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(54) Hydraulic press with automatic oil compensation

(57) Hydraulic press comprising a first chamber (2/10) for the compression of the hydraulic fluid, a second working chamber, respective pistons (2/11,2/15), a sealed conduit (2/4) connecting the inner volumes of said two chambers with wach other, a thrust element (2/12) adapted to press upon the piston of said first chamber, aperture (2/16) that enables the volume containing the hydraulic fluid to communicate with the outside ambient, shutting means (2/18) adapted to shut said aperture and linked with motion transmission means (2/13) that are displaceable into such distinct positions as to cause said shutting means to move into respective positions in which they fully shut and clear said aperture. The same aperture is provided both on a portion extending from said sealed conduit connecting the inner volumes of said two chambers with each other, and in the head of the piston of the hydraulic fluid compression chamber.

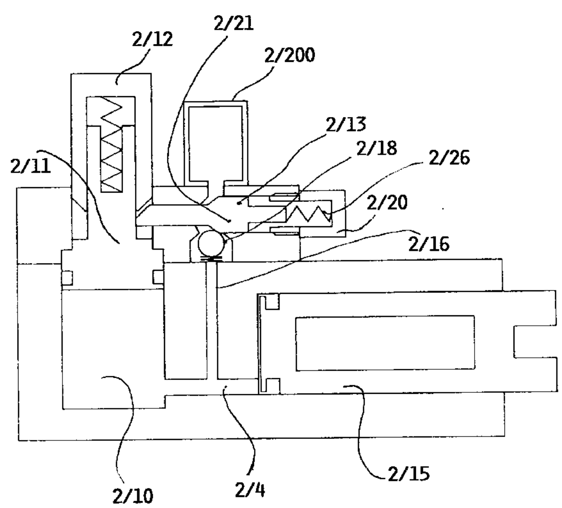

FIG. 14

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Description

The present invention refers to a hydraulic press for forming, mainly by deep-drawing and/or bending, sheet-metal plates, sheets or blanks.

Particular sheet-metal forming operations are known to exist which, owing to reasons of process automation, setting-up requirements or other production-related grounds, must be carried out with the working tool moving in a horizontal displacement direction or, anyway, with an inclination and position that are selectively variable with respect to the hydraulic pressure generating means.

Such presses are implemented by combining hydraulically the hydraulic pressure generating means, which are usually constituted by a piston, which is driven so as to hermetically slide within the sealed space of a cylinder containing a hydraulic medium, and the actual working means, which comprise the forming or final tool.

In this kind of machines, usually presses, the separation of the power cylinder and piston from the actuating cylinder and piston (ram) is most clearly exemplified in the patent EP 0 251 796 to LINVAL. However, the cited document does not disclose any solution to the problem of the thermal expansion of the hydraulic fluid and the consequences thereof. As a matter of fact, as it on the other hand emerges from the European patents EP 0 718 055 and EP 0 589 128, anyone skilled in the art is well aware of the existing need for sheet-metal working machines to comply with two basically conflicting requirements, ie. the requirement concerning the strength and the ability of producing high pressures in a controlled manner and the requirement concerning the high precision in the movement of the metalworking tool.

An apparatus for positioning and clamping sheet-metal plates or blanks that must be formed or anyway processed by means of a press to high precision standards, is known from the disclosure in EP 0 589 128 to MORITA AND COMPANY.

An apparatus for sheet-metal processing applications comprising a plurality of hydraulic balancing cylinders and corresponding pistons having their respective hydraulic chambers in communication with each other, in view of a more precise and synchronous operation of said pistons in precision forming operations, is further known from EP 0 718 055 to TOYOTA.

In particular, the problem connected with such a need is dealt with, for small dies, in the Japanese patent specification 60-40621, application no. 58-147686, priority August 11th, 1993, to NISSAN.

The above cited robustness, repeatability and precision requirements are usually complied with by having resort to compromise solutions, such as for instance the ones described in the above cited patents. The problem however is left of the imprecision that is introduced in the actual forming process by the thermal expansion of the hydraulic oil, which may reach a temperature of up to 70°C in the case of mineral oil, or even up to 120°C in the case of synthetic oils, in continuous-duty operations.

Such a temperature rise does of course not fail to bring about a volumetric expansion of the hydraulic oil normally used and involved in the process, and since such an oil has a coefficient of volumetric expansion of approx. 0.07%/°C, it ensues that the working temperatures that may be reached in the process will determine the expansion thereof to such an extent as to definitely jeopardize the processing precision, as anyone skilled in the art is well aware of, so that no further explanation shall be given here in this connection.

It should furthermore be noticed that the rise in the temperature of the oil depends, further to the actual working load, by a number of other variable and basically uncontrollable elements such as the initial transient state of the apparatus until the latter reaches steady-state conditions, the ambient temperature and the heat dissipation.

All such factors therefore contribute to an aggravation of both the variability and the imprecision of a prolonged working process carried out with the use of a hydraulic press, as this is particularly the case in sheet-metal forming operations.

From PCT WO 94/25260 to DANLY, a control module associated to a press is also known, in which a power cylinder is provided with an auxiliary compartment adapted to be connected with the working and pressure volume being defined by the displacement of a piston inside the same cylinder at least in the top dead center of said piston; in such a position of the piston, the hydraulic liquid contained in said working volume can therefore transfer its possible excess volume, brought about by the thermal expansion, towards said compartment.

Such a solution, although seemingly simple in itself, depends on the sealing effectiveness of the gaskets and is therefore strongly affected and impaired in its durability by such gaskets unavoidably wearing out and gradually loosing their sealing effectiveness.

In order to eliminate all of the afore cited kinds of drawbacks, ie. overtemperature and resulting thermal expansion, imprecision and/or inconstant precision of the forming operations, high pressures, sealing effectiveness of the gaskets, and the like, it is a generally known practice, so as this is shown in Figure 1, to provide between the cylinder receiving the pressure of the die and the actuating cylinder (ram) a hermetically sealed hydro-pneumatic accumulator containing a pre-determined volume of hydraulic liquid and a pre-determined volume of gas, said liquid and said gas being completely separated from each other by a moving piston inside said accumulator. When the volume of the oil increases, it causes the inner pressure to rise as well, so that said pressure then tends to discharge itself onto the above cited piston which is thereby caused to displace in the direction in which it compresses the gas and, as a result, leaves a greater volume available for the liquid.

Such a solution, however, has a clear drawback in that the compression of the gas occurs actually each time that the liquid is put under pressure and, therefore, specially at each actuation of the die. Such an occurrence therefore leads practically to a worsening precision in the transmission of the motion to the actuating cylinder (ram), as well as to a considerably reduced capability in transmitting high working pressures.

Another generally known practice, so as this is shown in Figure 2, calls for the use of an oil reservoir associated to a stop valve, or electromagnetic stop valve, installed between the two above cited cylinders. Such a valve is opened for a very short period of time between the moment in which the piston (pump) relating to the die terminates its return stroke, and the moment in which the same piston starts its subsequent delivery stroke; during such a period of time, any possible increase in the volume tending to occur in the hydraulic fluid is practically counteracted and neutralized by a sufficient amount of fluid passing automatically from the hydraulic circuit to the oil reservoir, which thing is effective in restoring correct pressure conditions in the fluid and, as a result, maintaining a correct volume thereof.

Such a solution, although fully effective in solving the afore described problem, is however quite complicated and expensive in its implementation; it further requires constant maintenance owing to the electromagnetic valve and the related control circuits.

It therefore is a main purpose of the present invention to provide a technical solution, for application to the pressure generating means (pump) of a hydraulic apparatus, which is actually capable of eliminating the afore cited drawbacks and ensuring full independence from the variations in the volume of the hydraulic fluid, whichever might the cause of such variations also be.

It is a further purpose of the present invention to ensure full automaticity of the action aimed at compensating for the variations in the characteristics of the hydraulic fluid, whichever may the cause of such variations also be, such as for instance variations that may be brought about by a replacement of the existing oil or a restoration of the poil level or amount through the addition of fluid having different thermal expansion properties.

All such aims of the present invention shall furthermore be capable of being reached through the use of simple techniques and materials that are readily available on the market.

The present invention describes a type of apparatus having the characteristics as substantially described with particular reference to the appended claims.

The characteristics and the advantages of the invention will anyhow be more readily understood from the description that is given below by way of non-limiting example with reference to the accompanying drawings, in which:

- Figures 1 and 2 are schematical views of two different configurations of an apparatus according to prior-art technique;
- Figure 3 is a schematical view of the main component parts of an apparatus according to the prior art and not provided with any means for the correction of variations in the volumes of the hydraulic fluid;
- Figure 4 is a schematical view of the architecture and the function of the sub-assemblies of a press according to the present invention;
- Figures 5 and 5a are views of two subsequent operating states, respectively, of an improved variant of the organs of the cylinder (pump) shown in Figure 4;
- Figures 6 through to 10 are views illustrating a sequence of five subsequent operating states of the apparatus shown in Figures 5 and 5a;
- Figure 11 is a view of a variant in the construction of the cylinder (pump) shown in Figure 5;
- Figure 12 is a view of a further variant in the construction of the cylinder (pump) of Figure 5;
- Figure 13 is a view of yet another variant in the construction of the cylinder (pump) of Figure 5;
- Figure 14 is a schematical view of the architecture and the arrangement of the component parts of a module according to a further variant of the present invention, in a first operational state thereof;
- Figures 15 and 16 are schematical views of the arrangement of the component parts of the above cited module, in a second and third operational state thereof, respectively;
- Figure 17 is a magnified view of a detail of the module of Figure 14;
- the pairs of Figures 18-19, 20-21 and 22-23 are views of corresponding constructive and operational variants of the solution illustrated in the preceding Figures 16 and 17.

According to prior-art technique, as best represented in Figure 3, the apparatus comprises two working chambers 1 and 2 wherein in the first chamber 1 the hydraulic fluid contained therein is put under pressure by the respective piston 3, which may be driven in any of the plurality of manners known in the art.

The so generated pressure is transmitted to the fluid contained in the chamber 2 through the conduit 4 which connects the inner volumes of said two chambers

1 and 2 so as to enable them to communicate with each other. As a result, the so transferred pressure actuates the working piston 5 associated to the chamber 2 and, therefore, the tool (not shown) that is solidly applied on to said piston 5.

It clearly appears that, given the hermetically sealed construction of the chamber, any variation in the volume of the hydraulic fluid, however it may also be produced, will bring about a corresponding variation in the "container" that may be defined here as the "aggregate of the volumes occupied by the fluid which is put under pressure", and in particular in the position and/or shape of the walls of said chambers, and therefore only in the position of the pistons, since it is assumed that the geometry of the chambers remains fixed and unaltered, except for the position of the pistons.

It also clearly appears that an expansion in the volume of the fluid, if the initial position of the piston of the first working chamber 1 is kept constant, will automatically have repercussions on the initial position, and therefore also on all other subsequent positions, of the working piston 5, with easily imaginable consequences in terms of a poorer precision of the deep-drawing and/or bending operations.

In order to eliminate such a drawback, the present invention therefore proposes the herein described solution , which does not propose a compensation of the total volume being occupied by the fluid, but rather the use of means capable of ensuring the constancy of the volume of the "container", so as the latter has been defined above, and in particular of the two chambers 1 and 2 and the conduit 4, regardless of the overall volume of the fluid which may on the contrary vary within even relatively wide limits.

This solution is based essentially on the fact that, for the volume of the "container" to be kept constant, the therein contained fluid in excess of a pre-determined volume is expelled or, better, "purged" out through at least an aperture that is provided in a wall of the same container, said aperture leading into an expansion (or even feeding) reservoir adapted to receive the excess amount of fluid flowing out through said aperture or, conversely, to feed in an amount of fluid as appropriate to restore the ideal conditions of total filing of said "container" when the fluid contracts.

The pre-determined amount of fluid is established in accordance with the geometry of the volumes involved, the general architecture of the apparatus, the initial working position, and all other factors that intervene in the process and are generally well-known and normally considered by anyone skilled in the art when identifying and setting the operational conditions of the apparatus for achieving the desired results.

With reference to Figure 4, which schematically illustrates in a simplified manner the principles of the present invention, notice should be taken of the working chamber 10, the respective piston 11, a so-called thrust element 12 adapted to act, after a short stroke, upon means 13 adapted to transmit said pushing action from said element 12 to the piston 11 and rigidly associated to the latter; the fluid expansion chamber, the connection between said two chambers and the actuating piston (ram), to which the final tool is applied, are not shown for reasons of both greater simplicity and practical irrelevance to the purposes of the present invention.

Connected to the same chambers there is provided a third chamber 16 that might be defined as a compensation chamber, which is totally enclosed, but provided with an aperture 17 capable of being closed with any shutting means 18 known in the art. Said shutting means 18 are elastically connected to the motion transmission means 13, or directly to the piston, by an elastic element 19 that is capable of transferring each movement and each position of the piston 11 to said shutting means 18 up to the point at which the latter tightly closes and seals said aperture 17.

The so arranged apparatus needs following initial settings and adjustments: an initial position is first of all defined for the piston 11, to which a coinciding initial position is then found for the actuation piston. This enables an inner volume to be defined for the chambers 10, 16, as well as the expansion chambers and the related connections (in other words, the "container"), which has then to be kept not only constant under any operational condition whatsoever, but also, and in particular, independent from any volumetric variation of the hydraulic fluid contained therein.

In order to do so, it is at this point necessary for a position of the shutting means 18 to be adjusted in such a manner that the same means are then able to hermetically shut the aperture 17. At the same time, however, it is also necessary for the elastic element 19 to be set in such a manner that it is practically at rest in this initial position, so that each upstroke of the piston 11 starting from said initial position causes also the shutting means 18 to be lifted and, as a result, the aperture 17 to be cleared.

The operating principle of the present invention will be now fully apparent: upon completing the initial settings and adjustments in the above described manner, the operation therefore starts from the piston 11 being raised beyond the initial position, ie. a condition in which the aperture 17 is not shut. At this point, when the piston 11 starts to move downwards, the hydraulic fluid, the amount of which is such as to be able to completely fill up the compensation chamber 16 under any condition, starts to flow out of said chamber through the aperture 17.

As the piston 11 keeps moving downwards, the same piston reaches the previously defined initial position, in which the elastic element 19 causes the shutting means 18 to shut the aperture 17. At this point, therefore, the afore mentioned "container" is put under pressure and the useful working stroke can start since, due to the only aperture 17 being shut, said "container" is hermetically sealed.

It is now fully apparent that any possible increase in the volume of the hydraulic fluid would be entirely reversed by the fact that the excess amount of fluid is caused to escape by the downward displacement of the piston 11, so that it flows out through the aperture 17 before said piston actually reaches its initial position so that, in any case, when said piston reaches said initial position, the aperture 17 is tightly shut and, at the same time, the "container" can be put under pressure with the inner volume thereof kept at a constant pre-determined value.

It can therefore be clearly appreciated that the initial position of the piston 11 is made fully independent from the variations in the overall volume of the hydraulic fluid used, and is defined solely by an appropriate combination of the initial geometries alone.

Although advantageous, however, such a solution has a drawback, since it may well occur that the high pressure generated by the piston 11 in the working chamber 10, and therefore in the whole "container", rises actually to a value that is capable of causing the shutting means 18 to move away from the aperture 17, which thing would of course cause the pressure to abruptly drop, thereby practically preventing the press from operating.

In order to eliminate such a problem, an advantageous solution consists in the use of a constructional and functional architecture as illustrated in Figures 5 and 5a. According to such an improved embodiment, an aperture 20 is provided in the bottom of the piston 11 to enable the working chamber to be put in communication with the inner volume of the same piston.

In front of said aperture, on the inner side of the piston, there is arranged an element 21 which is adapted to shut said aperture and is provided with a rod 22 that protrudes from the upper outer perimeter 23 of the piston.

The outer end portion of said rod is arranged so as to protrude from said outer perimeter by a length H that is similar to the distance which the same rod must cover in order to shut the aperture 20, when the thrust element 12 is separated from both said rod and the piston 11.

With the above described arrangement, when the thrust element 12 moves downward to the point in which it enters into contact with said upper outward perimeter 23 of the piston, but does not push it yet, the same element 12 will have by this time already pushed the rod 22 by such a length H as to cause the element 21 to shut the aperture 20 of the piston, while at the same time the upper edge of the same rod, which is flush, ie. on the same plane with said upper outer perimeter, starts to move jointly with the same piston. Even in this case, lifting means 25 are applied to said rod which are adapted to keep the same rod raised and therefore to prevent the element 21 from shutting the aperture 20 under resting conditions, ie. when the thrust element 12 is separated from both the rod and the piston. Again, a corresponding initial adjustment similar to the afore described one, and which shall not be described here for reasons of brevity since it is well within the abilities of anyone skilled in the art, must be carried out.

The operation of such an improved embodiment is as follows: when said thrust element starts its downstroke, as this is shown in Figure 6, any possible excess amount of hydraulic fluid will overflow through the aperture 20 into the inner volume of the cylinder.

Then, in a subsequent moment, the same thrust element 12 enters into contact with the rod, thereby pushing it downwards and, as a result, starting the phase leading to the aperture 20 being shut by the element 21. During this phase, said thrust element is not yet in contact with the piston 11, which therefore stays in its initial position.

By continuing with its downward displacement, the thrust element then reaches a position in which it enters into contact with the upper outer perimeter 23 of the piston and, at the same time, the shutting element 21 shuts the aperture 20, thereby hermetically sealing the "container" of the hydraulic fluid, as shown in Figure 7.

By further continuing with its downward displacement, said thrust element then presses at the same time upon said rod 22 of the shutting element and the piston 11, which therefore start displacing from such a position in perfect synchronism thanks to the geometry of said component parts and the described initial settings (see Figure 8).

It is therefore fully apparent that the shutting element 21 will by no means be capable of unduly clearing the aperture 20, owing to the rod thereabove being locked in its position relative to the piston by the resistance opposed by the thrust element 12.

As far as the upstroke is concerned, which is illustrated in the Figures 9 and 10, the above described sequence is performed in the exactly reverse order, in such a manner and with such methods as anyone skilled in the art is capable of imagining, so that they shall not be described here any further.

Even in this case a number of further variants and improvements are possible, basically in connection with the lifting means 25. As a matter of fact, these can be made to consist of either an elastic element arranged between the rod and the piston or even a floating element 29 linked to the rod at an appropriate height thereof and adapted to float on the surface of the fluid mass contained inside the piston, as shown in Figure 11. The use of such a floating element appears to be particularly advantageous in the case of low-weight rods, since it is not subject to wear and tear, must not be sized to any particularly tight tolerance and can further be replaced most easily, even with non-identical component parts.

As far as the elastic element is concerned, this can take various forms: a preferred embodiment thereof is however shown in Figure 5 *et seq.* to include a spiral spring accomodating said rod and retained at its upper portion by appropriate retaining means 26 arranged thereon said spring being further secured, at its bottom portion, on to a portion of the inner surface of the piston circumscribing the aperture 20.

Another variant may be as illustrated in Figure 12, wherein said elastic element is made to consist of one or more elastic reeds 30 attached with one end thereof against the side inner surface of the piston and with the other end against said rod.

Furthermore, in order to simplify said whole set of adjustments, reduce the weight and the inertia of the shutting means, as well as improve the safety of the press, Figure 13 teaches to arrange the contact zone between the thrust element 12 and the rod 22 in a position which, under any operational condition, is situated inside the volume of the cylinder 11.

However, the above described solutions, although generally effective in solving the afore mentioned problems, are not free from a couple of further drawbacks which are essentially due to the manner in which the above described embodiments of the present invention are actually carried out: the first problem relates to the difficulty lying in the actual ability of making the moment at which the thrust element 12 touches and starts to push the top edge of the piston 11 (and therefore starts the compression of the fluid in the working chamber 10) exactly coincide with the moment at which the lower end portion of the rod 22 hermetically shuts the aperture 20 in the bottom of the same piston, thereby once and for all defining the fixed volume of the afore defined "container".

The second problem is inherent to the illustrated configuration which makes use nof a flexible conduit 4 to connect the working chamber 10, which sustains the pressure induced by the piston 11, with the chamber 2 which converts such a pressure into a force acting upon the head portion of the working piston 5.

Such a flexible conduit, although useful in view of a more convenient operability and arrangement of the involved organs, is inherently provided with walls that are not totally rigid, so that the absolute constancy of the volume of the "container", when the latter is under pressure, is seriously impaired by said walls of the conduit 4 yielding in a slight, but anyway still perceptible manner.

Furthermore, notice should be taken of the fact that even the connections at both ends of said conduit are sensitive to and therefore affected by the same drawback, the effect of which is in this case further aggravated by the means used to ensure the sealing of said connections wearing down.

In order to overcome such problems, and with particular reference to Figures 14 through to 23, the present invention proposes a solution that is based on a more compact, one-piece configuration of the press.

In order to avoid the various means and devices illustrated in said Figures 14 through to 23 having to be given fully new reference numerals, which should on the contrary be mainatained substantially unaltered since largely similar to the reference numerals of the analogous means and devices described in connection with the afore illustrated solutions, the decision has been taken to let said reference numerals be preceded by the prefix "2/". So, for instance, the device 4 will be hereinafter identified by the reference numeral 2/4, the device 10 by the reference numeral 2/10, and so on.

With reference to the above cited Figures, and in particular to Figure 14 which is a simplified schematical view of the basic features of the above solution according to present invention, these features can be noticed to include a compression chamber 2/10, the related piston 2/11, a thrust element 2/12 adapted to act, after a short stroke, on means 2/13 provided for transmitting such thrust from said element 2/12 to said piston 2/11, the fluid expansion/working chamber 2/14, the conduit 2/4 connecting said two chambers and the actuation piston (ram) 2/15, to which the final tool is applied. Such a final tool is not shown in the Figures due to both reasons of greater simplicity and substantial irrelevance to the purposes of the present invention.

Connected to said conduit 2/4 there is provided a portion 2/16, which might be defined as an equalization oil passage portion, and which is therefore included in said "container", has a completely sealed construction, but for the provision of an aperture 2/17, which is best to be seen in Figure 17, where the thrust element 2/12 has been considerably raised with respect to such an aperture. Said aperture 2/17 is capable of being closed with any appropriate shutting means 2/18 known in the art. Motion transmission means 2/13 are provided between said thrust element 2/12 and said shutting means 2/18 and are so configured as to be capable of detecting whether said thrust element is sufficiently, ie. by an appropriate value, raised from the piston 2/11 or is in its lowest position from which it starts to press upon said piston.

In the first case shown in Figure 14, the thrust element 2/12 is so arranged as to be able to first act, while moving downwards, on the motion transmission means 2/13 and, only after it has fully actuated such means, it then actuates also said piston 2/11 in correspondence of the contact zones 2/11a and 2/11b thereof.

The means 2/13 are adapted to transfer the movement imparted thereto by said thrust element to said shutting means 2/18 up to the extent of causing the latter to fully and tightly shut the aperture 2/17.

In the preferred embodiment of the present invention illustrated in the accompanying Figures, the thrust element 2/12 and the motion transmission means 2/13 are two organs that move orthogonally, and their movement is transferred by means of two mating surfaces 2/12a and 2/13a, that are inclined with respect to the angle formed by the movement of said organs, so that the "cam effect" originated by their rubbing against each other brings about the desired displacement of the motion transmission means 2/13, which are represented as a slide in this case, in the desired direction, ie. rightwards in the Figures which reference is being made to.

Said slide 2/13 is adapted to move within a respective guide 2/20 which is open on a lower portion thereof and from which there is protruding a projection 2/21 that is provided with an inclined lower side, too.

Such a projection, the aperture 2/17 and the shutting means 2/18, the latter being constituted by a simple sphere, are sized and arranged so that, according to the position of the thust element and, as a consequence, the slide 2/13, said projection 2/21 presses said sphere 2/18 downwards for the latter to clear the aperture 2/17 or enables said sphere 2/18 to rise until it eventually shuts said aperture.

The so arranged machine needs following initial settings and adjustments: an initial position is first of all defined for the piston 2/11, to which a coinciding initial position is then found for the actuation piston 2/15. This enables an inner volume to be defined for the chambers 2/10 and 2/14, the conduit 2/4 and the portion 2/16 (in other words, the "container"), which has then to be kept not only constant under any operating condition whatsoever, but also, and in particular, independent of any volumetric variation of the hydraulic fluid contained therein.

In order to do so, it is at this point necessary for a position of the shutting means 2/18 to be adjusted, along with the position of the therewith associated organs, ie. the slide 2/13 and the thrust element 2/12, in such a manner that the same shutting means are then able to hermetically shut the aperture 2/17. At the same time, however, it is also necessary for said associated organs to be articulated in such an initial position in such a manner that, each time that the thrust element 2/12 rises starting from said initial position, it causes said sphere 2/18 to move downwards, owing to the pushing effect exerted by said projection 2/21, so as to clear the aperture 2/17.

The operating principle of the present invention will be now fully apparent: upon completing the initial settings and adjustments iaccording to the above described principle, the operation therefore starts from the thrust element 2/12 being raised beyond the initial position (Figures 14 and 17), ie. a condition in which the aperture 2/17 is not shut. At this point, when the said thrust element starts to move downwards, the hydraulic fluid, the amount of which is such as to be able to completely fill up the portion 2/16 under any condition, starts to flow out of the latter through the aperture 2/17.

As the thrust element 2/12 keeps moving downwards, the same element comes to reach the previously defined initial position (Figure 15), in which the slide 2/13 enables the shutting means 2/18 to shut the aperture 2/17. At this point, therefore, the afore mentioned "container" is sealed hermetically and, as a result, can be put under pressure and the piston 2/11 can start its useful working stroke (Figure 16) since, due to the only aperture 2/17 being shut, the force transmitted by the latter, and received by the element 2/12, can be fully transmitted hydraulically to the actuation slide 2/15.

It is now fully apparent that any possible increase in the volume of the hydraulic fluid within said “container” is entirely reversed by the fact that the excess amount of fluid is caused to escape by the downward displacement of the piston 2/11, so that it flows out through the aperture 2/17 before said piston actually reaches its initial position, so that, in any case, when said piston reaches said initial position the excess amount of fluid has been transferred into the expansion reservoir, the aperture 2/17 is tightly shut and, as a result, the "container" is automatically put under pressure with the inner volume thereof kept at a constant, pre-determined value.

It can therefore be clearly appreciated that the initial position of the piston 2/11 is made fully independent of the variations in the overall volume of the hydraulic fluid used, and is defined solely by an appropriate combination of the initial geometries alone.

As far as the return stroke is concerned, the above described sequence is repeated exactly in the reverse order, in a manner that is easily imaginable and, therefore, will not be described anew for reasons of greater simplicity.

The problem arising from the deformability of the conduit connecting the compression chamber 2/10 and the fluid expansion/working chamber 2/14 with each other can be radically overcome by making as a single rigid, preferably one-piece body the walls which, generally indicated at 2/31 in Figure 15, define said chambers 2/10 and 2/14, and therefore especially the conduit 2$ which, as a result, is created automatically by simply hollowing out an appropriate portion of said rigid body 2/31.

It will be appreciated that a number of further variants and improvements are of course possible. For instance, the shutting means 2/18, represented by a sphere, are contained in an enlargement 2/23 of the top end of the portion 2/16 extending from said conduit 2/4, and said enlargement comprises walls 2/24 oriented towards said aperture 2/17; furthermore, an elastic separation means 2/19, preferably a cylindrical spiral spring, is engaged between said shutting means 2/18 and said walls, so that said shutting means is in all cases forced to shut the aperture 2/17 when so enabled by the position of the slide 2/13.

Second elastic means 2/26 are further provided which are adapted to act on said motion transmission means 2/13 in such a manner as to force it to take the position to which a state of the aperture 2/17 corresponds in which the same aperture is not shut by said shutting means 2/18 appropriately pushed inwards by said projection 2/21, when said shutting means 2/18 are not moved away from said position by said thrust element 2/12.

With reference to Figures 18 and 19 it may be noticed that the shutting means can be advantageously constituted by a wedge 2/28 capable of sliding within the enlargement 2/23 of the top end of said portion 2/16; when the motion transmission means are pushed backwards, it releases the movement of said wedge which, by making also use of the side walls of said enlargement 2/23 as a guide, perfectly fits into the aperture 2/17, thereby shutting it tightly.

With reference to Figures 20 and 21 it may be observed that the shutting means are constituted by the same motion transmission means 2/13 that are formed by an actuator capable of sliding, also as a small piston, within the respective guide 2/20. Said small piston is configured with two prominent and opposite portions 2/38 and 2/48, which are arranged and sized in such a manner that, in a first operational position shown in Figure 20, said portions plug the passage between the portion of conduit 2/16 and either the outside ambient or an appropriate sealed expansion chamber 2/200. The advantage of using a sealed chamber derives from the fact that, in this way, contaminants or foreign matters are prevented from mixing with the working hydraulic fluid and thereby altering the properties thereof. For the tightness of said expansion chamber to be more effectively ensured, it is a preferred solution to provide for said chamber to be brought at a low overpressure above the atmospheric pressure using a suitable neutral gas.

Such a configuration is of course made to correspond to the position of the slide displaced by the lowering motion of said thrust element 2/12, whereas, with reference to Figure 21, when said thrust element is raised and separated from the slide 2/13, the latter elastically moves into such a position as to clear the respective passages toward the expansion chamber 2/200 and the portion of conduit 2/16 from the respective plugging prominent portions 2/38 and 2/48.

A further embodying variant is illustrated in Figures 22 and 23, wherein the clearness and the simplicity of the afore given illustrations and explanations are such as to exempt from giving further explanations. In this connection, it may be sufficient to point out how, in this case, the motion transmission means 2/13 are formed by a rocker lever hinged on an axis 2/35 and having the tappet end 2/36 adapted to be actuated by the inclined surface 2/12a of said thrust element 2/12, whereas the opposite end 2/37 is adapted to actuate said plugging means 2/18, which may in turn be configured exactly as the sphere that is substantially represented in Figures 14 to 17.

Claims

1. Hydraulic apparatus comprising:

- a first chamber (10) for the compression of the hydraulic fluid,
- a second chamber for the expansion of the same hydraulic fluid,
- a sealed conduit connecting the inner volumes of said two chambers with each other,
- a piston slidably arranged within said first chamber, adapted to slide hermetically relative to the inner walls thereof and tightly compress the hydraulic fluid contained therein,
- a thrust element (12) adapted to press upon the outer perimeter (23) of said piston,
- a container adapted to delimit the surfaces containing the hydraulic fluid that is put under pressure,

characterized in that

- said container is provided with an aperture (17) that enables the inner volume thereof to communicate with the outside ambient, or with a tightly sealed expansion chamber (2/200),
- shutting means (18, 2/28) are provided that are capable of shutting said aperture (17),
- said shutting means are linked with motion transmission means (13) comprising move-away means (19, 2/25, 2/26) adapted to automatically keep said shutting means open when said means (13) are disengaged from said thrust element, said motion transmission means being adapted to transfer the positions that can be taken by said piston (11) to said shutting means until the latter eventually tightly shut the aperture (17, 20).

2. Hydraulic apparatus according to claim 1, **characterized in that** it is capable of going into a first operational state in which said thrust element does not act either on said motion transmission means (13) or on said piston, a second operational state in which said thrust element acts on said means so as to induce said shutting means (18) to shut said aperture (17), while however not acting on said piston yet, and a third operational state in which said thrust element eventually acts on said piston, thereby inducing it to reduce the inner volume of said first chamber (10), while keeping said shutting means (18) in their shut condition.

3. Hydraulic apparatus according to claim 2, **characterized in that**

- said piston is a hollow tubular element,
- said aperture (20) is provided in the hydraulic thrust wall of said piston and said shutting means (18) are a shutting element (21) provided with a rod (22) protruding from the upper outer perimeter (23) of the piston.

4. Hydraulic apparatus according to claim 3, **characterized in that** said move-away means (19) or lifting means (25) consist of at least an elastic element arranged to act between said piston and said rod.

5. Hydraulic apparatus according to claim 4, **characterized in that** said elastic element consists of a spiral spring accomodating said rod and retained on one side by appropriate retaining means (26) arranged thereon, and on the other side on a portion of the inner surface of the piston circumscribing said aperture (20).

6. Hydraulic apparatus according to any of the preceding claims, **characterized in that** said elastic element is formed by at least an elastic reed (30) arranged between said shutting means or element (18, 21) and a point which is integral with the press.

7. Hydraulic apparatus according to claim 4, **characterized in that** said move-away or lifting means are formed by at least an elastic reed (30) arranged between a point of said rod and a zone on the inner surface of said piston.

8. Hydraulic apparatus according to any of the preceding claims, **characterized in that** said move-away means are formed by at least a floating element (29) applied to said rod or said motion transmission means (13).

9. Hydraulic apparatus according to any of the preceding claims 3 to 8, **characterized in that** the contact and thrust zone between said thrust element (12) and the rod (22) is in all cases kept inside said piston.

10. Hydraulic apparatus according to claim 1 or 2, **characterized in that** said aperture is provided on an enclosed portion (2/16) extending from said sealed conduit (2/4).

11. Hydraulic apparatus according to claim 10, **characterized in that** said shutting means comprise a valve in the shape of a sphere (2/18) or of a wedge (2/28) contained in said enclosed portion (2/16) and adapted to take at least two distinct positions, ie. a first position in which said aperture is not shut, and a second position in which said aperture is shut by said valve.

12. Hydraulic apparatus according to claim 11, **characterized in that** said valve is contained in an enlargement (2/23) of said enclosed portion (2/16), said enlargement being provided with walls (2/24) oriented towards said aperture, and that said elastic separation means (19) are engaged between said walls and said valve.

13. Hydraulic apparatus according to claim 12, **characterized in that** said elastic separation means (19) are formed by a cylindrical spiral spring.

14. Hydraulic apparatus according to any of the claims 1, 2 or 10, **characterized in that** a side (2/12a) of said thrust element is adapted to engage a corresponding side (2/13a) of said motion transmission means (2/13) comprising a slide, with respect to which it acts in a cam-like manner, said sides (2/12a, 2/13a) being inclined relative to the direction of movement of said means and said thrust element so as to be able to slide on at least a portion of the respective surfaces.

15. Hydraulic apparatus according to claims 14, **characterized in that** there are provided second elastic means (2/26) acting on said motion transmission means (2/13) and adapted to force the latter to automatically move into a position enabling the passage of hydraulic fluid through said aperture during said first operational state in which said thrust element is not acting on said motion transmission means.

16. Hydraulic apparatus according to claim 14 or 15, **characterized in that** said motion transmission means (2/13) are themselves forming said shutting means, which are provided with prominent portions (2/38, 2/48) that are arranged and sized so that, in a first operational position of said motion transmission means, said prominent portions plug the passageway between said enclosed portion (2/16) and the expansion chamber (2/200) and, in a second operational position thereof, a passage of hydraulic fluid between said enclosed portion (2/16) and the expansion chamber (2/200) is on the contrary enabled.

17. Hydraulic apparatus according to any of the claims 1 2 or 10, **characterized in that** the motion transmission means (2/13) comprise a rocker lever hinged on an intermediate axis (2/35) and having a tappet end (2/36) adapted to be actuated by said inclined side (2/12a) of said thrust element (2/12), whereas the opposite end (2/37) thereof is adapted to actuate said shutting means (2/18), which are preferably configured in the shape of a sphere.

18. Hydraulic apparatus according to any of the preceding claims, **characterized in that** said expansion chamber (2/200) is kept at a pressure which is slightly above the atmospheric pressure.

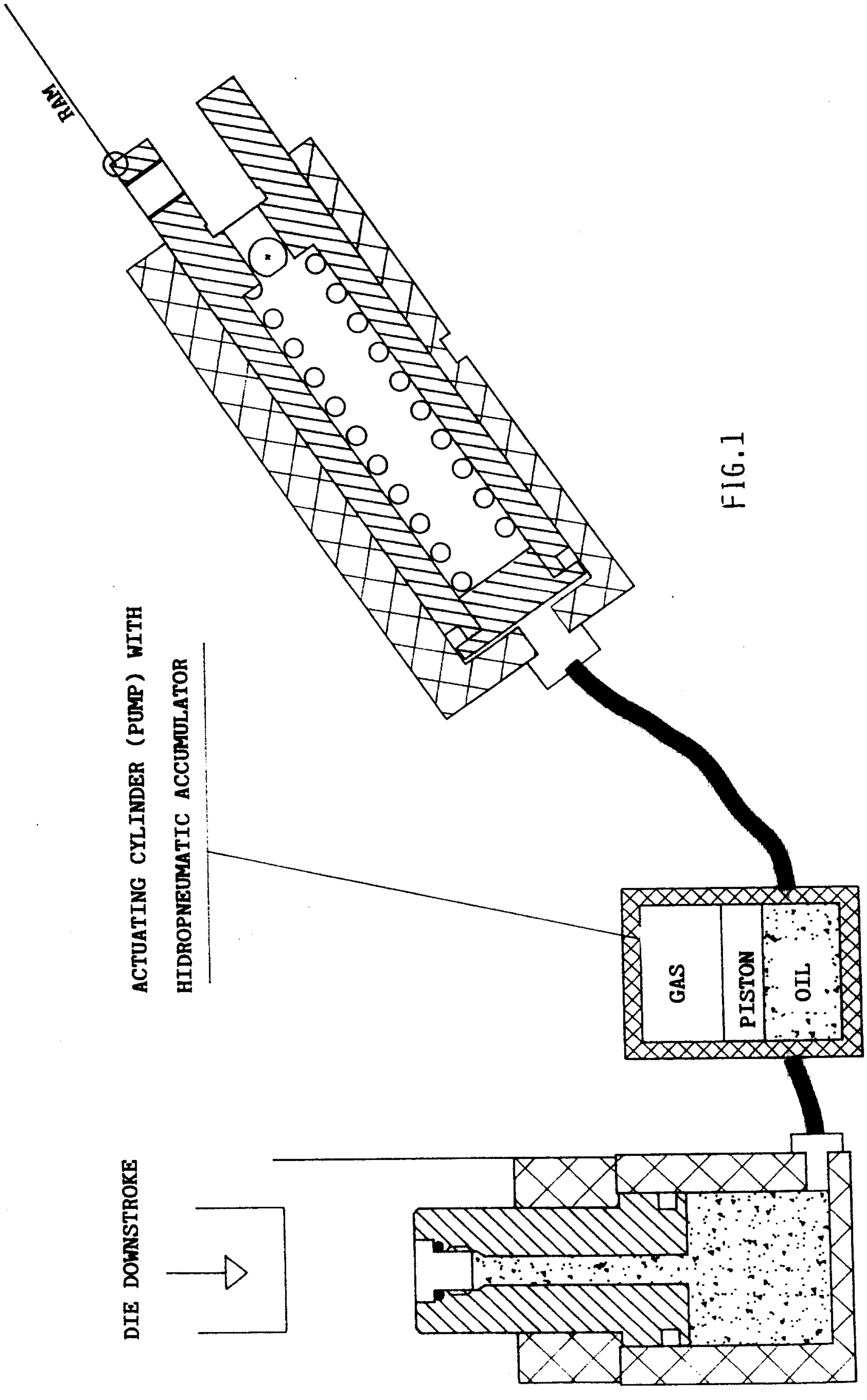

RAM
ACTUATING CYLINDER (PUMP) WITH
HIDROPNEUMATIC ACCUMULATOR
GAS
PISTON
OIL
DIE DOWNSTROKE

FIG.1

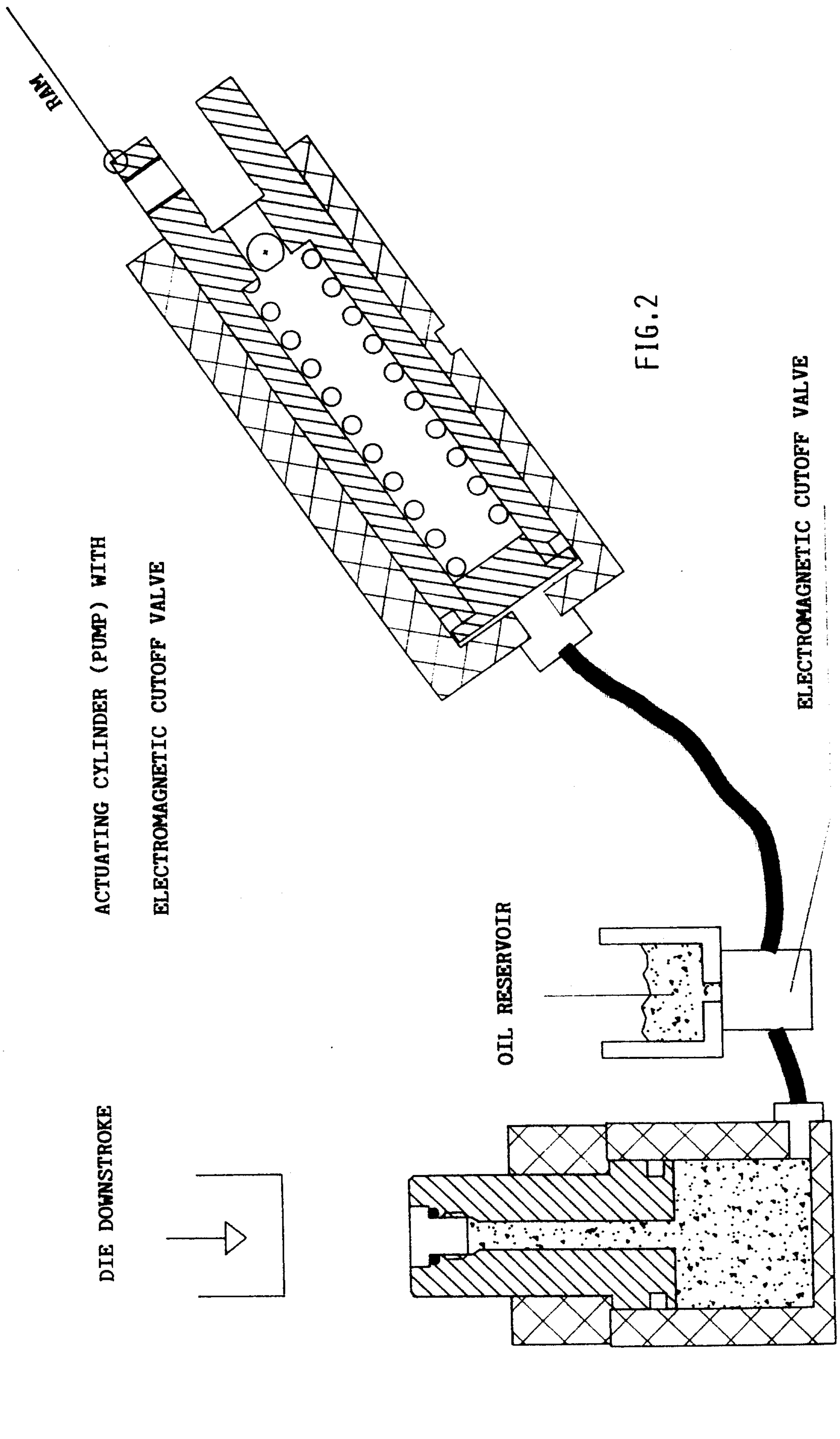
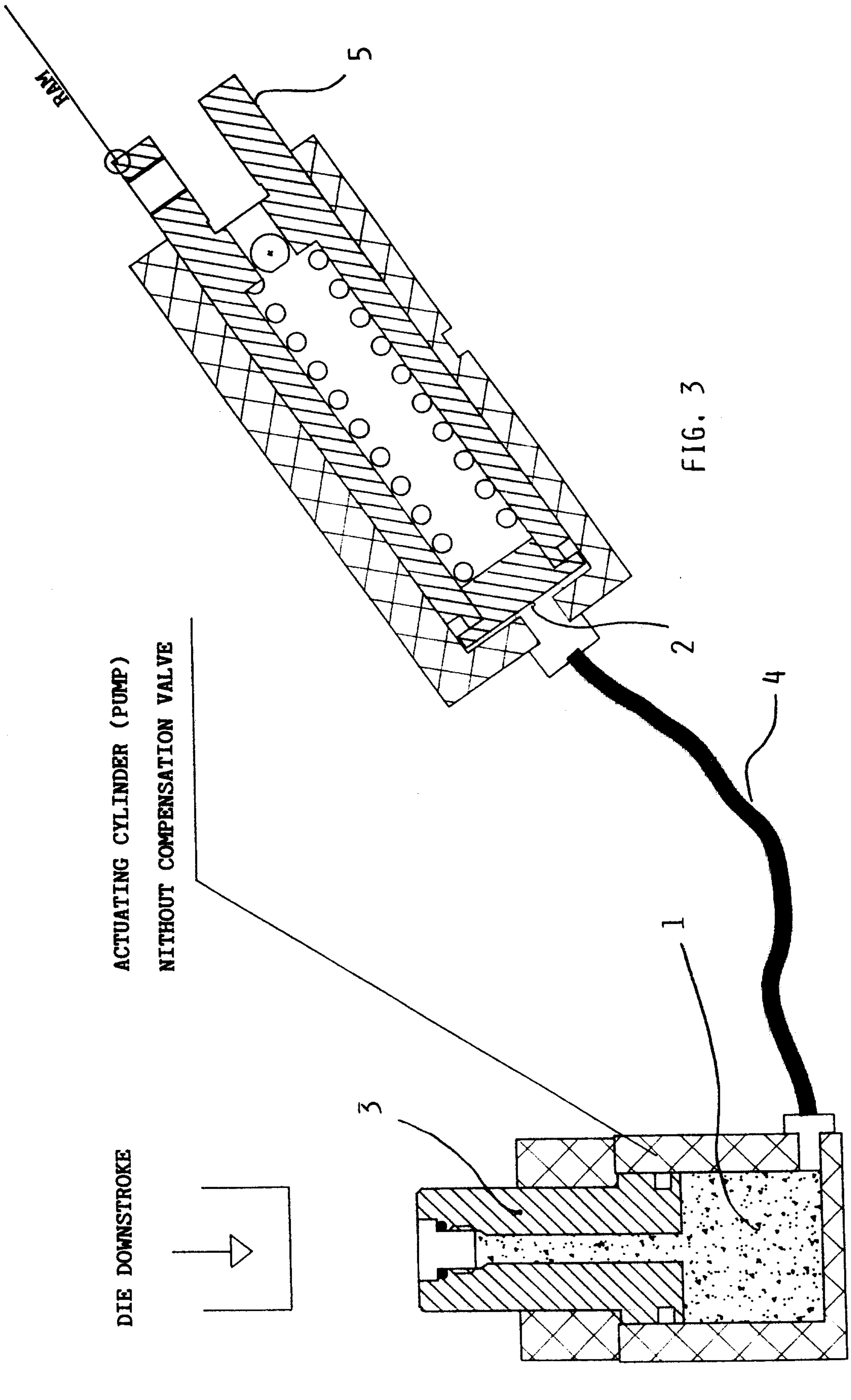

RAM
ACTUATING CYLINDER (PUMP) WITH
ELECTROMAGNETIC CUTOFF VALVE
ELECTROMAGNETIC CUTOFF VALVE
OIL RESERVOIR
DIE DOWNSTROKE

FIG.2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NITHOUT COMPENSATION VALVE
2
4
1
3
DIE DOWNSTROKE

FIG. 3

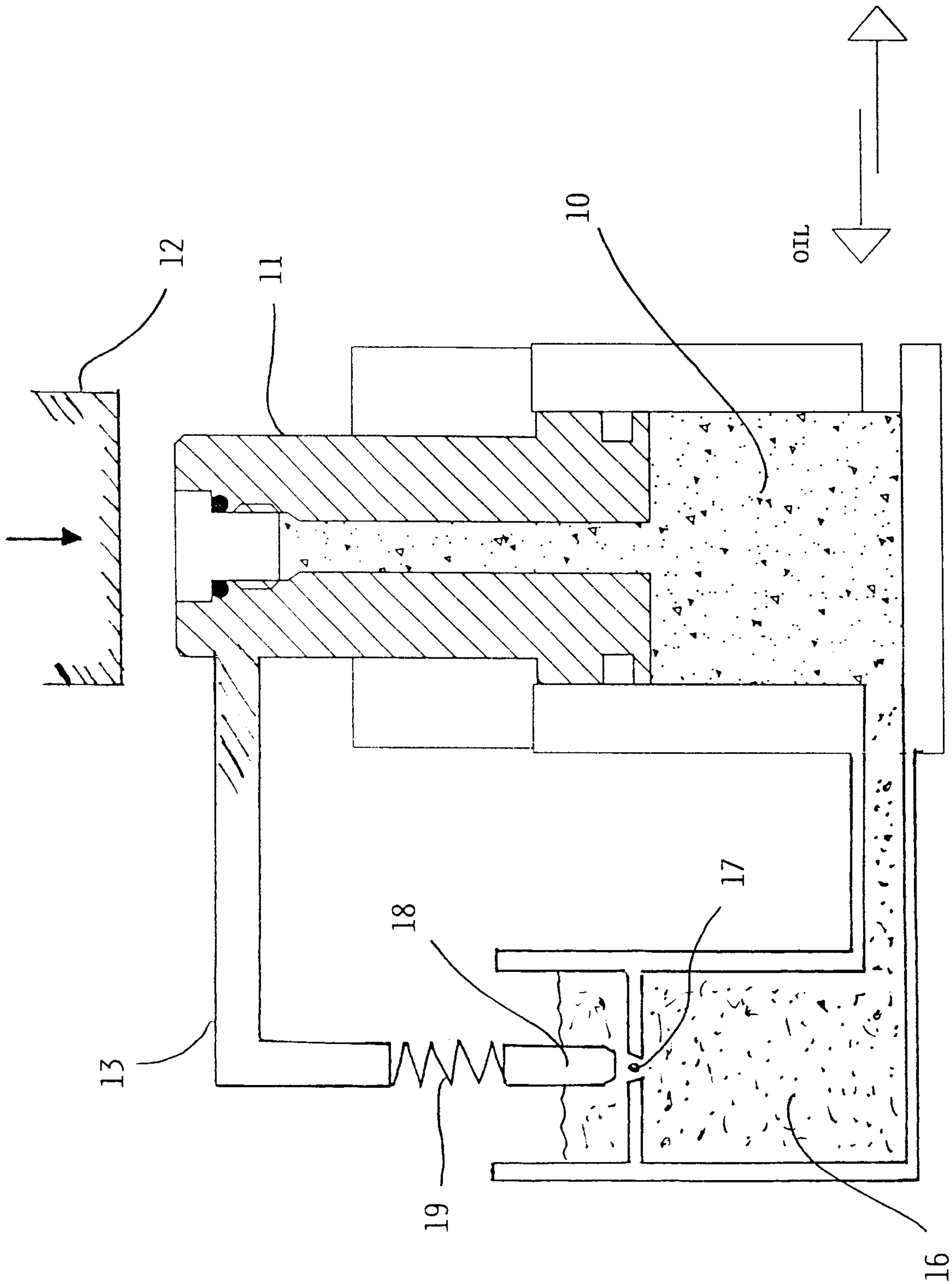

FIG.4

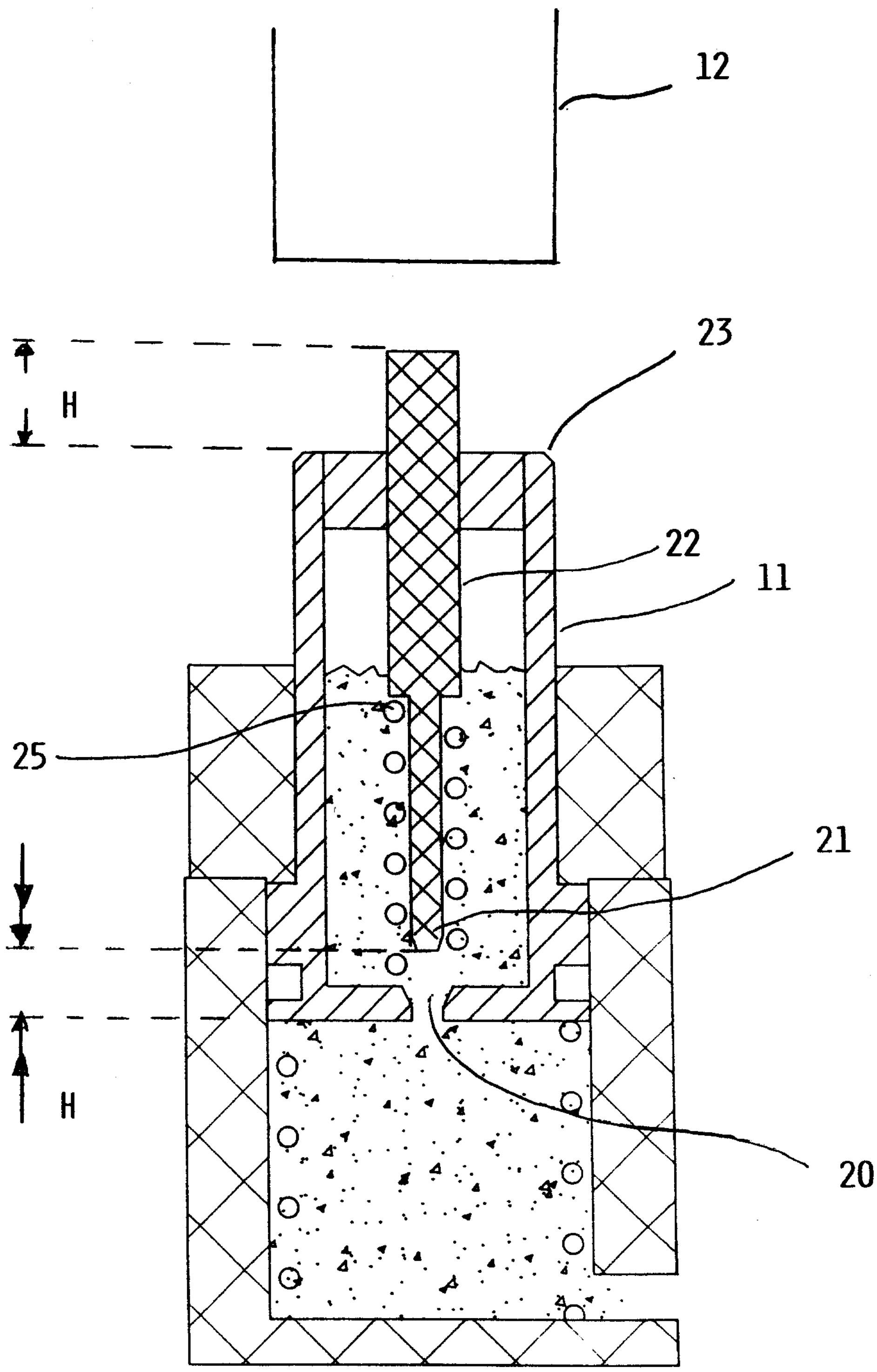

FIG. 5

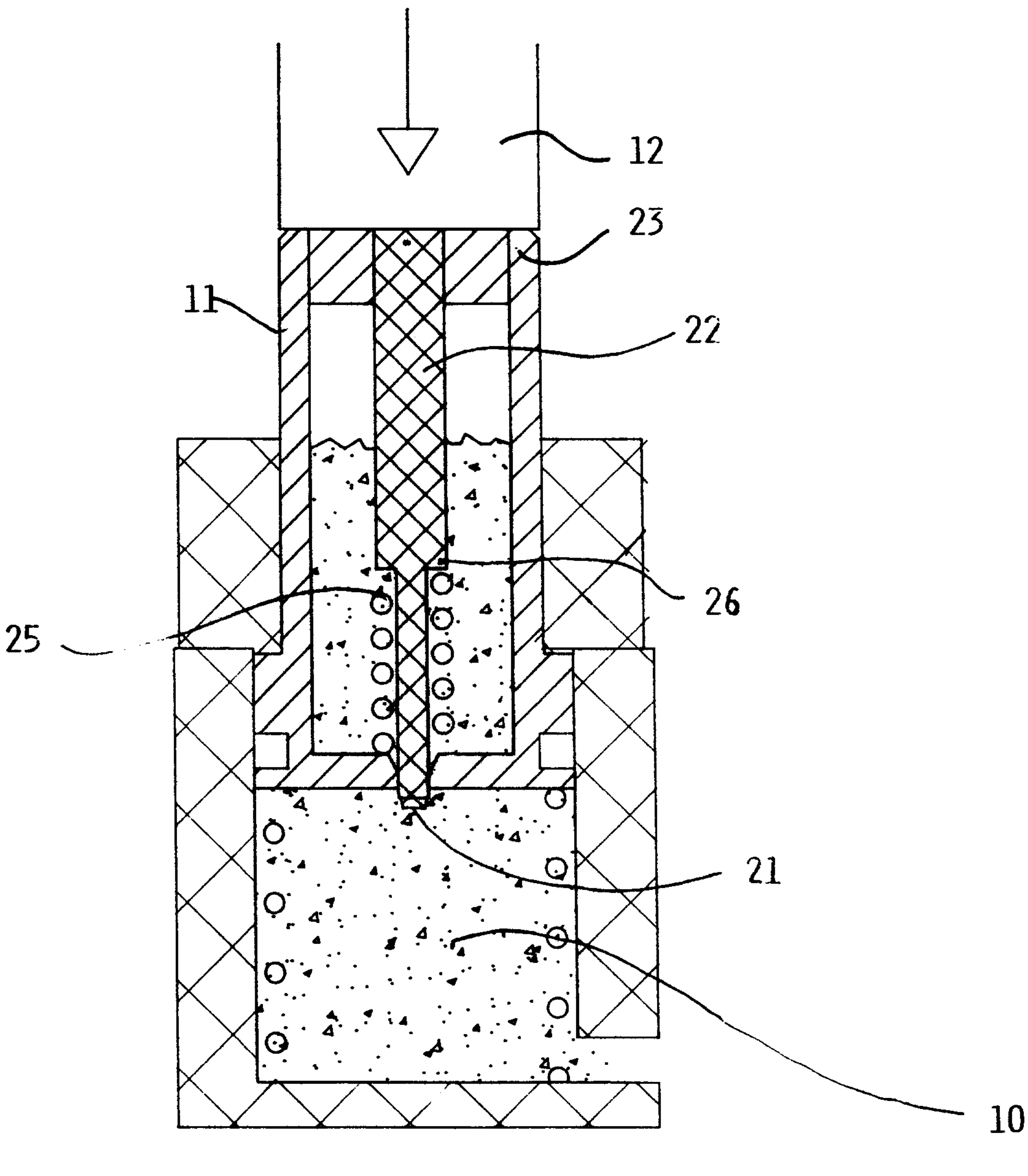

FIG. 5A

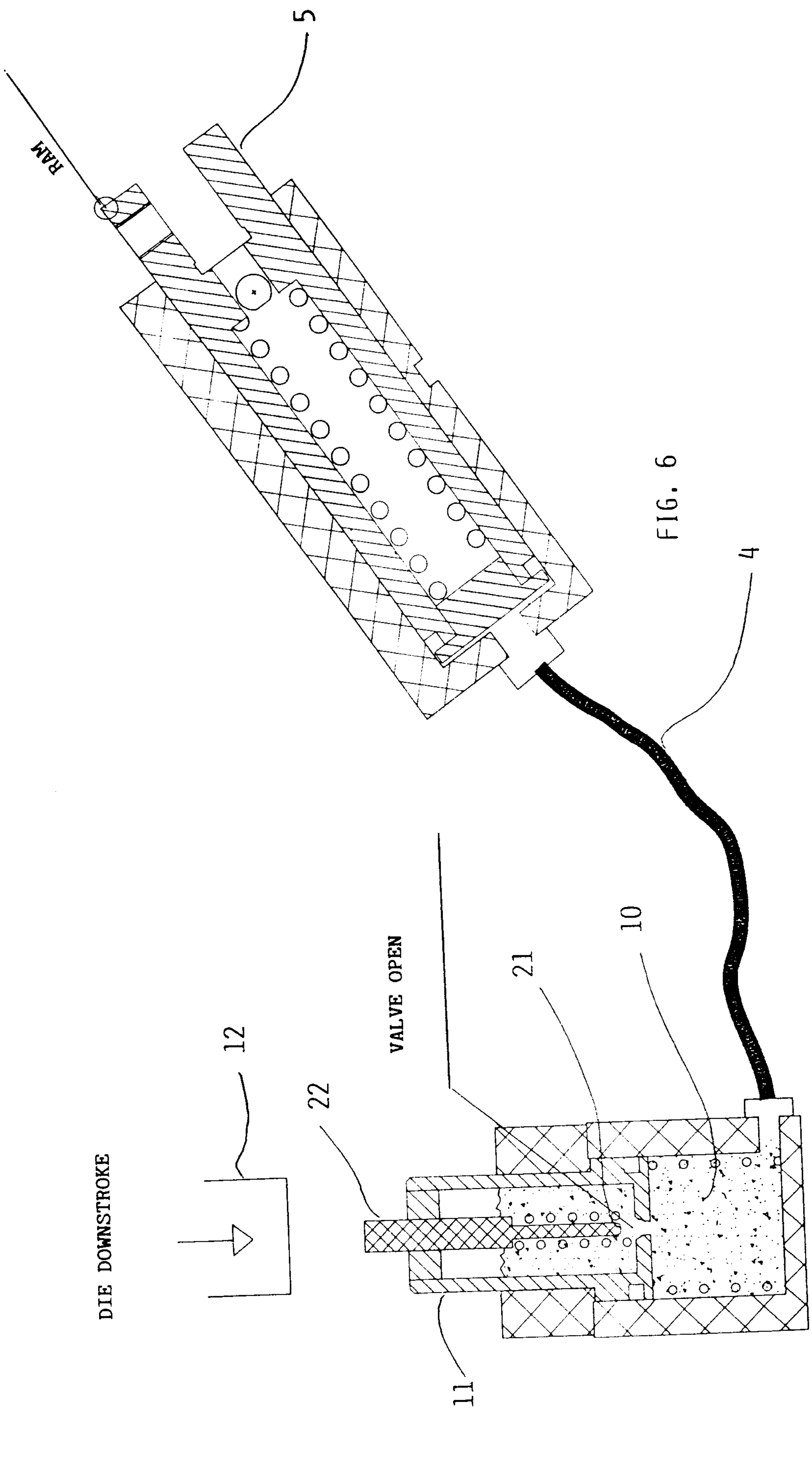

FIG. 6

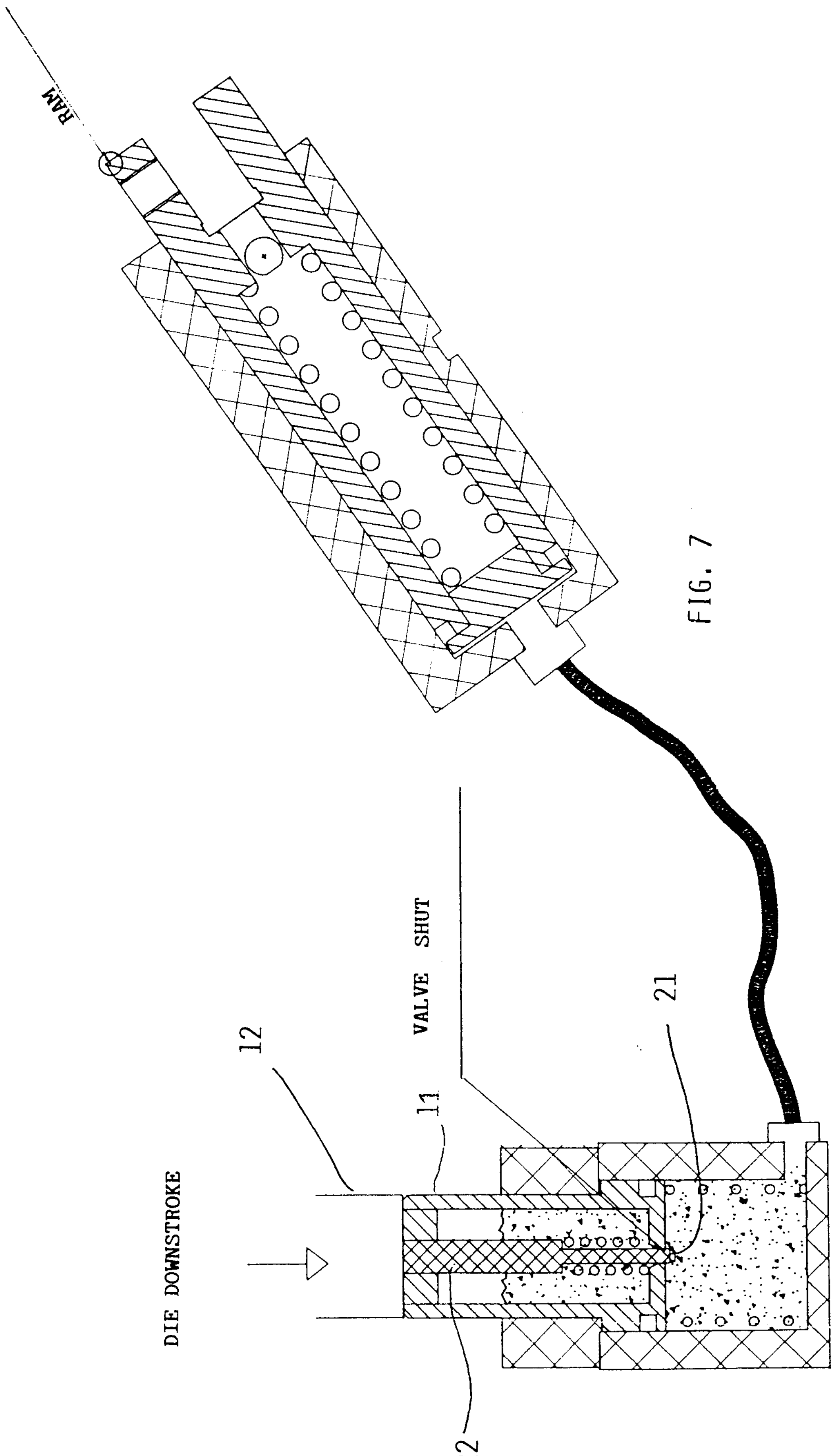

FIG. 7

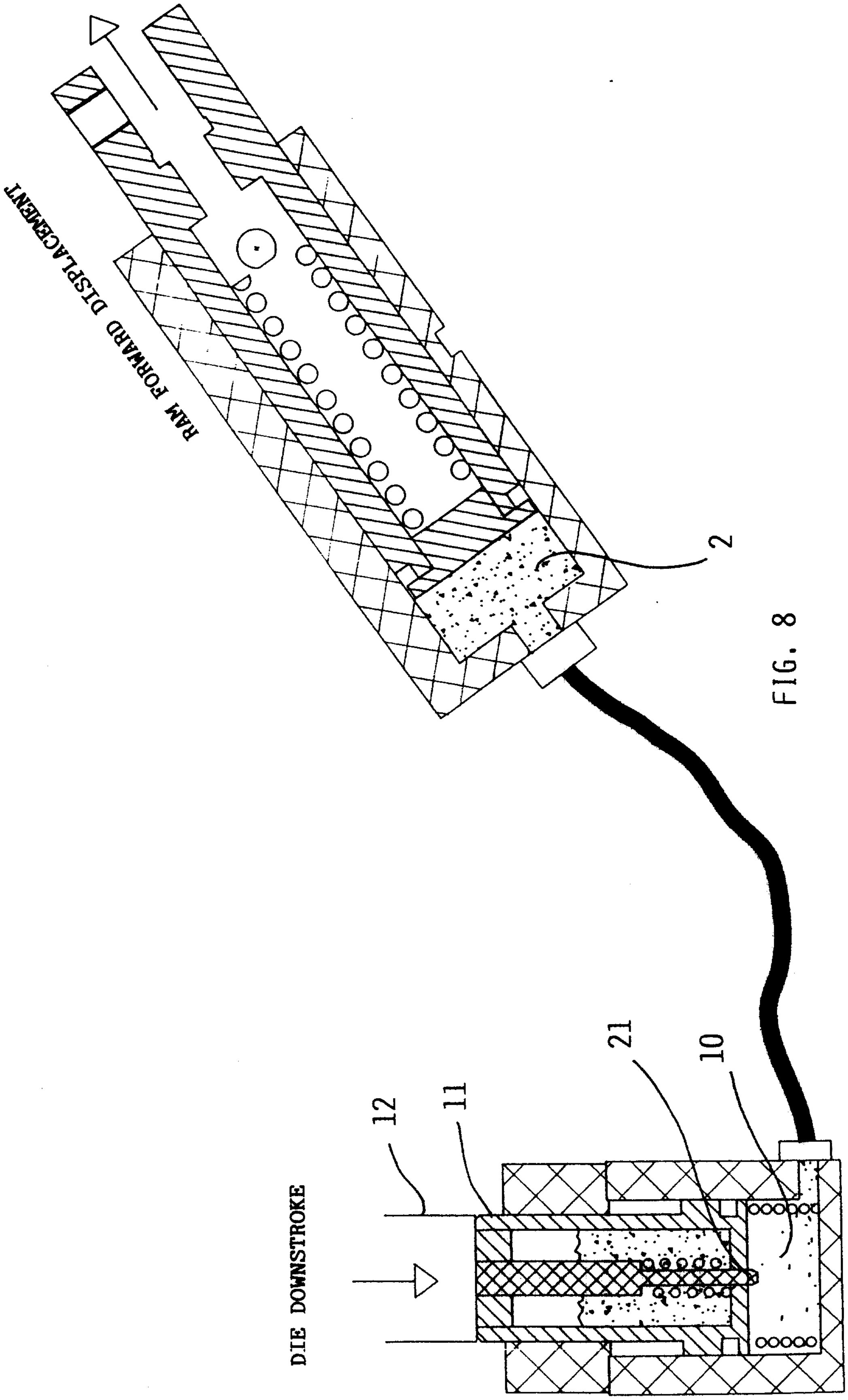

FIG. 8

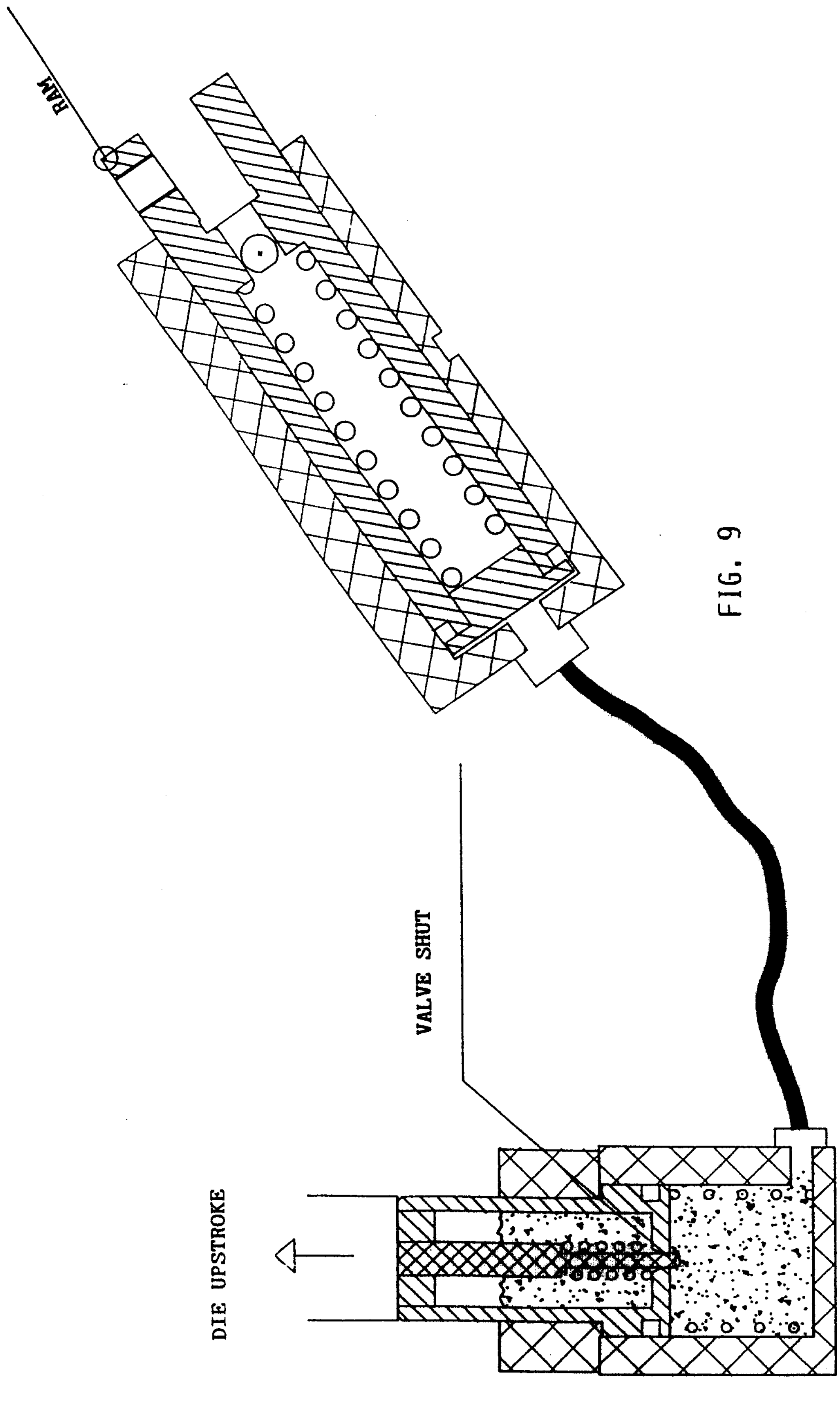

FIG. 9

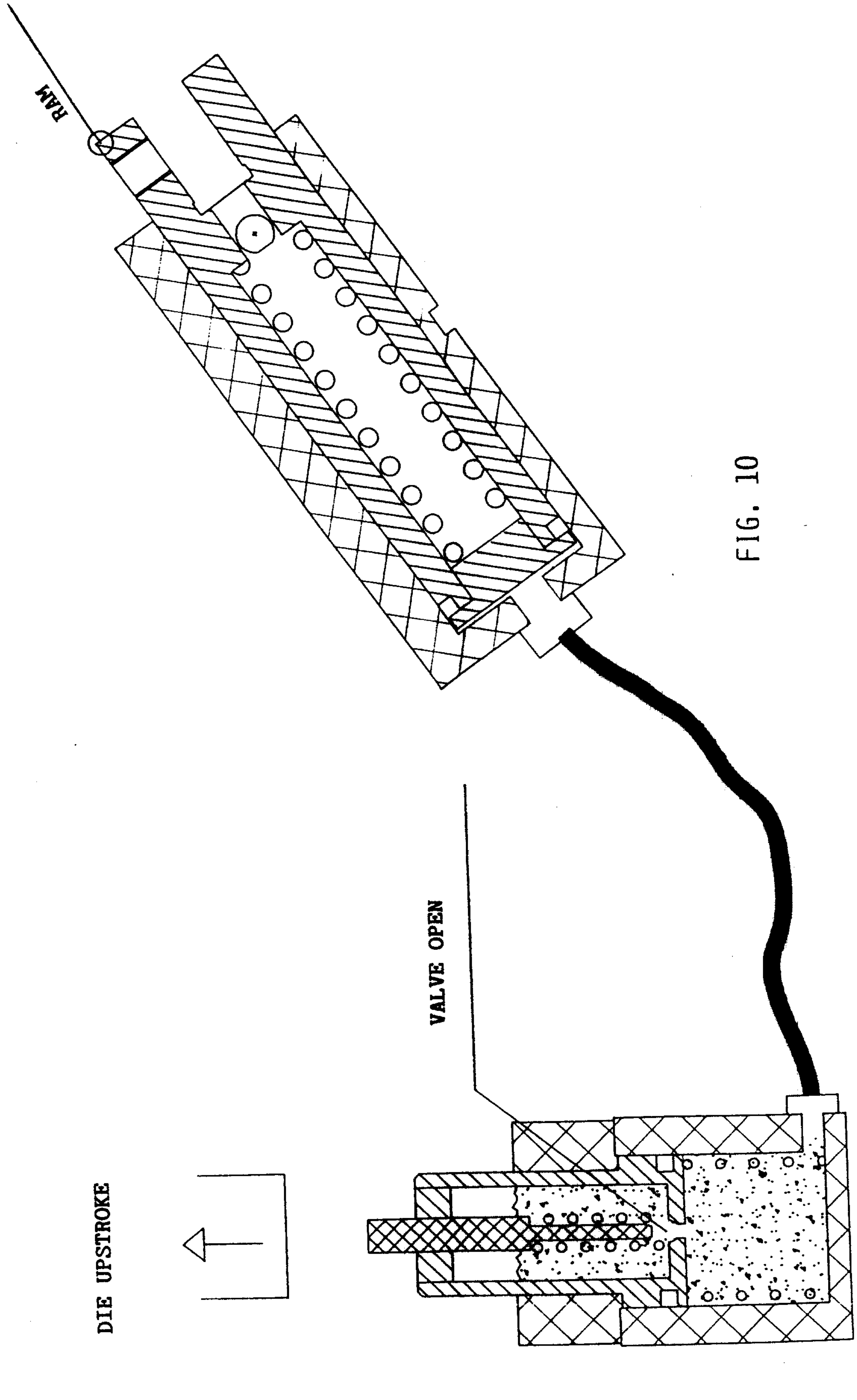

FIG. 10

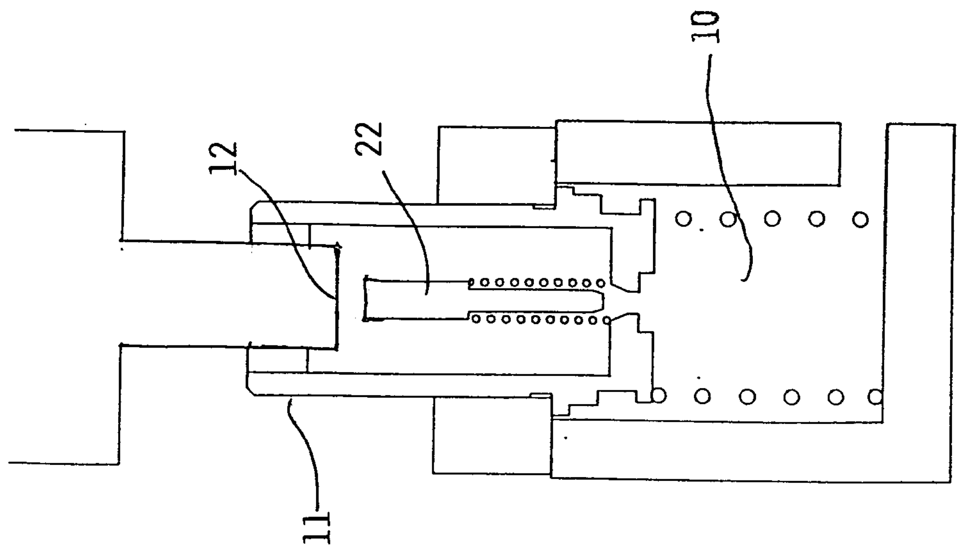

FIG. 13

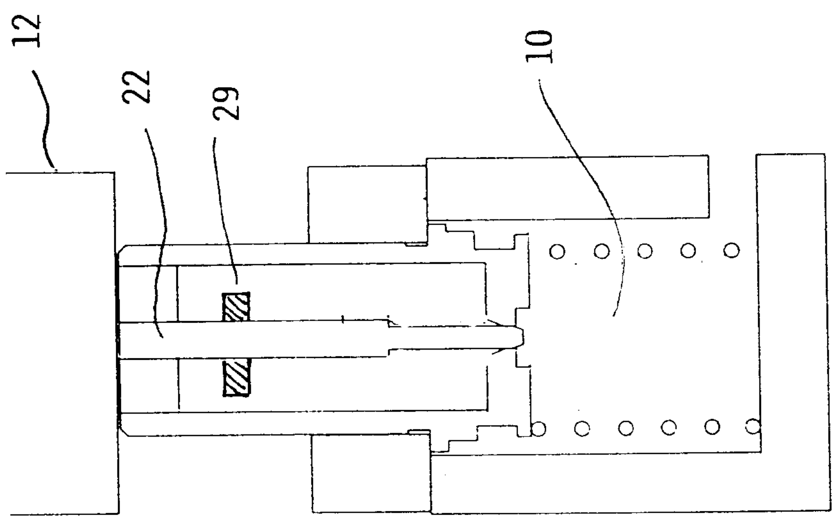

FIG. 11

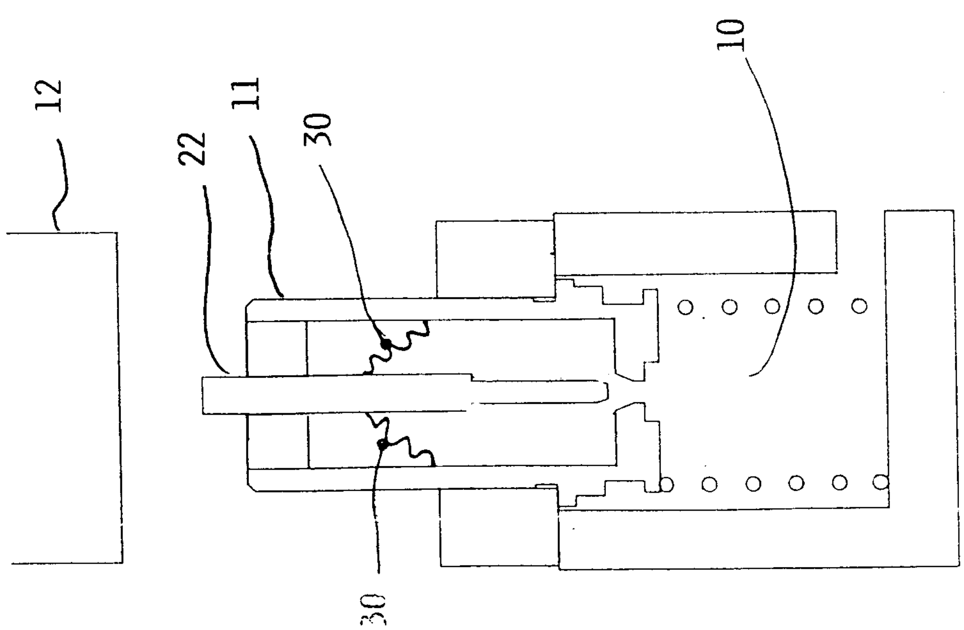

FIG.12

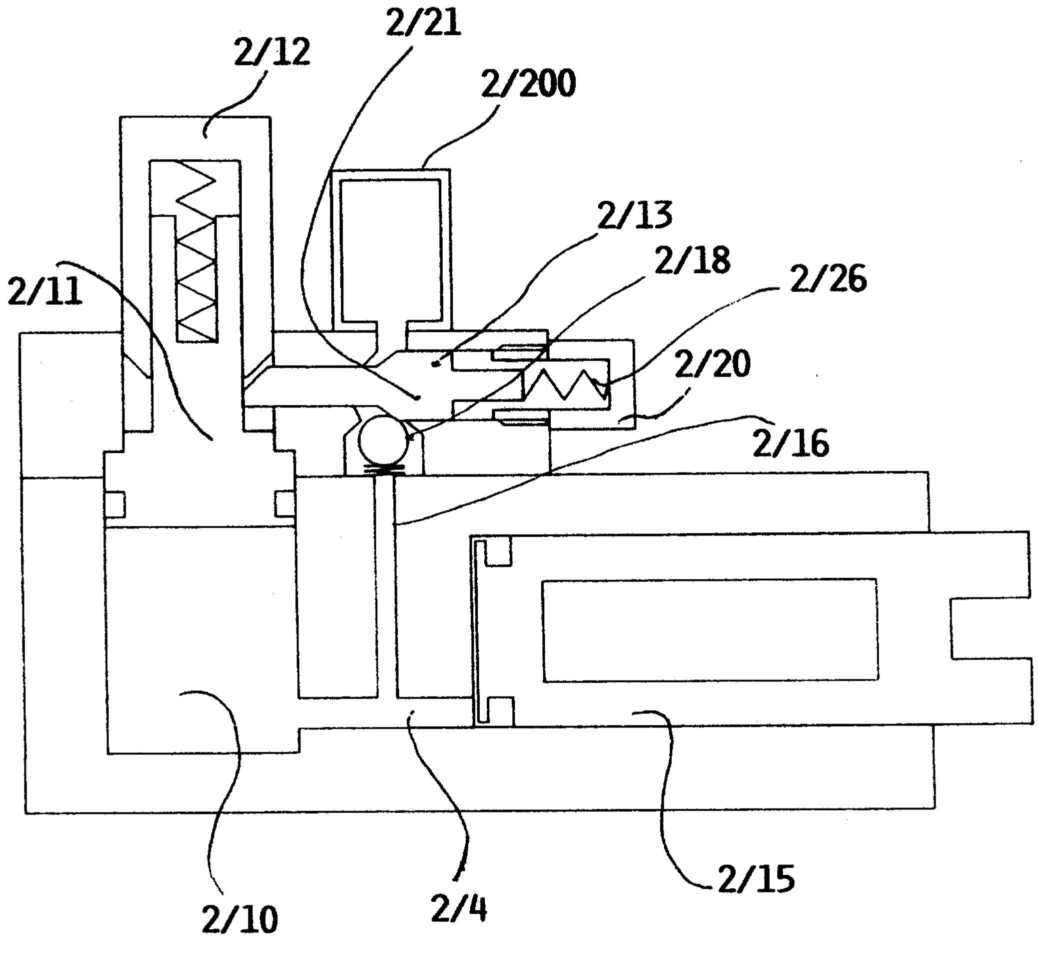

FIG. 14

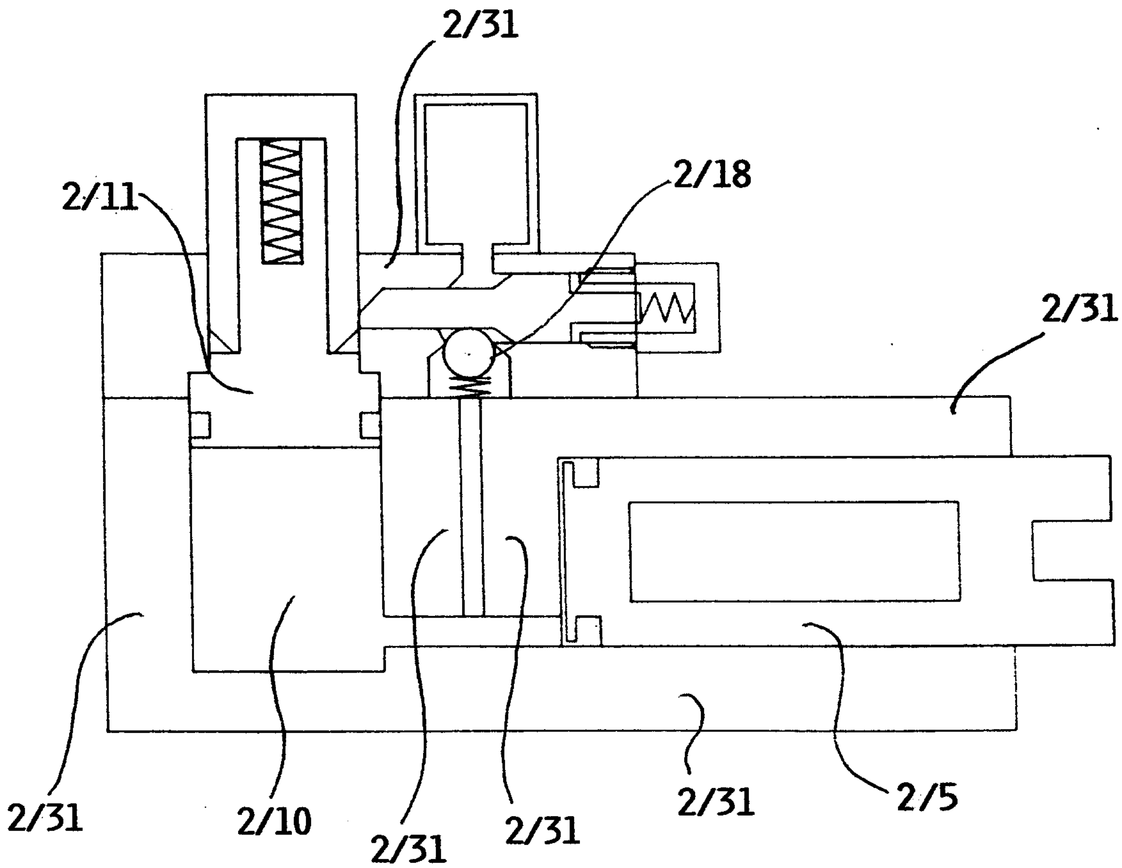

FIG. 15

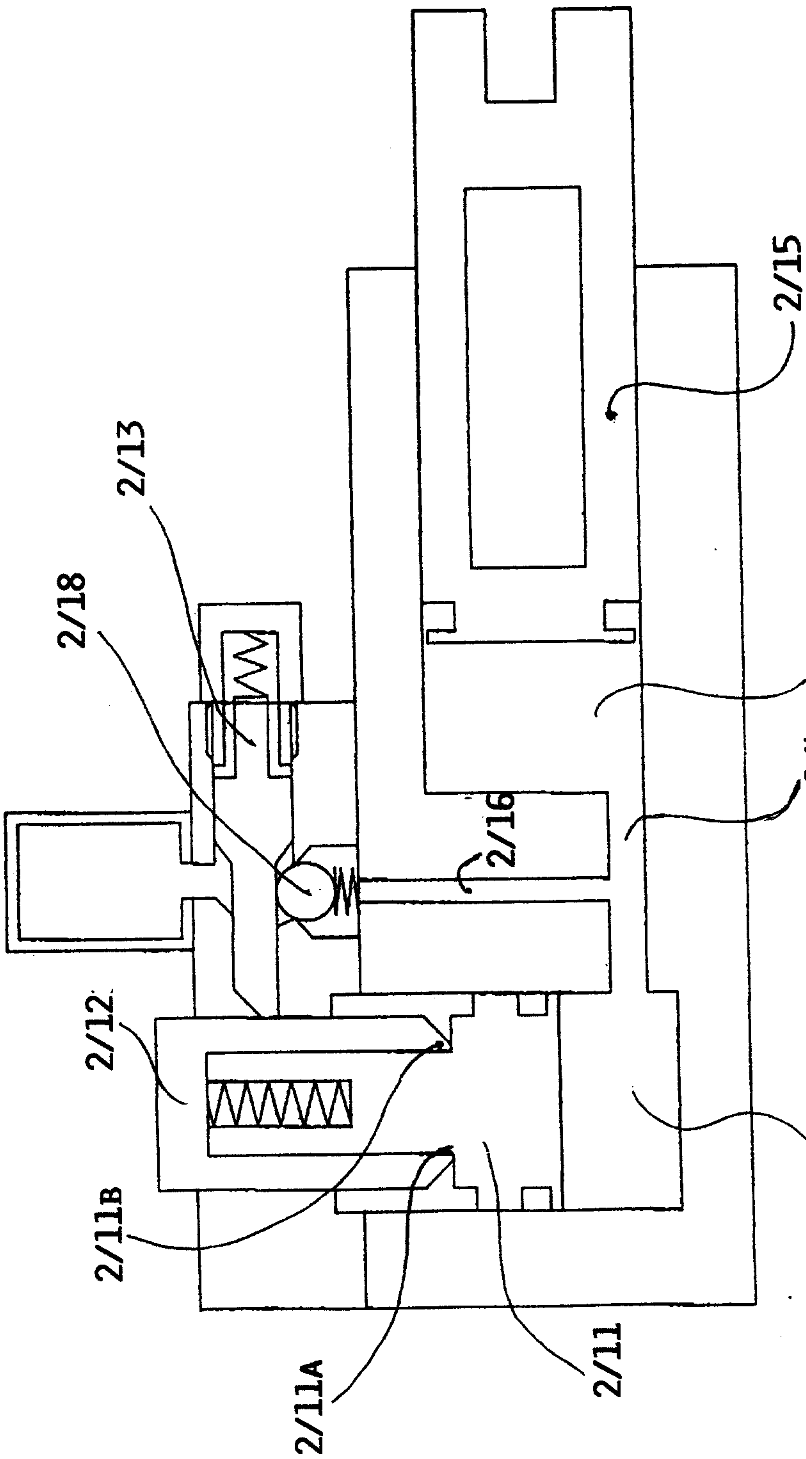

FIG. 16

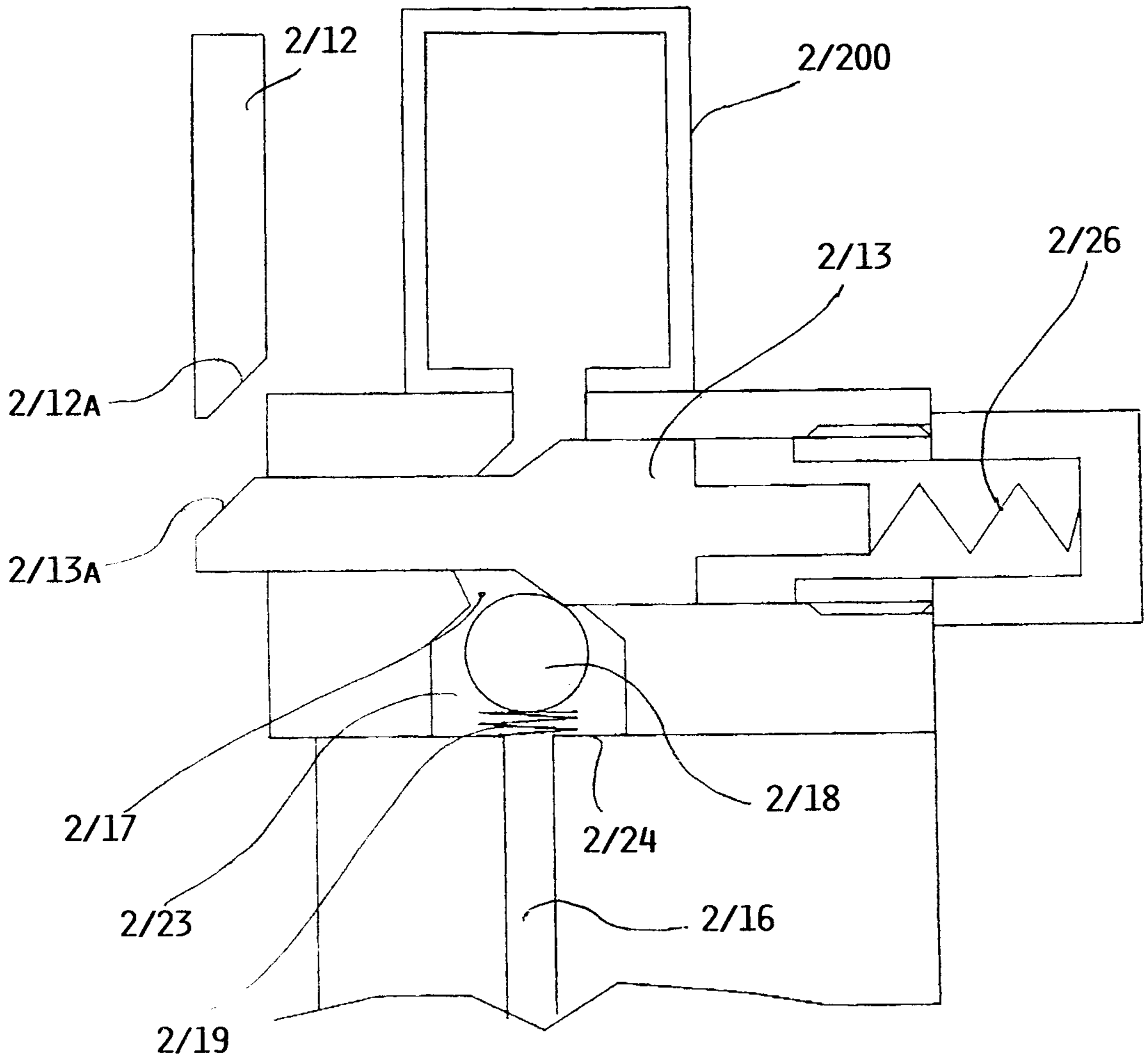

FIG. 17

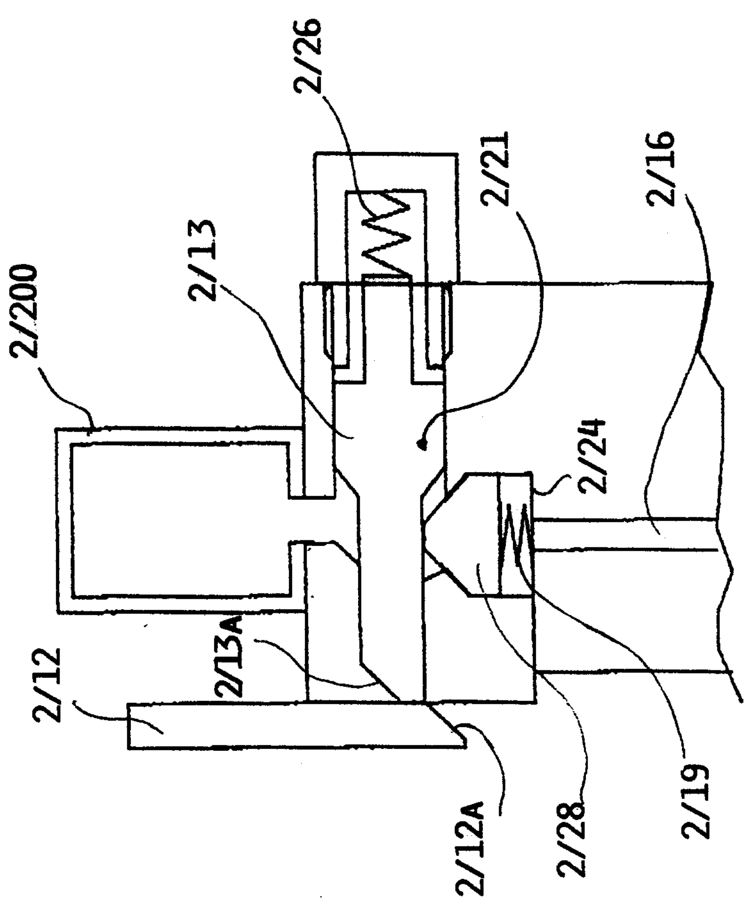
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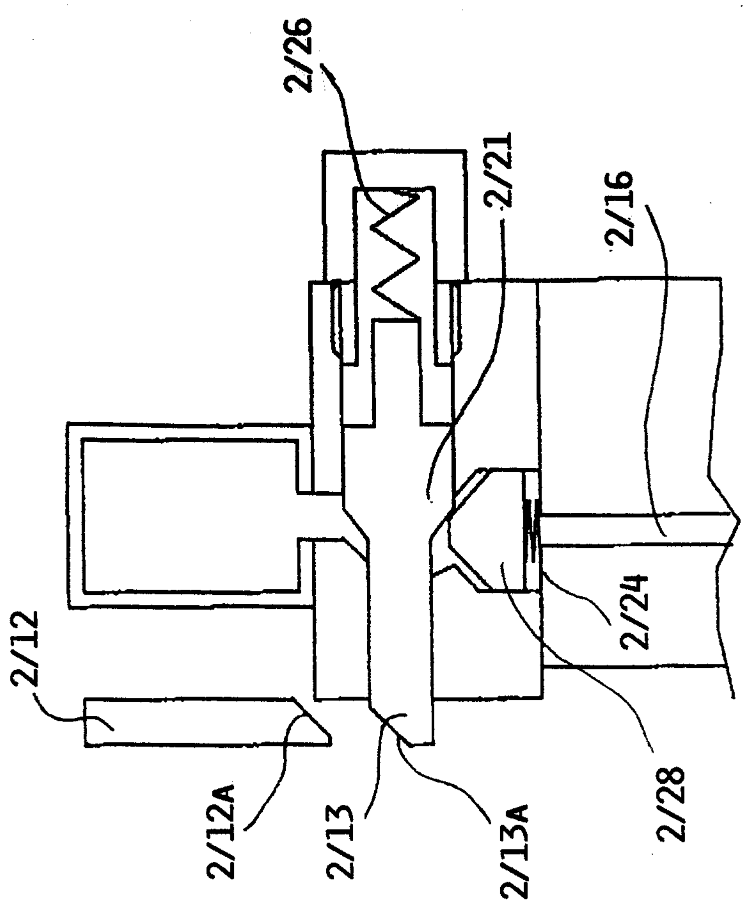
FIG. 18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2/13A
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FIG. 19

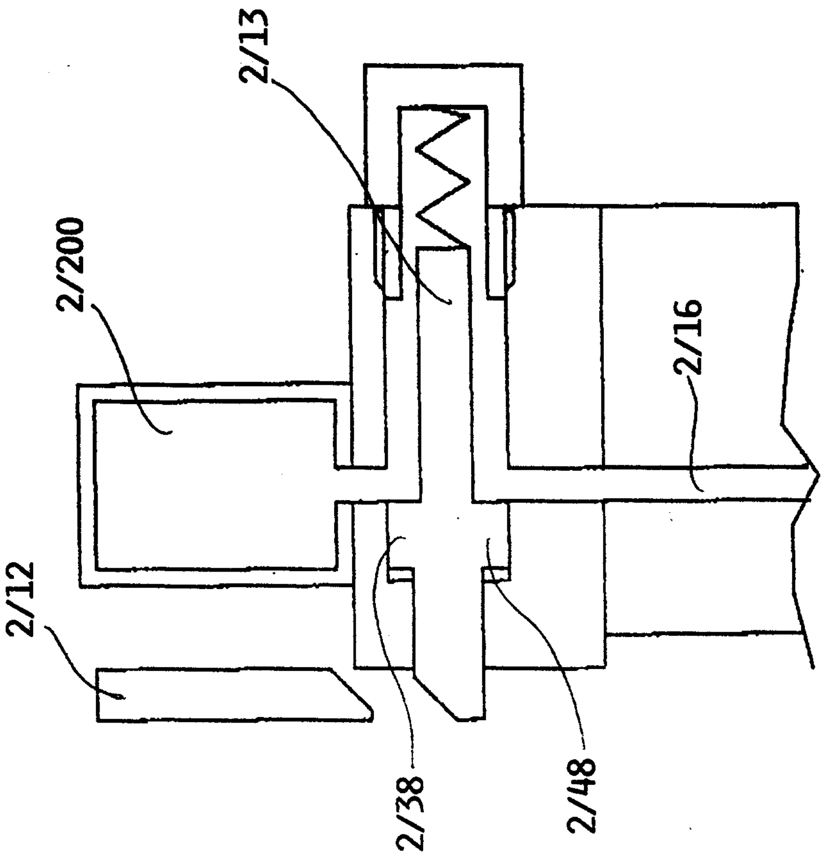

FIG. 21

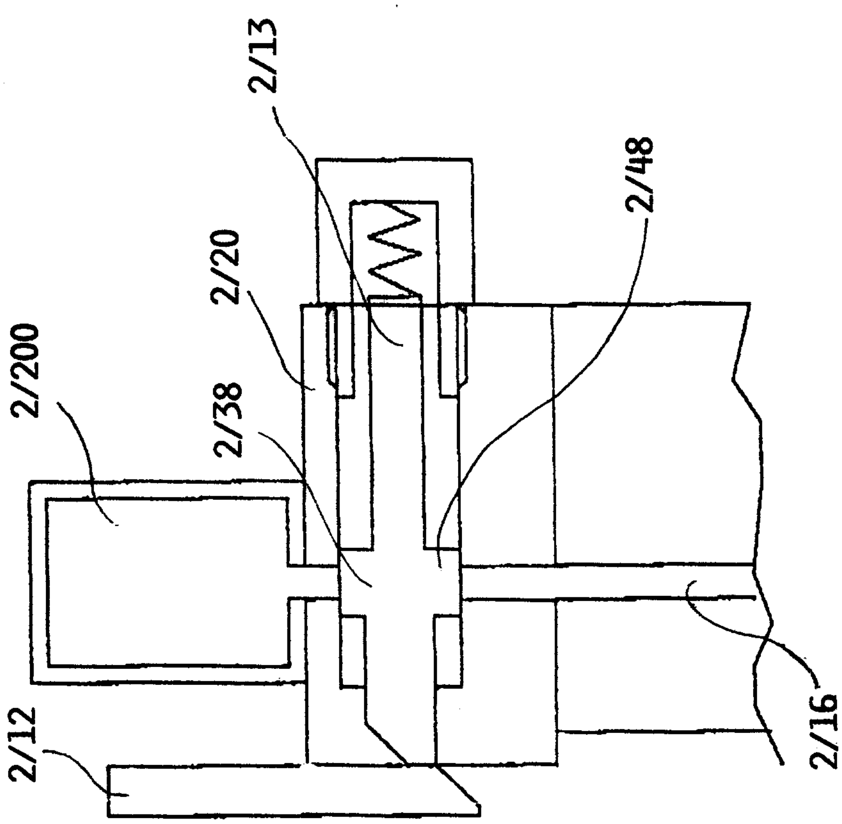

FIG. 20

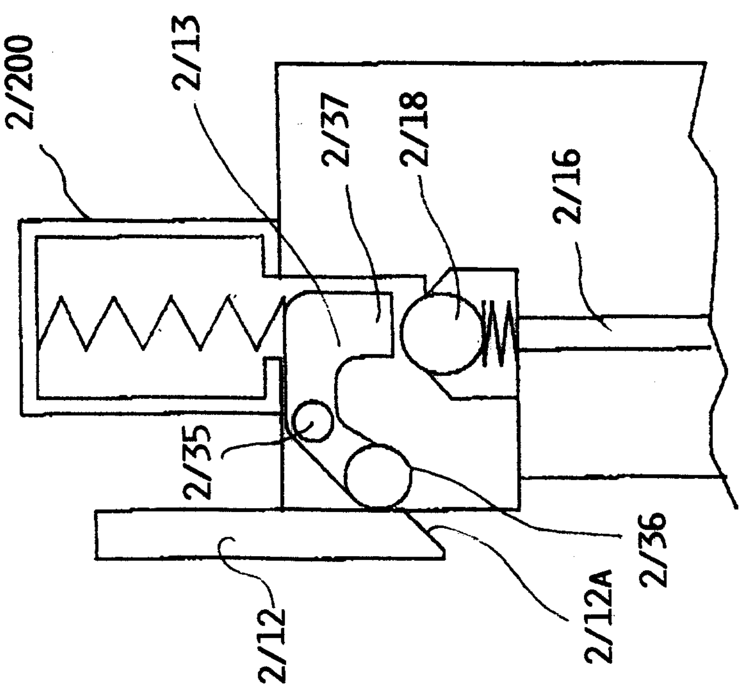
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FIG. 22

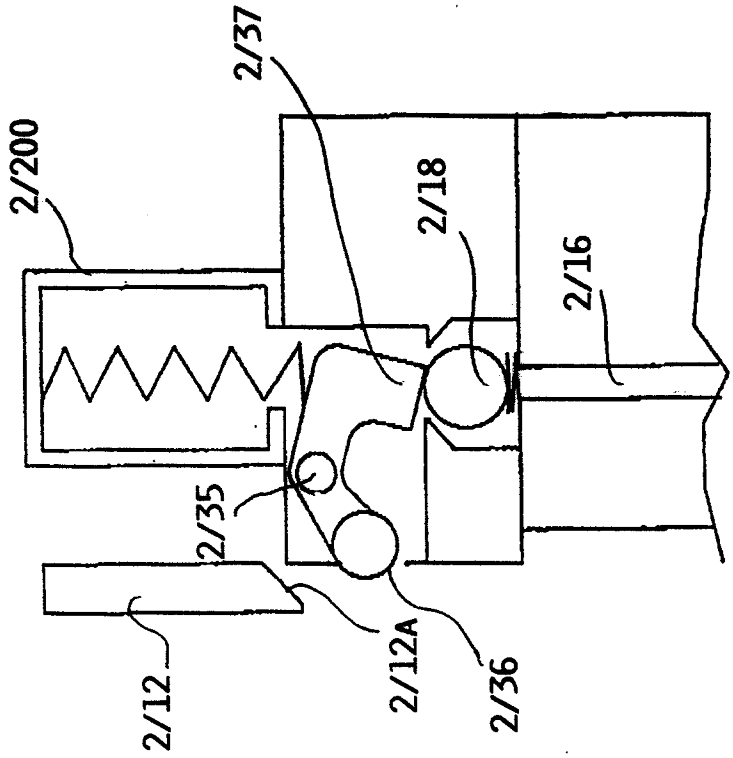
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FIG. 23

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 11 5451

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	GB 542 871 A (PRAT) * page 4, line 17 - line 64; figure * ---	1-5	F15B7/08
A	DE 30 02 850 A (AUDI NSU AUTO UNION AG) * page 7; figure * ---	1	
A,D	EP 0 251 796 A (LINVAL RODNEY) * abstract * ---	1,10	
A,D	WO 94 25260 A (DANLY MICHAEL D ;KATZ WOLFGANG (DE)) * abstract * -----	1,10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			F15B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 December 1997	Christensen, J

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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