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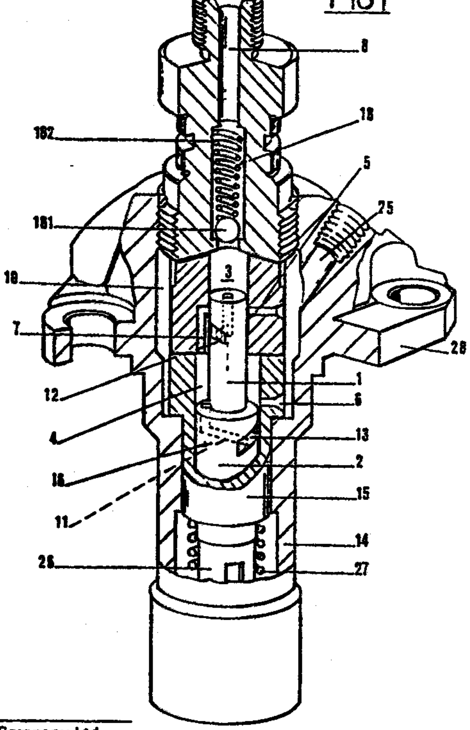
(54) A two-stage pumping element for a fuel injection pump, with mechanical governor.

(57) The mechanically governed fuel injection pumping element disclosed is embodied with a piston (16) in two stages (1, 2), and a barrel (15) incorporating a gallery (7) which interconnects two pressure chambers (3, 4) to the end of producing a dual injection when the assembly is reciprocated by a common drive component (17), thereby providing a more gradual rate of injection. In a preferred embodiment, the two stages (1, 2) are proportioned such as to dictate the quantity ratio between the two injections, and the interval of time separating them.

FIG1



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Croydon Printing Company Ltd.

A two-stage pumping element for a fuel injection pump, with mechanical governor.

The invention relates to a two-stage pumping element for a fuel injection pump, in which flow rate of the fuel is governed mechanically.

The art field in question embraces two types of fuel system for the Diesel internal combustion engine: indirect injection and direct injection.

In the first system, the requisite quantity of fuel is injected into a pre-combustion chamber which communicates with the cylinder, before passing into the combustion chamber proper. This is a technique permitting of relatively low injection velocity, and of combustion whereby propagation can be controlled in such a way that the engine runs more quietly and is subject to less of the mechanical stresses typical of detonation.

In the direct injection system, the requisite amount of fuel is injected into the combustion chamber direct, and at high velocity, a condition necessary in particular where high performance is to be obtained in terms of output. This signifies that ignition is brought about in a shorter interval of time than is the case with indirect injection, since one firing wave only is propagated, and all the fuel is burned at once. In effect, detonation occurs, with the result that the engine is more noisy, and is subjected to greater mechanical stresses than those undergone by an engine in which injection is indirect.

Direct injection offers the advantage, however, of providing lower specific fuel consumption than indirect injection.

The drawback with pumps of conventional injection systems, direct injection especially, is that one has a relatively great volume of fuel injected into the combustion chamber, the flow of which cannot be controlled over a given period of time; this results in the hazard of detonation.

Accordingly, the object of the invention disclosed is that of overcoming the drawbacks mentioned above. Adopting a pumping element as characterized in the appended claims, one is provided with a solution to the problem of embodying such an element for a fuel injection pump with mechanical governor in which the facility exists of injecting each discrete quantity of fuel into the combustion chamber gradually, and at the optimum rate for the given combustion system. Such an object is realized by splitting the injection sequence into two stages, in the first of which a small amount of fuel is injected, sufficient to produce combustion of limited violence; the remainder of the overall quantity of fuel is then injected gradually, metered in such a way that any violent propagation of the firing wavefront is avoided, and detonation duly prevented. In a preferred embodiment, the first injection stage is produced with a small diameter pumping element the dimensions of which enable ultra-precise metering of a miniscule quantity of fuel.

One of the advantages provided by the invention consists essentially in the fact of obtaining low cost and high dependability, typical of mechanical pump equipment, at one and the same time. This is made possible by virtue of the two-stage design of the pumping element, which first injects a fraction of the requisite discrete quantity of fuel to act as a pilot jet, and then injects the remainder following a given interval of time. The function of the pilot jet is that of providing an activating component to promote more gradual combustion of the quantity of fuel required to produce specified output.

Another advantage of the invention is that it gives the facility of metering any given proportion between flow required to produce a pilot jet and flow supplying the remainder of the discrete quantity of fuel. Such a feature is yet easier to incorporate, at no great expense, with the piston of the pumping element split into two sections; in such an embodiment, one has only to modify the combination of the piston's component parts to produce pumping elements having different operating characteristics.

A further advantage provided by a pumping element according to the invention, stemming from the fact that the piston is split into two sections, is that of an embodiment in which the two sections are absolutely coaxial and require no special machining. The idea is carried easily into effect by virtue of the fact that the two sections are associated in a loose fit, the flat end of the one section being brought into contact with the slightly-domed ball end of the other in such a way that the two adapt readily and fall into coaxial alignment. This loose fit between the two sections of the piston in no way jeopardizes operation of the pumping element, since the greatest effort required of the piston will always be exerted when its two confronted ends are in contact.

The invention will now be described in detail, by way of example, with the aid of the accompanying drawings, in which:

fig 1 shows the perspective of a pumping element according to the invention, in which certain parts are cut away, and certain omitted, better to reveal others;

figs 2 and 3 are axial elevations of two alternative embodiments of the piston utilized in a pumping element according to the invention, in which certain parts are cut away better to reveal others;

figs 4...8 are axial sections which illustrate the succession of steps in the work cycle of a pumping element according to the invention;

figs 9...12 are schematic representations indicative of the basic positioning options for two helical grooves provided in respective stages of a pumping element according to the invention, and illustrating the relative manner in which flow is governed.

With reference to fig 1, a pumping element for fuel injection pumps with mechanical governor consists of a housing 14 accommodating a barrel 15 inside which a piston 16 is reciprocated axially, in fluid-tight conditions, by a drive component 17 impinging on one of its ends (the bottom end, as illustrated in figs 4...8).

An inlet chamber 10 is created between the housing 14 and the barrel 15, which is supplied with fuel at a given pressure via a port 25 in the housing 14. The barrel 15 is held in position within the housing by a check valve 18 the outlet of which, hereinafter referred to as the pressure outlet 8, connects with the combustion chamber.

The barrel 15, piston 16 and check valve 18 combine to establish a pressure chamber 3 that connects with the pressure outlet 8. The check valve 18 is of the type having a ball 181 (see figs 1 and 4...8), this being biased by a spring 182 into a position which blocks that end of the pressure outlet 8 connecting with the pressure chamber 3. With such an arrangement, a rise in pressure within the chamber 3 beyond the setting of the bias spring 182 will cause fuel occupying the chamber 3 to exhaust via the pressure outlet 8, thence into the combustion chamber (not illustrated).

1 denotes the first stage of the piston 16, which exhibits a peripheral helical groove 12 into which one end of an orifice 9 emerges, the remaining end of the orifice emerging into the pressure chamber 3. The helical groove 12 connects intermittently, when the piston 16 is reciprocated, with orifices that are located in the barrel 15 and connect with the inlet chamber 10. The piston 16 is rotatable about

its own axis, and is engaged from beneath by means, denoted 26, for governing flow rate; accordingly, by rotating the piston 16 and its helical groove 12, one alters the length of time per given engine speed for which the groove 12 is connected with the inlet chamber 10, thereby adjusting the rate of flow.

The bottom end of the piston 16 will be seen (figs 1 and 4) to extend a given distance beyond the barrel 15 and through a coil spring 27 which is designed to urge the end of the assembly into contact with the drive component 17, generally a cam 171 (one to each piston 16), and with the governor 26 which engages two parallel faces of the one piston 16.

The housing 14 incorporates at least one mounting 28 through which a bolt (not shown) may be inserted.

According to the invention, the piston 16 has an enlarged intermediate section 2, the second stage of the two stage design, accommodated slidably and in fluid-tight relationship by and with a corresponding section 15a of the barrel 15 with similarly enlarged bore. A chamber is thus formed between the barrel 15 and the first stage 1 of the piston 16, hereinafter referred to as the second pressure chamber 4, for a purpose that will become apparent.

The second stage 2 of the piston 16 also exhibits a helical groove 13, which connects with the second pressure chamber 4 by way of a second orifice 11 in the piston.

The barrel 15 incorporates at least a first and a third gallery 5 and 6 designed to connect the inlet chamber 10 with the first and the second pressure chamber 3 and 4, respectively, as well as being provided with at least one gallery 7 interconnecting the two pressure chambers 3 and 4, which emerges into the first pressure chamber 3 at the same height as the first gallery 5.

Fig 2 shows a first embodiment of the piston 16, in which one has two sections 19 and 20 associated in a loose fit.

The bottom section 19, which in substantial terms represents the second, larger diameter stage 2 of the piston 16, has a flat top end disposed normal to the longitudinal axis of the bottom section 19 itself, and exhibits a catch 21 directed toward the self-same longitudinal axis and positioned at right angles thereto.

22 denotes a slot at bottom of the top section 20, positioned to one side, in which the catch 21 of the bottom section 19 is loosely accommodated. The lower end of the top section 20 offered to the bottom section 19 exhibits a ball end of particularly gentle curvature which is designed make contact with the confronting flat end of the bottom section 19.

A structure such as this is made feasible by virtue of the fact that the greatest effort required of the piston 16 will always be compression-related -viz, with the top section 20 driven against the bottom section 19; accordingly, any misalignment between the two will be compensated by the ball end of the top section 20.

The second embodiment of the piston 16 illustrated in fig 3 likewise incorporates two sections, top 19 and bottom 20, loosely associated. In this instance, the bottom section 19, of larger diameter, exhibits an axial bore 23 of diameter marginally greater than the diameter of the top section 20 inserted therein. The fit between the two is achieved using a pin 24, inserted loosely in a diametral hole offered by the top section 20, and located tightly in corresponding radial holes in the bottom section 19.

The bottom end of the top section 20 in this embodiment likewise exhibits a ball end of gentle curvature, whereas the axial bore 23 of the bottom section 19 is stopped, the base of the bore being embodied flat and located at right angles to the longitudinal axis of the bore itself.

Operation of a pumping element according to the invention will now be described, with reference to figs 4...8.

At the start of the work cycle, the piston 16 will be at its lower limit position (see fig 4); in this state, the galleries 5, 6 and 7 are fully open, and the pressure chambers 3 and 4 are filled with fuel.

Next, one has an initial build-up of pressure produced by the first stage 1 of the piston, or pilot pressure (see fig 5), which comes about the moment that the piston, urged upwards by the cam 17, blocks the galleries denoted 5 and 7. Continuing on stroke, the first stage 1 of the piston displaces a given volume of fuel from the chamber denoted 3 into the outlet 8, at high pressure. This initial volume of fuel will be metered to precision, seeing that the first stage 1 of the piston 16 is of small diameter, and any minimal departure of the piston from its prescribed stroke will have no significant effect on displacement.

The volume of fuel displaced by the second stage 2 during this phase will vent to the inlet chamber 10 via the third gallery 6.

Pilot pressure terminates the instant that the orifice 9 serving the first stage 1 of the piston is connected with the interconnecting gallery 7 (as in fig 6).

Fuel under pressure in the first pressure chamber 3 is now vented to the second pressure chamber 4, in which pressure is lower, and from there drains to the inlet chamber 10 by way of the third gallery 6.

Between termination of the pilot injection (shown in fig 6) and commencement of the following injection (shown in fig 7), the piston 16 accomplishes a given travel during which there is no displacement of fuel through the pressure outlet 8. Entry into action of the second stage 2 of the piston, or full pressure, occurs the moment that the second stage 2 blocks the third gallery 6 (as in fig 7); it happens in this instant, that fuel displaced from the first pressure chamber 3 by the first stage 1, and fuel displaced by the second stage 2 toward the second pressure chamber 4 (by way of the interconnecting gallery 7 and the stage one orifice 9), will be exhausted as one through the pressure outlet 8.

Full pressure terminates the moment that the stage-two orifice 11 and the third gallery 6 are connected (as in fig 8). In this situation, fuel entering the pressure chambers 3 and 4 is vented to the inlet chamber 10 at low pressure, interrupting high pressure flow to the outlet 8.

The situation remains the same during completion of the stroke which brings the piston 16 to its upper limit, whereupon the return stroke takes the piston back toward the lower limit; during the course of the return stroke, the pressure chambers 3 and 4 will begin charging by way of the first and third galleries 5 and 6.

The quantity of fuel displaced by each stage 1 and 2 of the piston 16 during its work stroke is adjusted rotating the piston itself by way of the mechanical governor 26.

Set formats for variation of flow can be obtained by appropriate alteration of the lead angle, hand, and shape of the helical grooves 12 and 13 of the first and second stages 1 and 2 (see figs 9...12); there are four basic options in the case in point.

In describing the different types of adjustment in detail, use will be made of the expressions "groove leading" which signifies initial adjustment, hence an adjustment of the injection advance, and "groove following" which signifies a tail end adjustment, hence an adjustment of injection retard; all adjustments illustrated represent an increase in flow.

In fig 9, the first stage 1 has its groove leading, whereas the second stage 2 has its groove following. In this instance, the interval of time **k** between pilot pressure and full pressure remains constant; advance flow on pilot injection **a** increases whilst retard flow remains constant; retard flow on full injection **b** increases whilst advance flow remains constant.

In fig 10, both stages 1 and 2 have groove leading: the interval of time **k** between pilot pressure and full pressure is shortened; advance flow increases on both injections, retard flow on both remaining constant.

In fig 11, the first stage 1 has groove following, whereas the second stage 2 has groove leading: the interval of time **k** between pilot pressure and full pressure is shortened; retard flow on pilot injection **a** increases, and advance flow remains constant; advance flow on full injection **b** increases whilst retard flow remains constant.

In fig 12, both stages 1 and 2 have groove following: the interval of time **k** between pilot pressure and full pressure is shortened; retard flow is increased on both injections, advance flow on both remaining constant.

Claims

1) A pumping element for a fuel injection pump, with mechanical governor, of the type comprising:
-a housing (14) accommodating a barrel (15) inside which a piston (16) is reciprocated axially and in fluid-tight relationship by a drive component (17) impinging on one of its ends;
-an inlet chamber (10) created between the housing (14) and the barrel (15) and connected with a source of pressurized fuel;
-a pressure chamber (3) encompassed by the remaining end (1) of the piston (16) and the barrel (15), connecting on the one hand with a pressure outlet (8), by way of a check valve (18), and on the other with a helical groove (12) exhibited by the periphery of the piston (16), by way of an orifice (9) in the piston itself, wherein the helical groove (12) connects intermittently with the inlet chamber (10), and the piston (16) is rotatable about its own axis and driven in such rotation by the governor,
characterized
in that the piston (16), the one end (1) of which constitutes a first stage, comprises a second stage (2), located at an intermediate position along its length and accommodated slidably and in fluid-tight relationship by a corresponding section (15a) of the

barrel (15), which combines with the first stage (1) to create a respective second pressure chamber (4) and is provided with a respective peripheral helical groove (13) that connects with the second pressure chamber by way of an orifice (11) located in the piston (16);

in that the barrel (15) incorporates a first gallery (5) connecting the first pressure chamber (3) with the inlet chamber (10), a second gallery (7) inter-connecting the two pressure chambers (3, 4), and a third gallery (6) that connects the second pressure chamber (4) with the inlet chamber (10), wherein the first and second galleries (5, 7) emerge into the first pressure chamber (3) at the same height, and the first and third galleries (5, 6) emerge into the relative first and second pressures chambers (3, 4) at points spaced apart such that the piston (16) may be shifted by the drive component (17) from a first limit position in which the three galleries (5, 7, 6) connect directly with the first and second pressure chambers (3, 4) and the inlet chamber (10), respectively, to a second limit position in which the first gallery (5) is blocked by the first stage (1) of the piston and the second and third galleries (7, 6) are connected with the orifices (9, 11) of the first and second piston stages, respectively, passing through a first intermediate position in which the first and second galleries (5, 7) are blocked by the first stage (1) of the piston such

that pressure in the first pressure chamber (3) will build in excess of the check valve (18) setting and cause an initial, small quantity of fuel to exhaust by way of the pressure outlet (8), while the third gallery (6) connects the second pressure chamber (4) with the inlet chamber (10), and a second intermediate position in which the first and third galleries (5, 6) are blocked respectively by the first and the second stage (1, 2) of the piston, and the second gallery (7) connects with the first orifice (9), such that pressure in the first and second chambers (3, 4) will build in excess of the check valve (18) setting and cause a further quantity of fuel, greater than the initial quantity, to exhaust by way of the pressure outlet (8); and,
in that the first stage (1) of the piston (16) is embodied with a smaller diameter than that of the second stage (2) in order that the initial quantity of fuel exhausted by way of the pressure outlet (8) can be metered with greater precision.

2) Pumping element as in claim 1, the piston (16) of which consists in two coaxial sections (19, 20) of dissimilar diameter associated one with the other in a loose fit, wherein the section (20) of smaller diameter is the embodiment of the first stage (1) of the piston, and the remaining section (19) of larger diameter is the embodiment of the second stage (2) of the self-same piston.

3) Pumping element as in claim 2, wherein that end of the section (19) of the piston (16) having the larger diameter which is offered to the section (20) of the piston (16) having the smaller diameter, is embodied flat, and provided with a catch (21) disposed at right angles to the longitudinal axis of the piston that engages loosely in a slot (22) offered by the relative end of the section (20) of smaller diameter, and wherein the end of the section of smaller diameter offered to the section of larger diameter exhibits a ball end of particularly gentle curvature designed to make contact with the confronting flat end of the section of larger diameter.

4) Pumping element as in claim 2, wherein that end of the section (19) of the piston (16) having the larger diameter which is offered to the section (20) of the piston (16) having the smaller diameter, incorporates a stopped axial bore (23), with a flat base, that loosely accommodates the section (20) of smaller diameter, and the two sections (19, 20) of the piston (16) are united by a pin (24) passing loosely through the section of smaller diameter (20) and located tightly in the section of larger diameter (19); and wherein the end of the section (20) of smaller diameter accommodated by the axial bore exhibits a ball end of gentle curvature.

5) Pumping element as in claim 1, wherein the helical grooves (12, 13) of the piston (16) are of similar hand.

6) Pumping element as in claim 1, wherein the helical grooves (12, 13) of the piston (16) are of dissimilar hand.

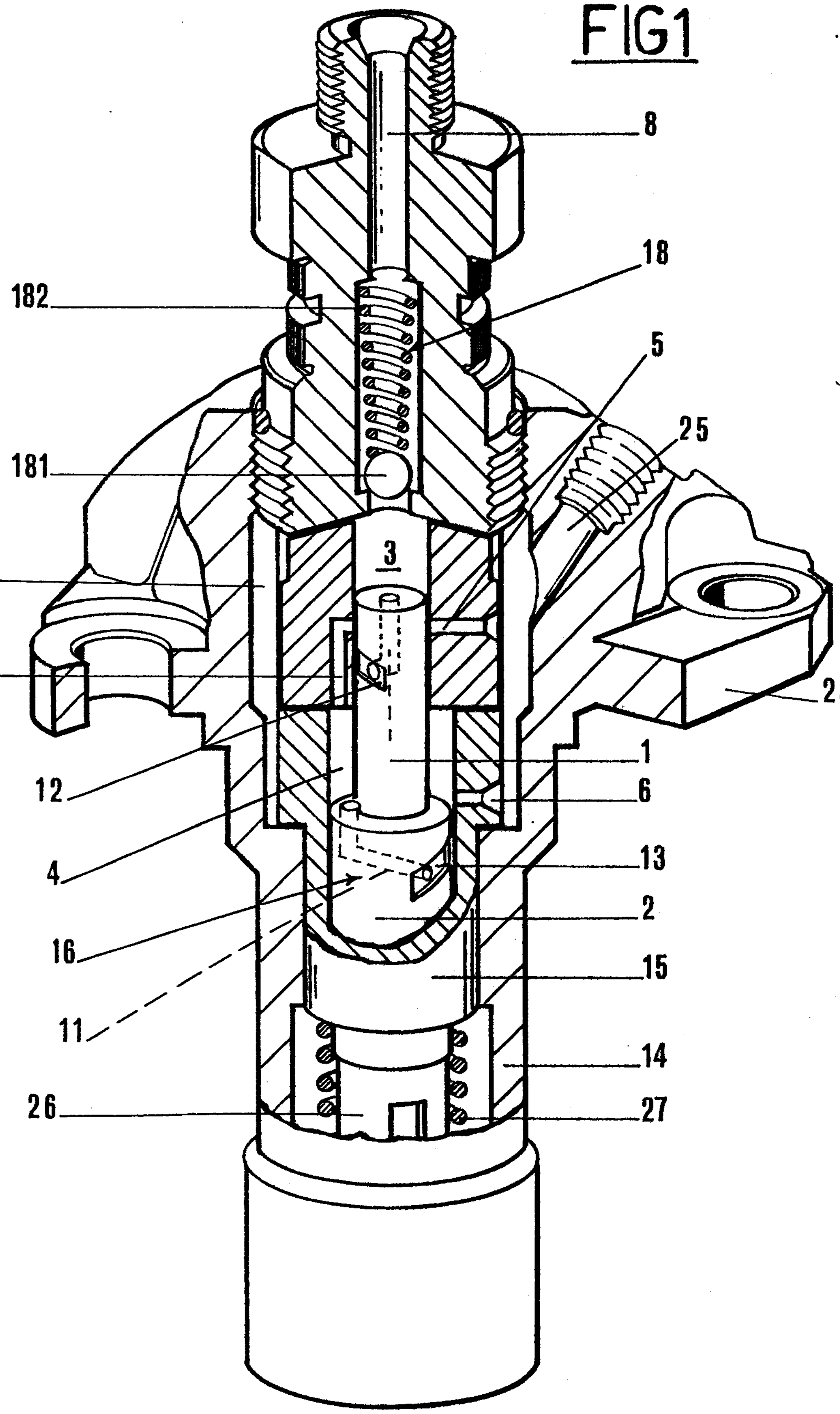
7) Pumping element as in claim 5 or claim 6, wherein the helical grooves (12, 13) of the piston (16) are identical in shape.

8) Pumping element as in claim 5 or claim 6, wherein the helical grooves (12, 13) of the piston (16) are dissimilar in shape.

9) Pumping element as in claim 7 or claim 8, wherein the helical grooves (12, 13) of the piston (16) exhibit identical lead angle.

10) Pumping element as in claim 7 or claim 8, wherein the helical grooves (12, 13) of the piston (16) exhibit dissimilar lead angle.

FIG1



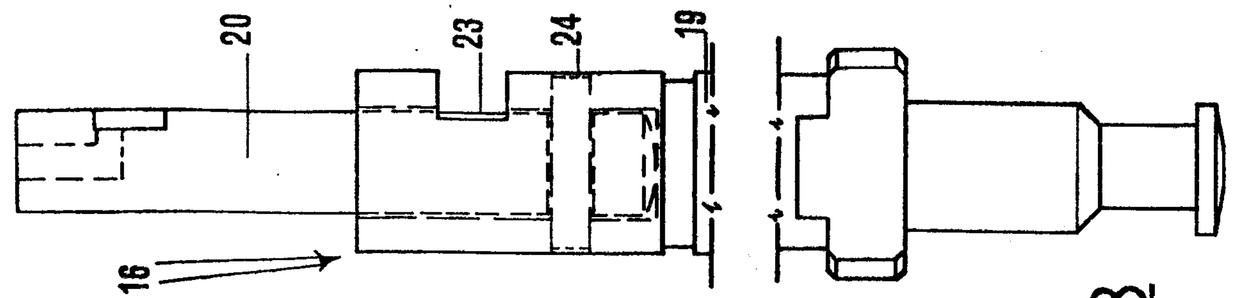


FIG3

FIG2

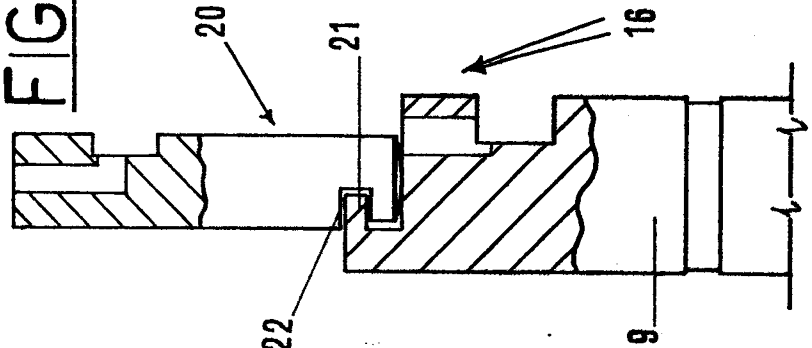


FIG8

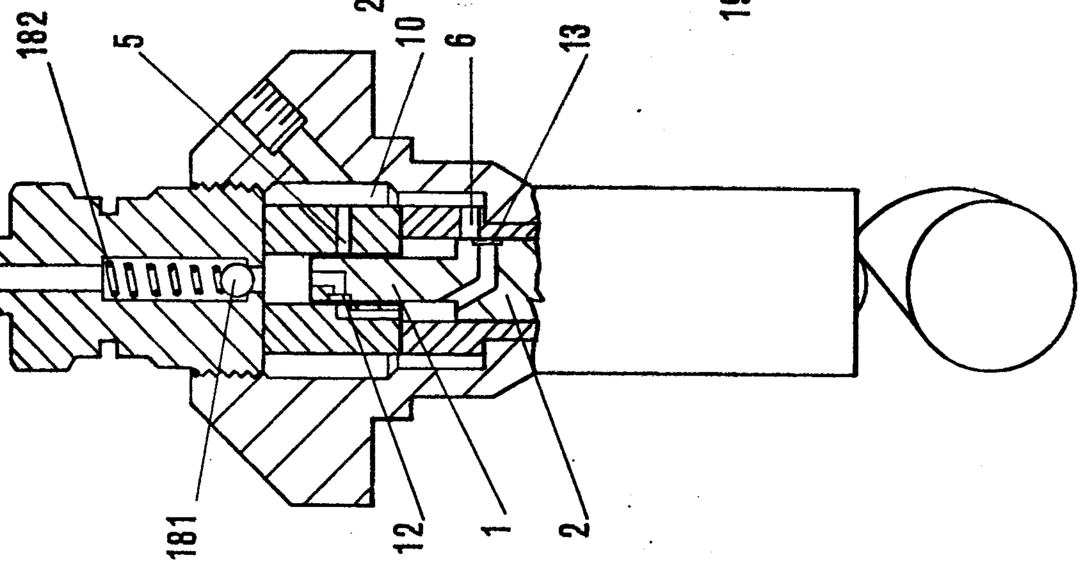


FIG7

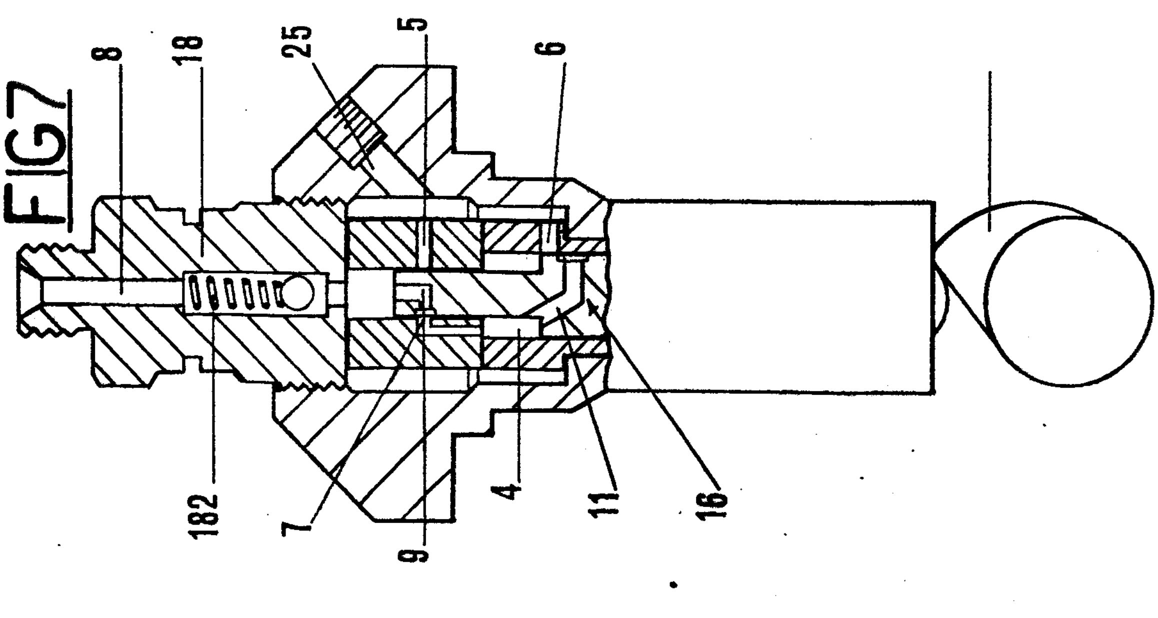


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FIG6

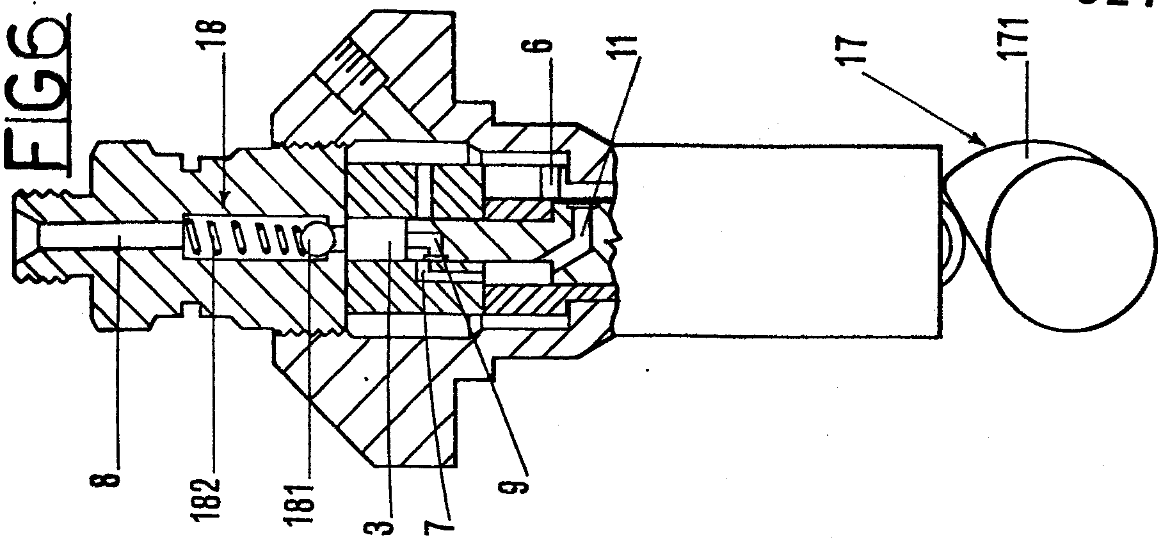


FIG5

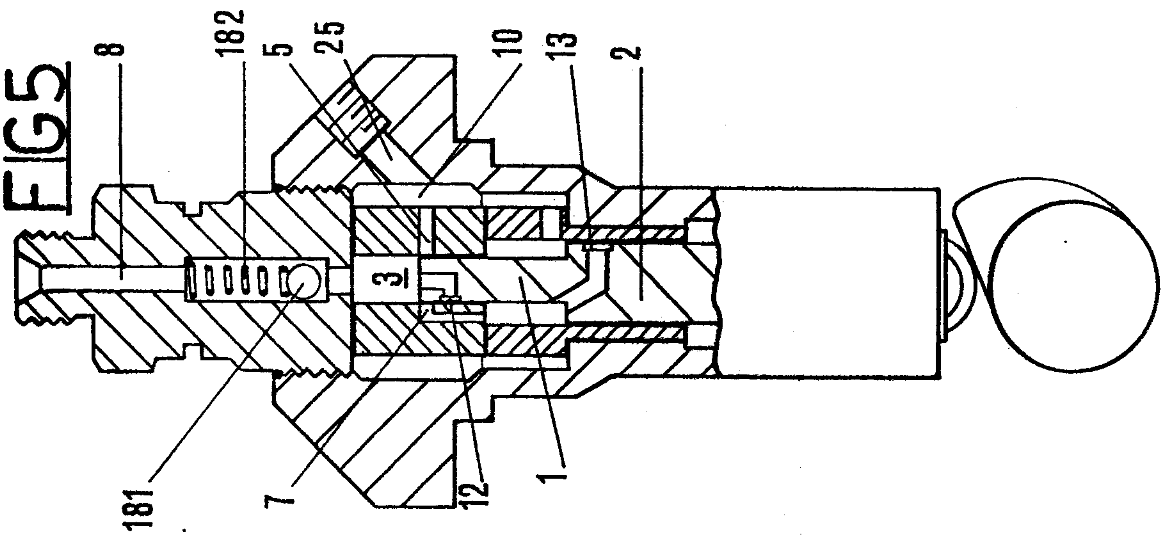
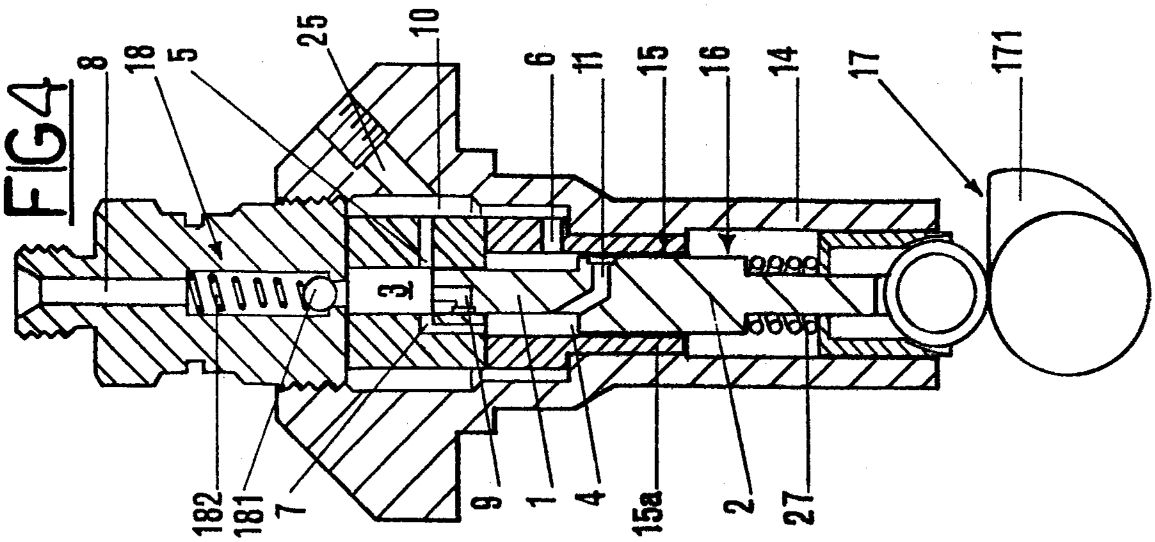


FIG4



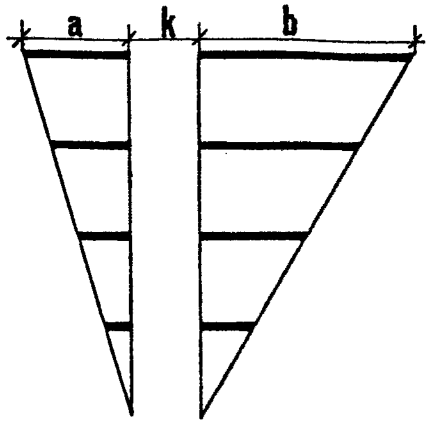
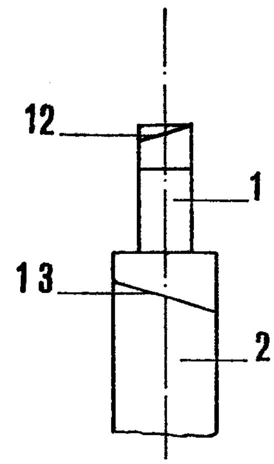


FIG9



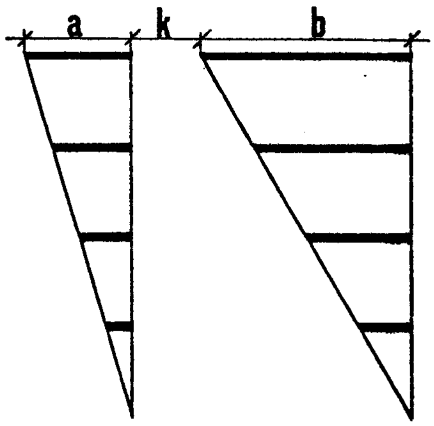
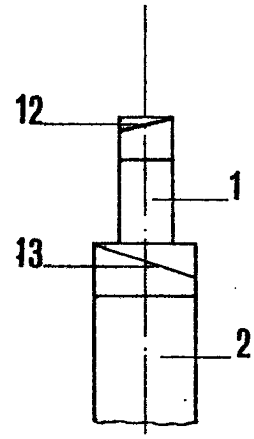


FIG10



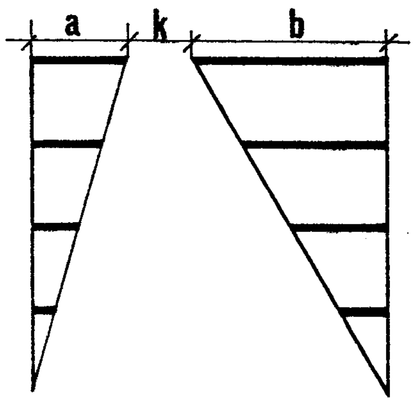
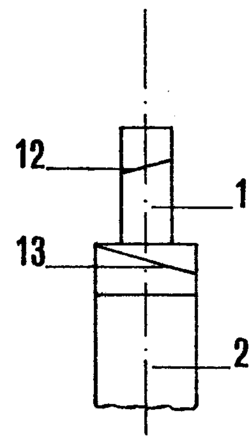


FIG11



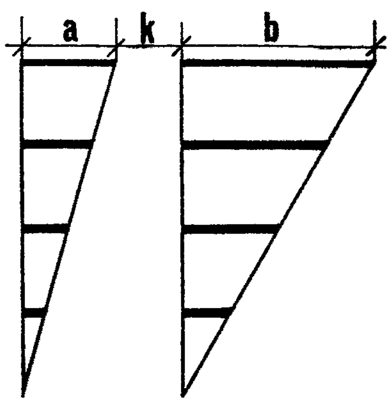


FIG12