an angle that may be situated anywhere between the theoretical extreme values from 0° to 180° with respect to the axis of the plunger, but preferably an inclination of 90°, consistently with the existing geometrical constraints.

[0083] Furthermore, said conduit 10 connects the side of said plunger which is in communication with said injection conduit 6, with the interior of said first chamber beyond said transition portion, as this is clearly illustrated in the Figure. In practice, this is instrumental in enabling a pressure to act on said annular step-like configuration that tends to cause said plunger to lower and, therefore, to move into closing, wherein such a condition is still a preferred one in the case that the position of the plunger cannot be perfectly and effectively controlled with usual means.

[0084] It clearly appears that, for the fuel pressure induced in said first chamber 11 to be able to exert such an overall pressure on the plunger as to impress on it a force that tends to move it into its closing position, or at least favour its moving into such a position, while overcoming any other hydraulic pressure of the fuel tending to keep it in its opening position, the area of said annular step-like configuration, on a plane that is orthogonal to the moving direction of the plunger, must be sized appropriately and, therefore, also the mutual dimensions of said two bodies of the plunger are thereby determined. The applicable sizing criteria are well within the ability of all those skilled in the art, so that they shall not be dealt with here.

[0085] Similarly to the example that has been described above with reference to Figure 8, a variant is further possible in which the conduit 10 can be provided outside the plunger, through an appropriate fixed conduit contained in said valve body 1 as shown in Figure 14.

Claims

1. Injector, preferably of the electromagnetic type, adapted to supply fuel to an internal-combustion engine, in particular a Diesel engine, comprising:

   - an upper portion provided with an actuator (2) adapted to be selectively energized and de-energized,
   - a valve body (1) provided with an inner housing,
   - a plunger (4) operated by said actuator and mounted slidably within said housing in which there are provided, in the space that is not occupied by said plunger, at least a first chamber (11) and a second chamber (12),
   - a needle valve (51) adapted to control the flow of fuel under pressure and capable of moving towards an opened position to enable the fuel

under pressure to pass therethrough when said alternating plunger, operated by said actuator, is in the position defined by said actuator being energized, and a closed position to interrupt the flow of the fuel under pressure when said plunger moves into the position defined by the actuator being de-energized,

- a first conduit (5) adapted to transfer an intermittent flow of fuel from a high-pressure fuel source to one of said chambers,
- a second conduit (7), which is also defined as discharge conduit, adapted to transfer an intermittent flow of fuel from one of said chambers to fuel discharge means,
- a third conduit (6) adapted to transfer an intermittent flow of fuel from one of said chambers to said needle valve, even via appropriate conduits (61) arranged between said one chamber and said needle valve,
- said first, second and third conduits (5, 7, 6) being capable of being selectively and alternately connected and/or closed in accordance with the position taken by said plunger (4), which is adapted to be operated into selectively taking a first position corresponding to the related actuator being de-energized, so that said first conduit (5) is closed, and a second position corresponding to the related actuator being energized, so that said second conduit (6) is opened,

characterized in that:

- the outer walls of said plunger (4) are fully adhering, although slidably, against part of the inner walls of said housing, so as to prevent any fuel from seeping or flowing between said two chambers (11, 12) through passages or gaps provided between said plunger and the inner walls of said housing,
- said discharge conduit (7) flows into said first chamber (11),
- said first conduit (5) and said third conduit (6) flow into said second chamber (12),
- the outflow section (B) that connects, inside said second chamber (12), said first conduit (5) with said third conduit (6) is of the same order of magnitude as the outflow section of said needle valve, and significantly smaller than the outflow section (A) that connects, inside said first chamber (11), said second or discharge conduit (7).

2. Injector according to claim 1, **characterized in that**:

   - in the full-open position of said plunger, said third conduit (6) is set in connection with said first conduit (5), while said second conduit (7) is fully closed:
   - in the opposite extreme position of said plunger, said third conduit (6) is separated from said first conduit (5) and set in connection with said second or discharge conduit (7).

3. Injector according to claim 2, **characterized in that**:

   - the outflow port (5a) of said first conduit (5) into said second chamber (12) is substantially adjacent to the outflow port (6a) of said third conduit;
   - the final portion of said second chamber (12) is in the shape of a frustum of cone and the corresponding final portion of said plunger has, in correspondence of the outflow section of said first conduit (5), a frusto-conical shape adapted to fittingly join with said final portion of said second chamber (12) and close said outflow section (B);
   - the outflow port (5a) of said first conduit is arranged on a wall of the final frusto-conical portion of said second chamber (12);
   - the inlet port (6a) of said third conduit is arranged on the bottom of said second chamber (12).

4. Injector according to claim 3, **characterized in that**:

   - the minimum outflow sections in said inlet passage (B) and discharge passage (A) are determined by the inside diameters of the respective seats (D0, D2), the angle of the respective sealing cones, and the maximum lift of the plunger;
   - the outside sealing diameter of the inlet seat (D1) is made equal to the inside diameter of the discharge seat (D2);
   - the outside diameter (D3) of the plunger in correspondence of the discharge seat is sized so that the surface of the circular crown comprised between said inside diameter (D2) of the discharge seat and said outside diameter (D3) of the plunger is equal to the surface of the circle of said outside sealing diameter (D1) of the inlet seat.

5. Injector according to claim 4, **characterized in that** said plunger is provided with at least a longitudinal inner channel (10), and that an aperture (10c) of said longitudinal channel is situated in front of said inlet port (6a) of said third conduit (6).

6. Injector according to claim 5, **characterized in that** said inner channel (10) flows, with its upper section, into said first chamber (11).

7. Injector according to claim 6, **characterized in that** between the upper portion of said inner channel (10) and said first chamber (11) there is arranged a further conduit (31) that has two distinct outlets into said first chamber.

8. Injector according to claim 7, **characterized in that** said distinct outlets are opposite with respect to each other.

9. Injector according to claim 4, **characterized in that** a conduit (21A) connecting said third conduit (6) to said first chamber (11) is arranged in said valve body (1).

10. Injector according to claim 4, **characterized in that** between the upper portion of said inner channel (10) and said first chamber (11) there are arranged two distinct conduits (10a, 10b).

11. Injector according to any of the preceding claims, in which said first chamber (11) is subdivided into two different contiguous and alternately connected chambers, of which a chamber (11A), which is also called the compensating chamber, is formed by the portion of said housing that is defined as the separate hollow portion permanently communicating with the discharge conduit (7) when said plunger is in its closing position, the actual first chamber (11) being delimited, towards said discharge conduit (7), by said plunger closing against the corresponding portion of said valve body (1), **characterized in that**:

- said actual first chamber (11) is provided with a wall adapted to engage a corresponding portion of said plunger to close said second or discharge conduit (7), said wall having a frusto-conical contour with a specified angle (X) at the base that delimits the stroke of said plunger;
- said corresponding portion of said plunger has a frusto-conical contour, with a specified angle (Y) at the respective base, coaxially to said frusto-conical contour of said portion of said first chamber (11), in which said angle at the base of said portion of said first chamber is greater than the angle at the base of said frusto-conical portion of said corresponding portion of said plunger.

12. Injector according to claim 11, **characterized in that**:

- in the full-open position of said plunger, said third conduit (6) is set in connection with said first conduit (5) while said second conduit (7) is fully closed;
- said first chamber (11) is closed with respect to said second conduit (7) by the cylindrical base (45, 46) of said portion of said plunger abutting against said frusto-conical contour of said portion (20) of said first chamber;
- in the opposite extreme position of said plunger, said third conduit (6) is separated from said first conduit (5) and set in connection with said second or discharge conduit (7).

13. Injector according to claim 11 or 12, **characterized in that** said plunger (4) is provided with an upper portion (47) that, on the side thereof facing said compensating chamber (11A), has at least an enlargement shoulder (48) adapted to intercept the pressure of said first chamber so as to exert a force on said plunger that acts in the opening direction thereof

14. Injector according to the preamble of claim 1, **characterized in that**:

- said plunger (4) is provided with two cylindrical and coaxial bodies (50, 51), of which the first body (50) comprises a cylindrical portion and a frusto-conical portion (21) adapted to move into abutting against an outer wall of said first chamber (11);
- the second body (51) has a diameter that is larger than the diameter of said first body (50),
- said body being freely slidable within said housing, without any gap or side clearance:
- the transition portion between said first body and said second body is in the form of an annular step-like configuration (60):
- said annular step-like configuration has an inclination that may be situated anywhere between the theoretical extreme values from 0° to 180°, but preferably an inclination of 90°, with respect to the axis of the plunger:
- said conduit (10) connects the lower end portion of said plunger, which communicates with said injection conduit (6), with the interior of said first chamber (11), which is delimited on a side by said annular step-like configuration.

15. Injector according to claim 14, **characterized in that** the area of said annular step-like configuration (60), on the plane that is orthogonal to the moving direction of the plunger, is sized so that the pressure induced by the fuel on said annular step-like configuration is capable of exerting a pressure on said plunger that, when the latter is in its open position, is such as to impart to the same plunger a force that tends to move it into its closing position by overcoming any other hydraulic pressure of the fuel that tends to keep it in its open position.

FIG. 1

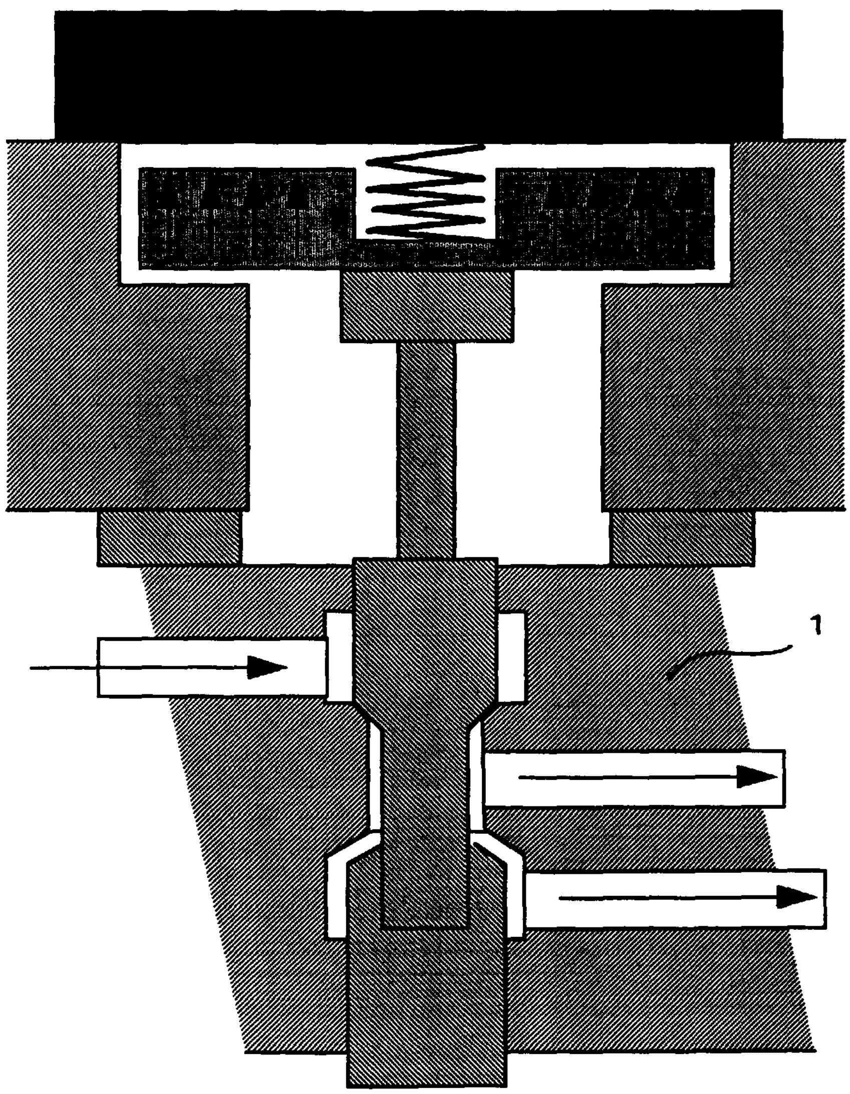
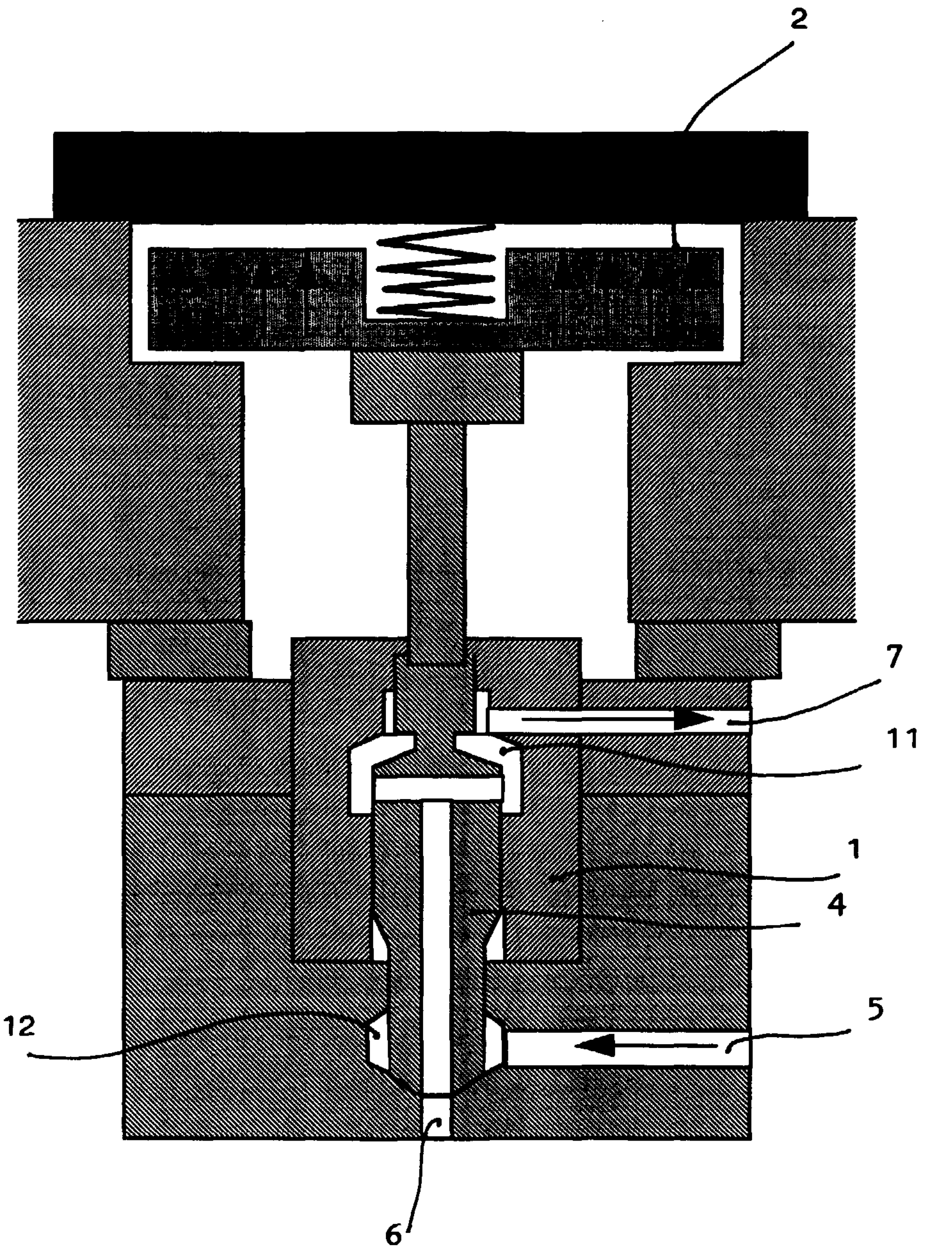


FIG. 2



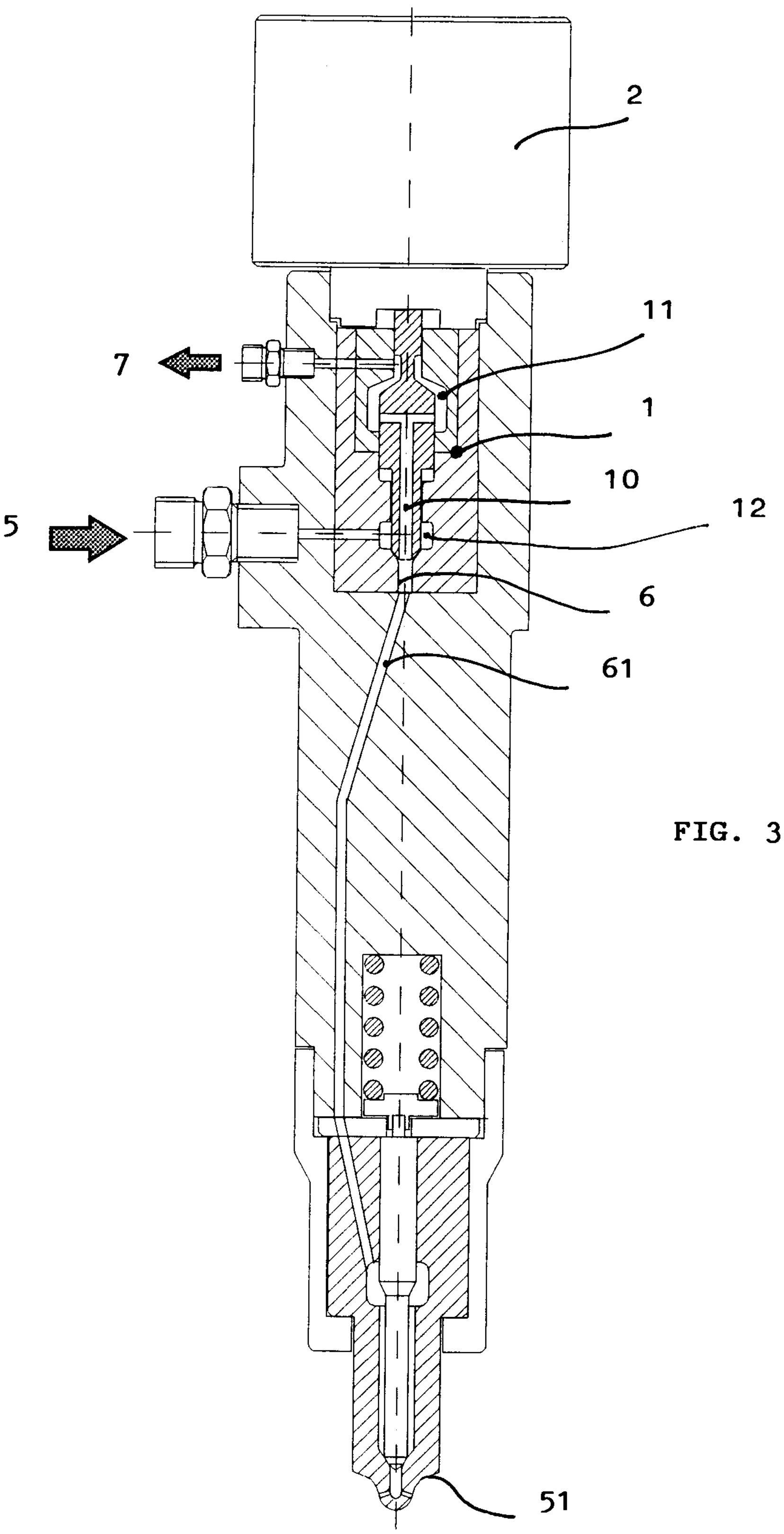


FIG. 3

FIG.4

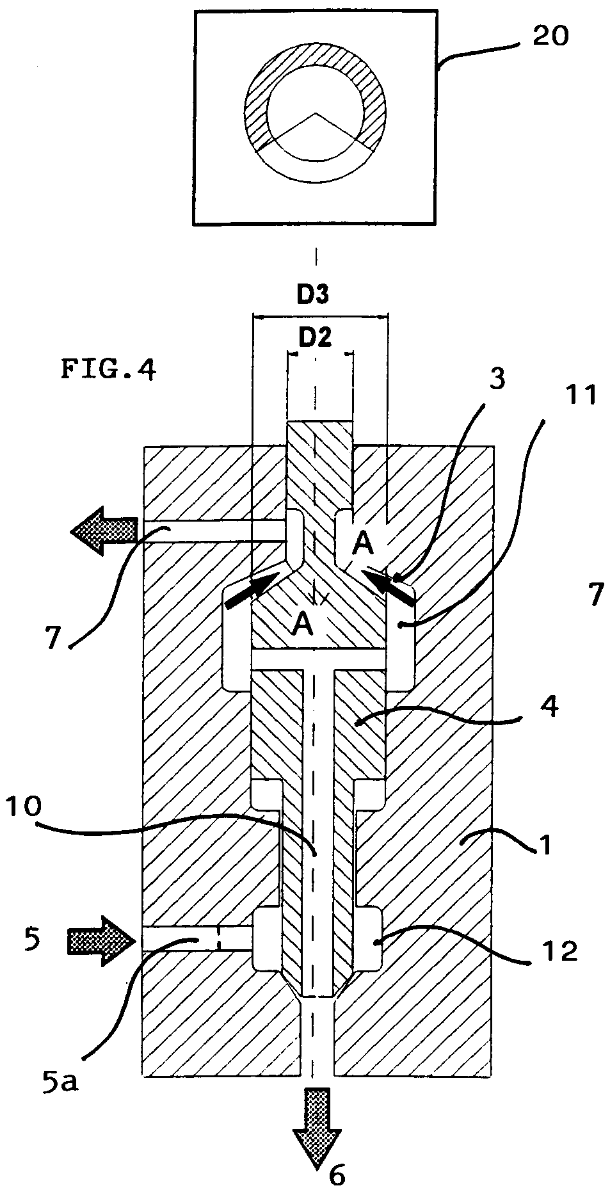
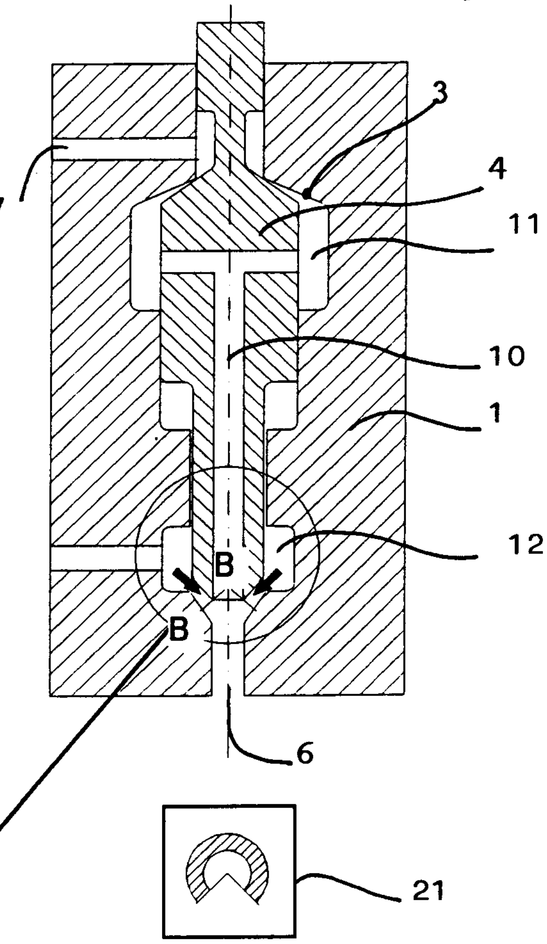


FIG. 5



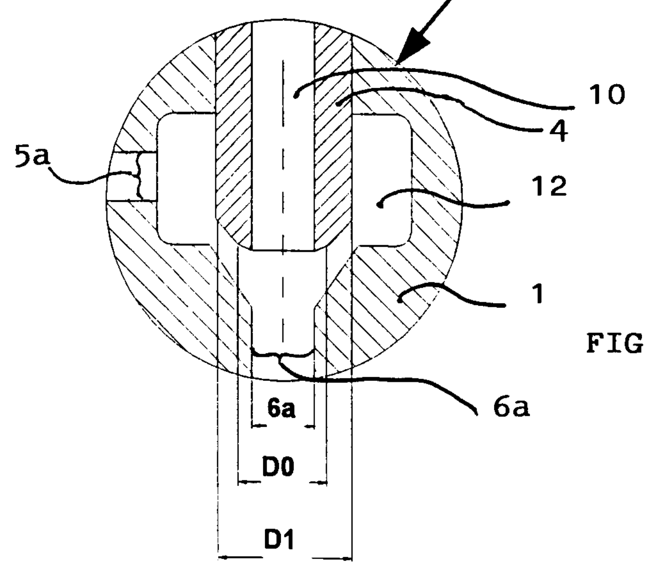


FIG. 6

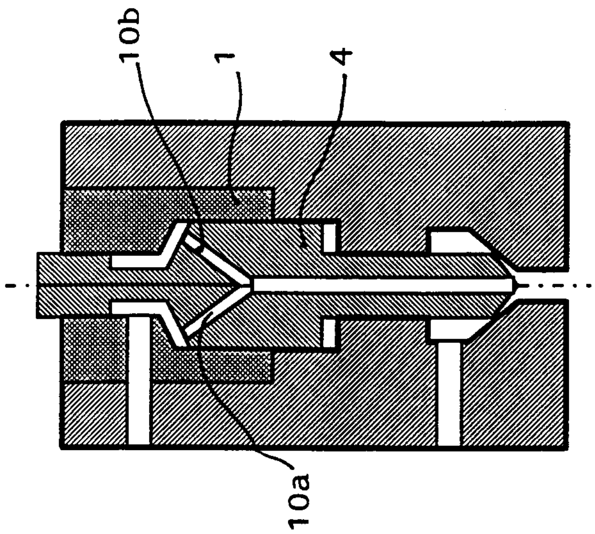


FIG. 9

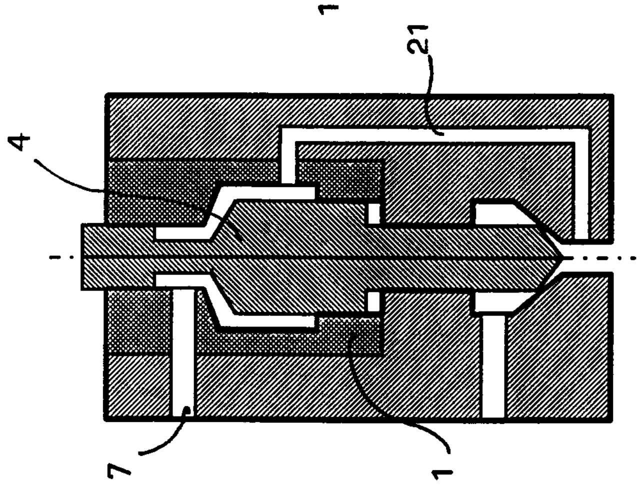


FIG. 8

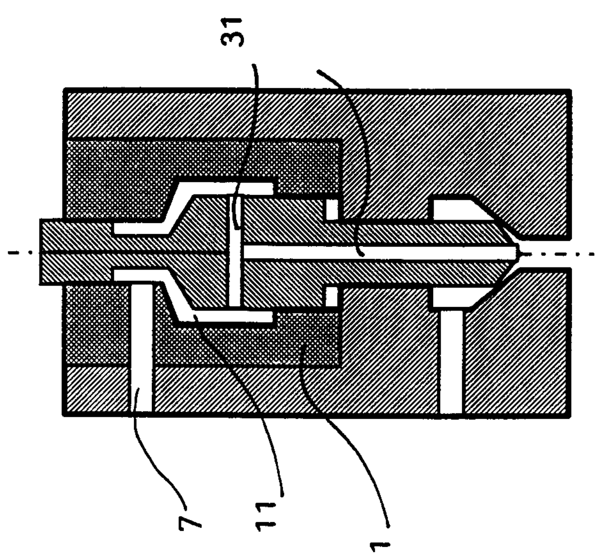


FIG.7

5/11

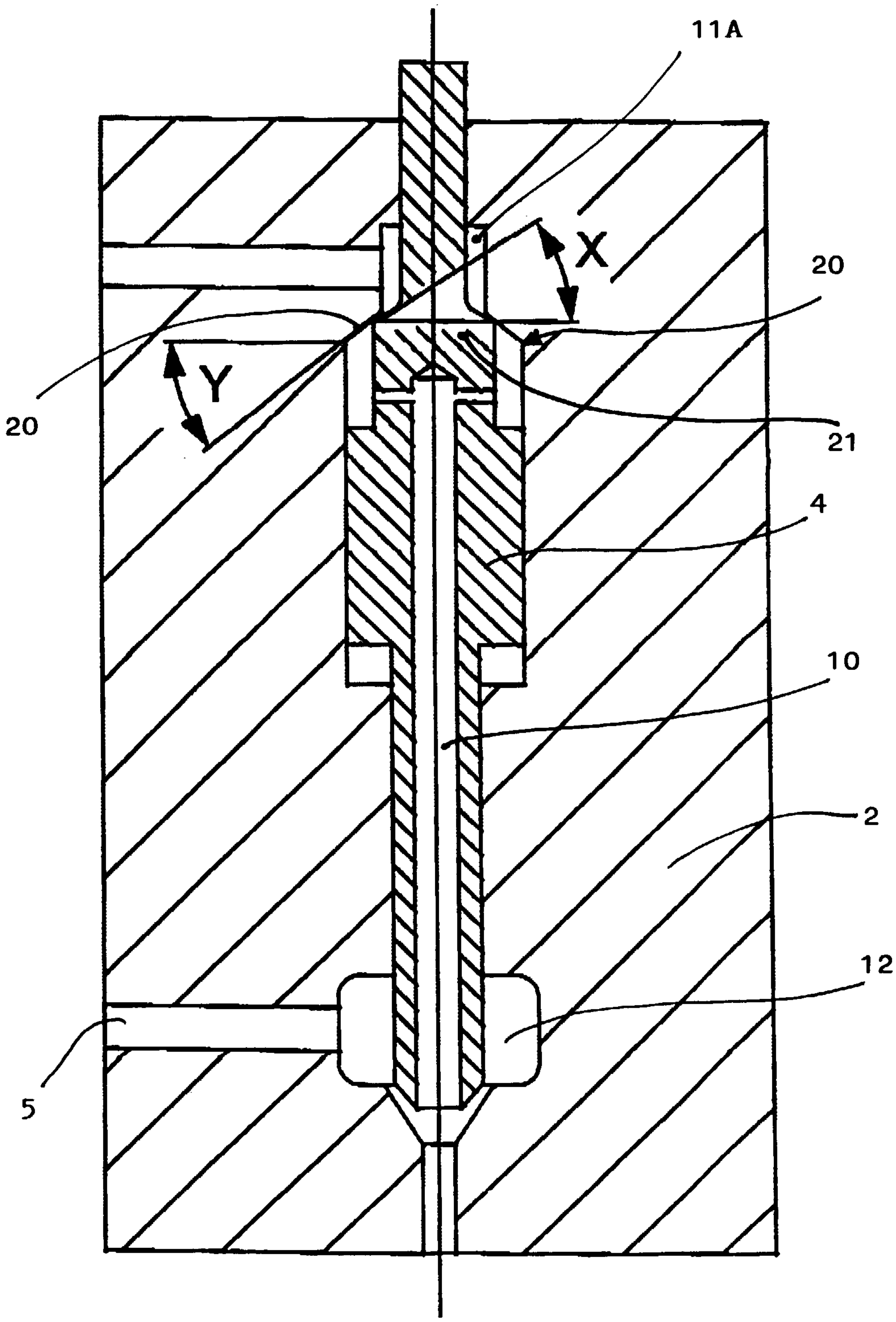


FIG. 10

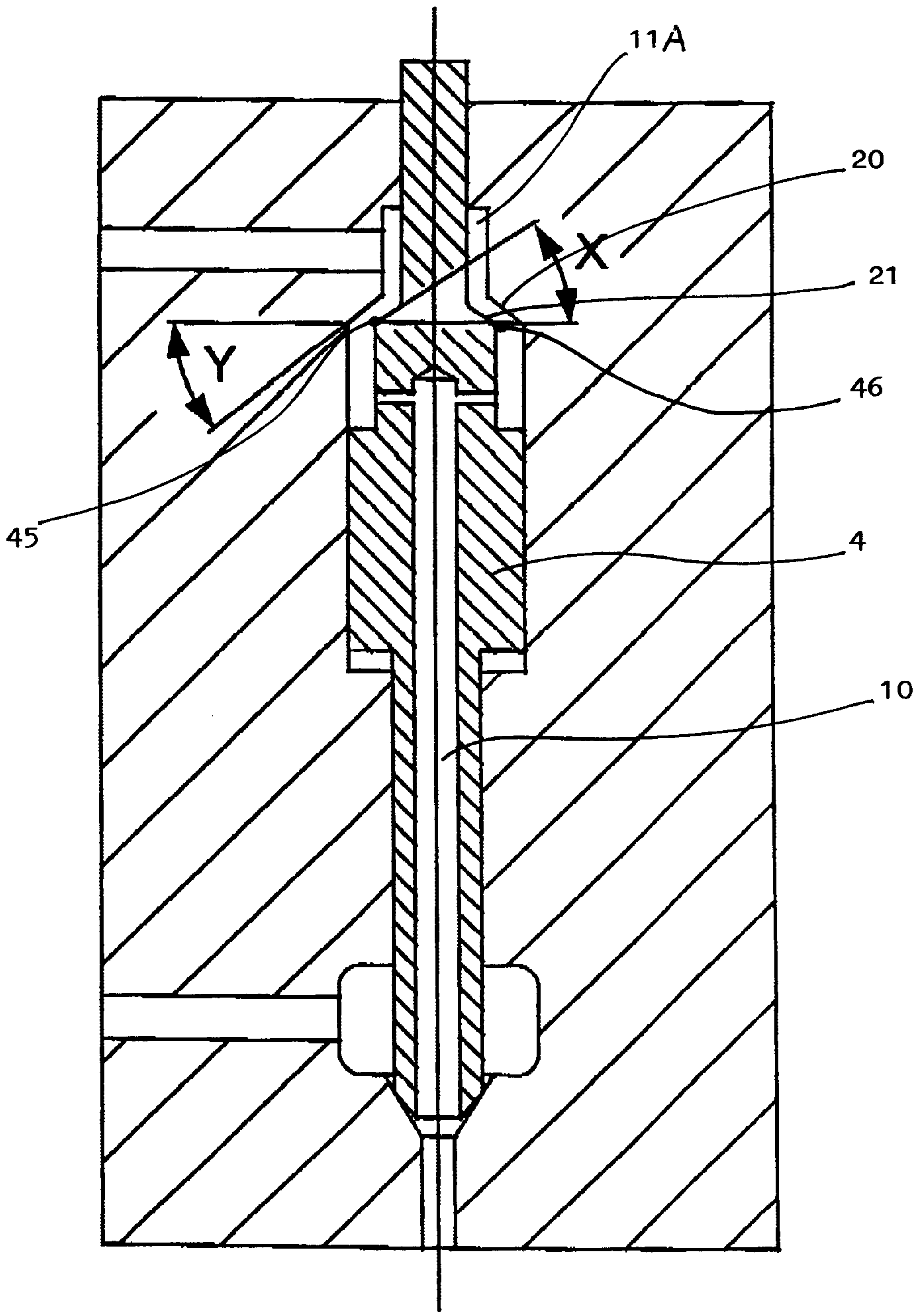


FIG. 11

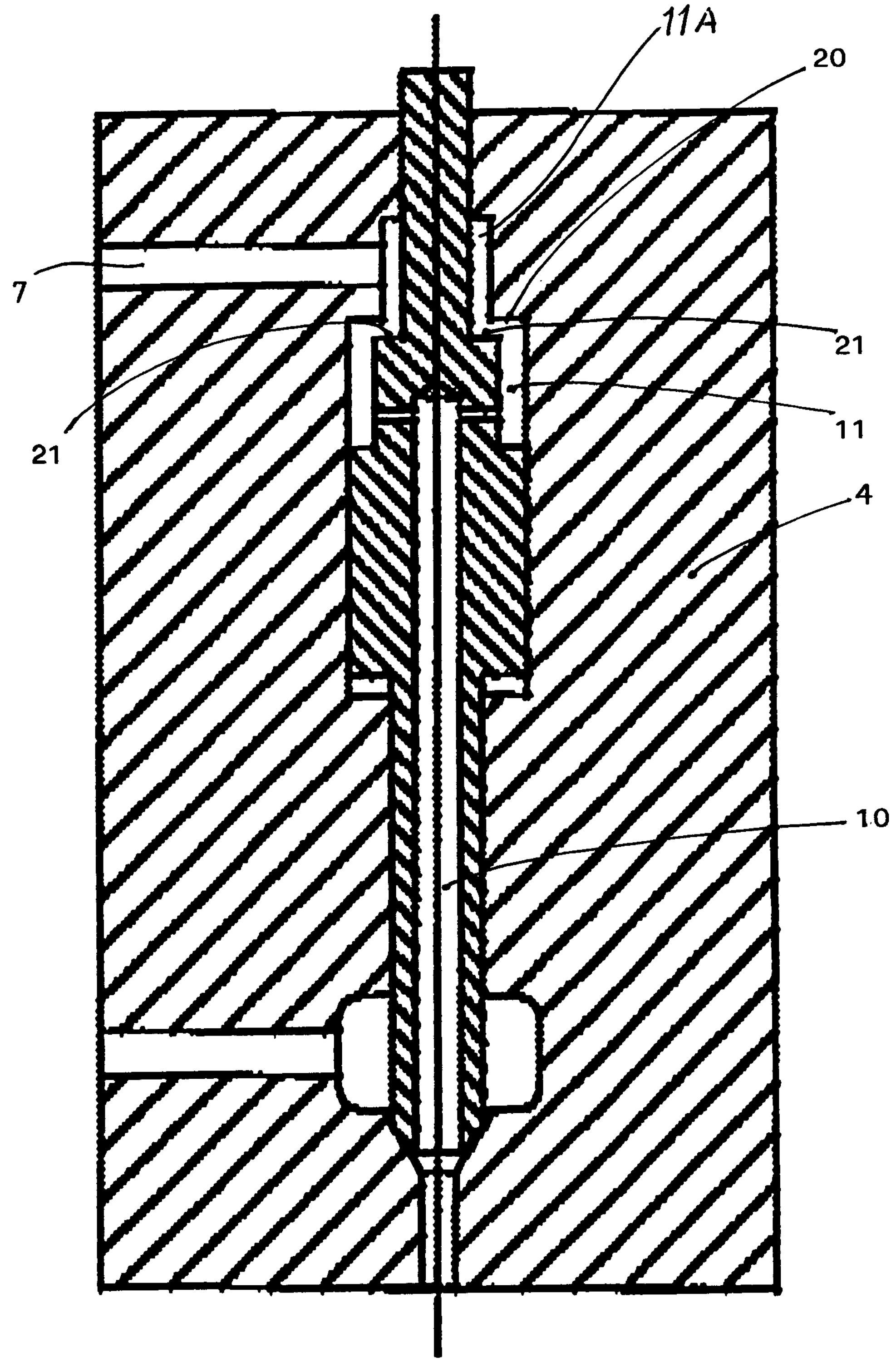


FIG. 11A

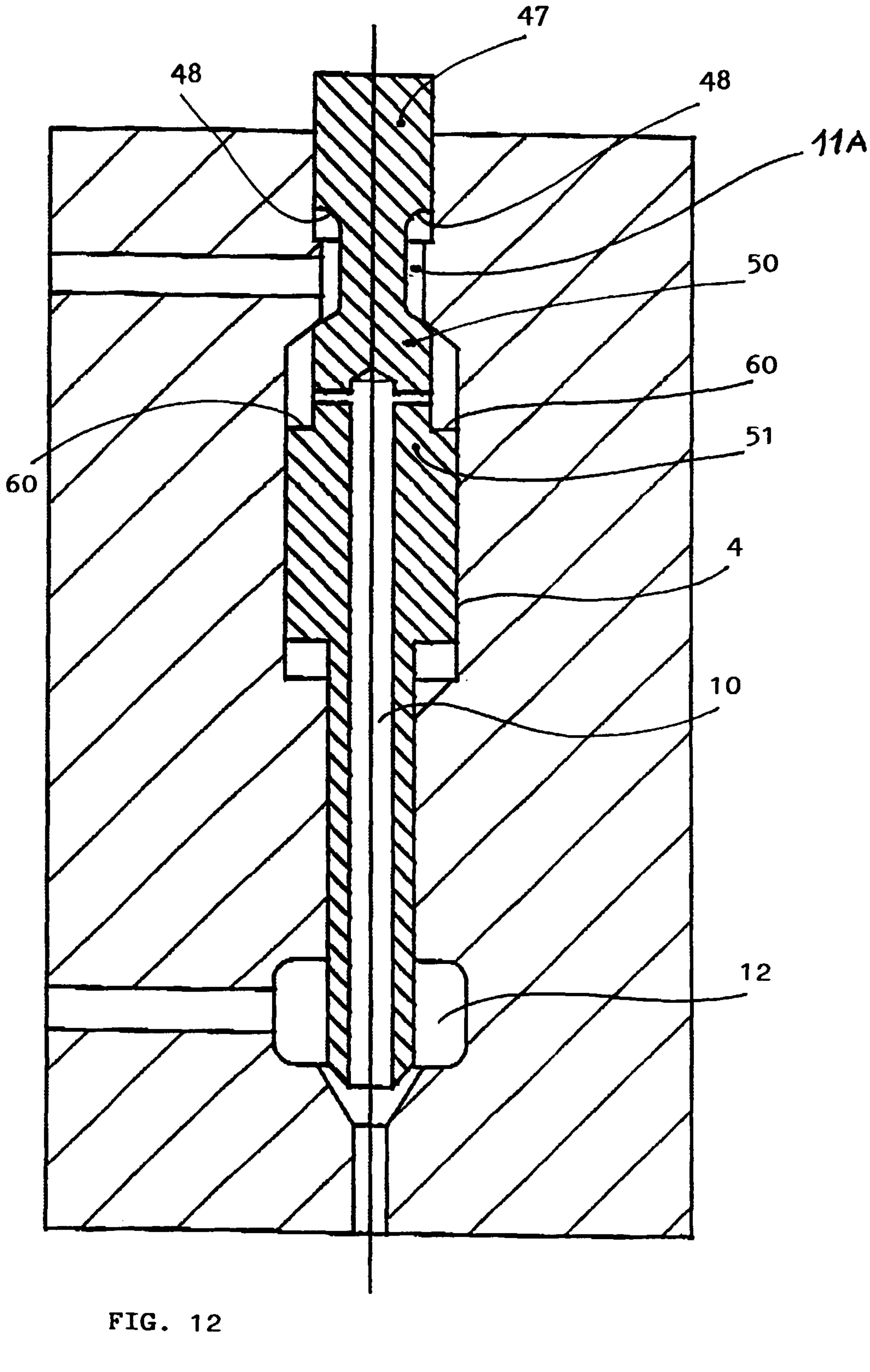
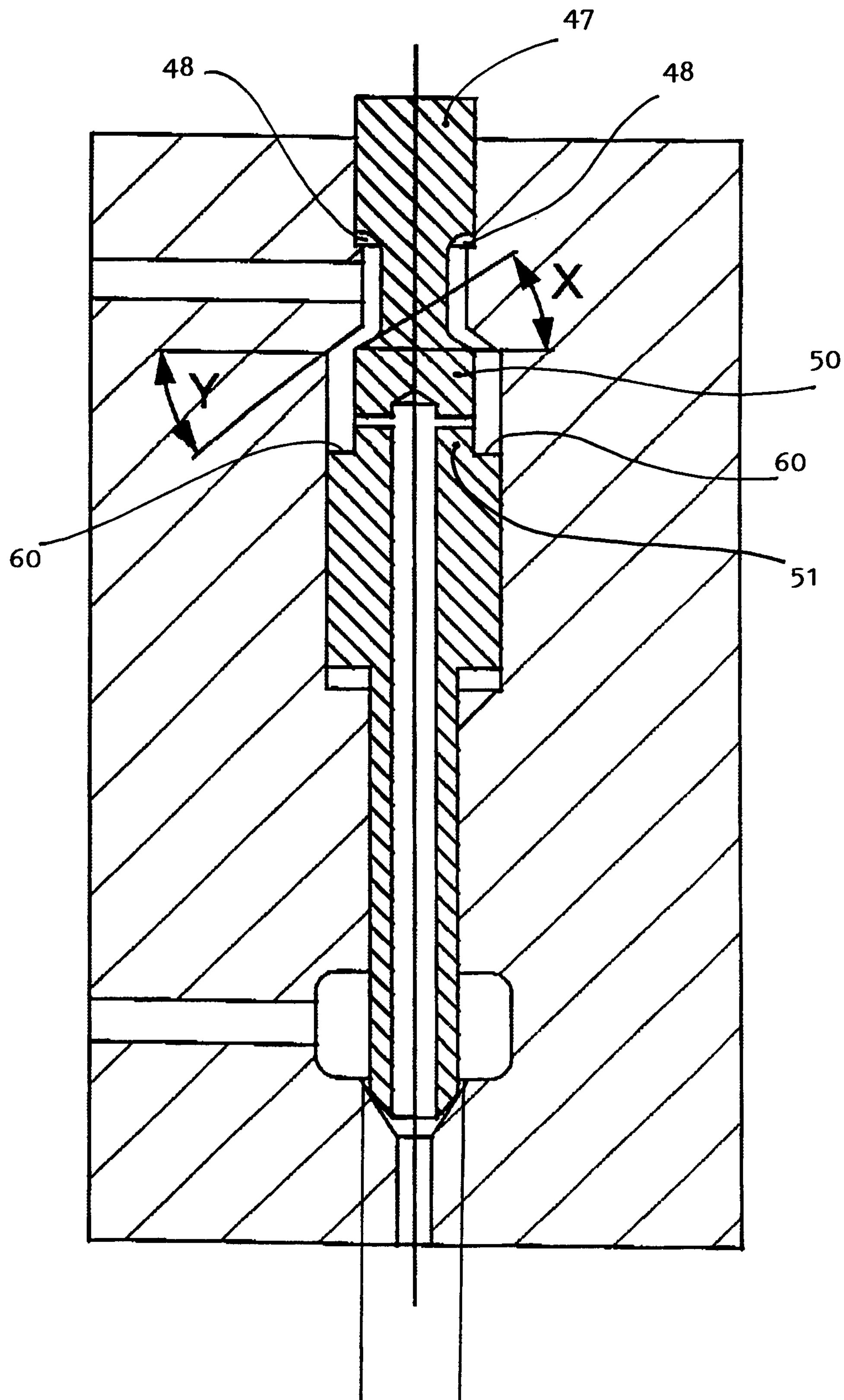


FIG. 12

FIG. 13



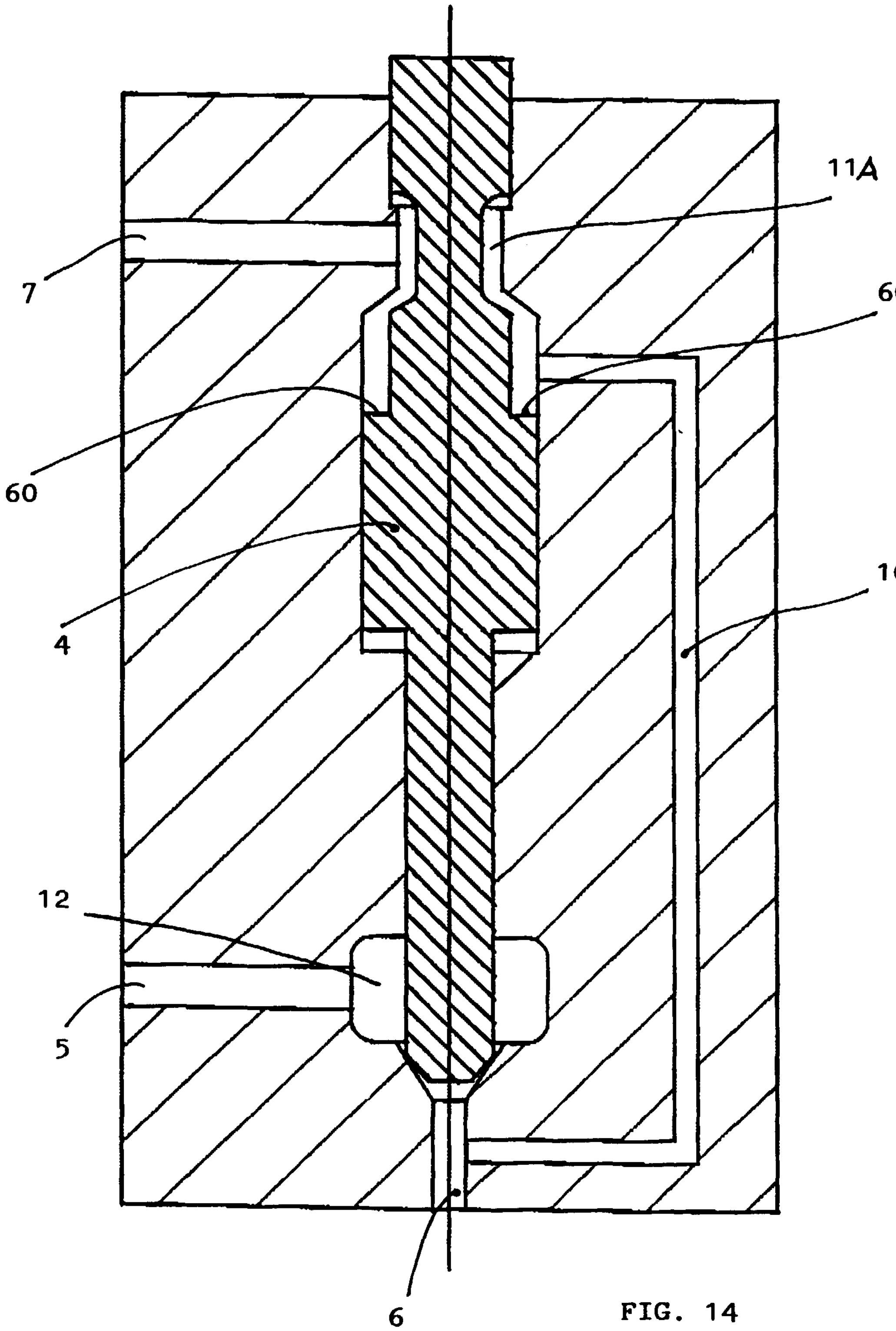


FIG. 14