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(54) Linear actuator of cylindrical type

(57) A linear actuator of cylindrical type based on differentiated thrust fluid pressure and comprising on outer cylinder (9) coaxial to an inner cylinder (20). The inner cylinder (20) comprises a pipe (11), while the outer cylinder (9) is provided with a piston (16) solid with this pipe (11) of the inner cylinder (20). The heads (12, 22) of both these cylinders (9, 20) slide on a same rod (10).

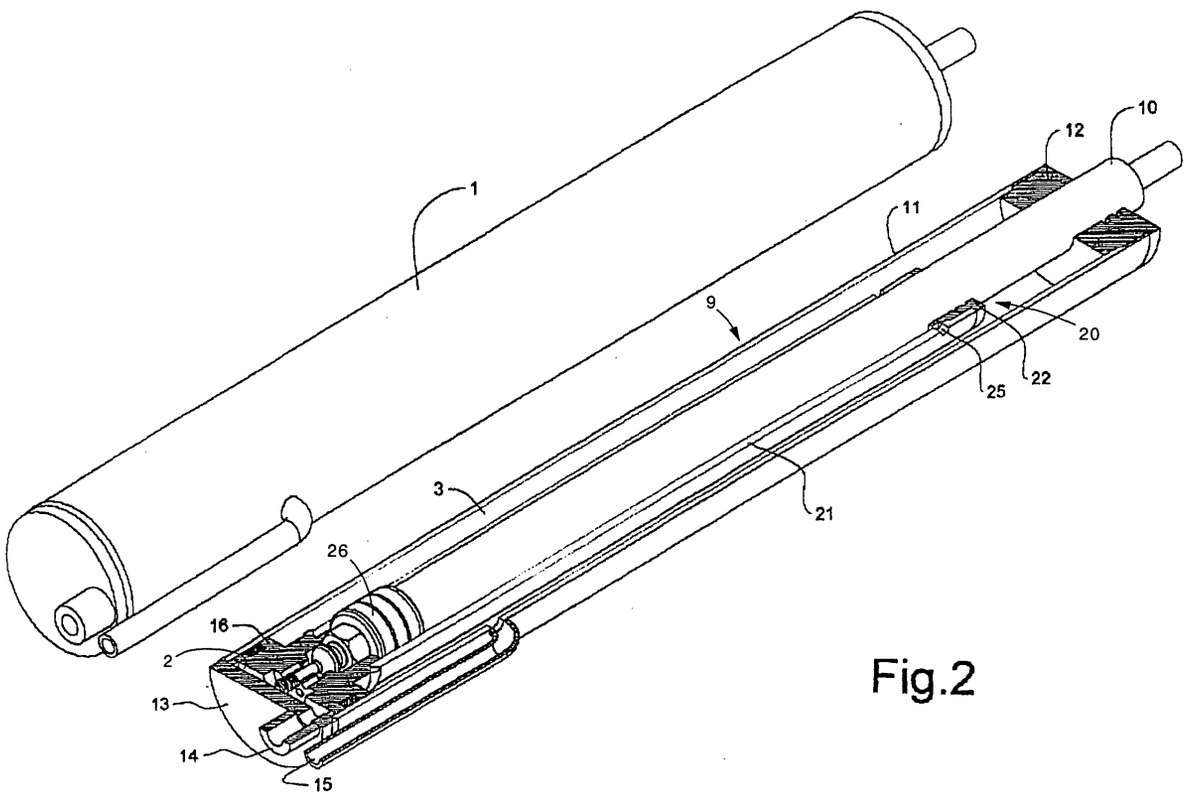

Fig.2

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Description

FIELD OF THE INVENTION

[0001] The invention concerns a hydraulic fluid linear actuator made by means of two coaxial cylinders which is used advantageously in applications in which maximum force is required only during an interval less than the total travel of the actuator, whereas a high speed of approach and return is required.

[0002] A typical field of application is presses, press-benders, wood-cutting or trunk-cutting machines, hydraulic shears and similar machines.

BACKGROUND OF THE INVENTION

[0003] At present wood-cutting machines, presses and similar machines, which have a working principle based on the force generated by a fluid pressure, are equipped with a hydraulic jack as a power actuator. There are innumerable circuit types adopted in order to obtain maximum speed and maximum force. It is difficult to list them all.

[0004] The most economical machines adopt double effect hydraulic cylinders and fixed cc pumps; in this case the speed of the jack is constant and depends on the Force (P) of the motor and the max Force (F) which it is desired to obtain according to the equation V=P/F, while the speed of return or re-entry depends on the geometry of the jack, that is, the ratio between the surface of the cylinder and the surface of the rod.

[0005] One evolution of this technique is to adopt circuits with a double pump: during the approach to the piece, both the pumps deliver hydraulic fluid to the cylinder, whereas during the working step a pressure valve excludes the pump with the bigger cc and the movement of the actuator is determined by the delivery of the smaller cc pump alone. This solution not only entails using two pumps, it also makes necessary to size the hydraulic circuit according to the maximum delivery.

[0006] Another solution is to use variable delivery pumps, generally with pistons or blades, controlled by the fluid pressure by means of a circuit which keeps constant the power absorbed by the pump or the torque required by the pump. This solution entails using costly apparatus and is applied on high category machines. Moreover, as in the previous case, the hydraulic circuit has to be sized according to the maximum delivery supplied by the pump.

[0007] Another solution is to use circuits of a regenerative type, in which the hydraulic jack is driven in its approach, by connecting both the chamber on the rod side and also the rear chamber behind the pressurized branch of the circuit; in this way the flow emerging from the front chamber is added to the flow generated by the pump and conveyed into the rear chamber. This solution appears quite economical and can be controlled both manually, by acting on a suitable distributor, and also automatically, by means of valves which switch the circuit when a threshold pressure is reached, determined by the contact of the tool with the piece being worked. On the other hand, this solution, which is generally used on jacks with a rod area equal to half the area of the cylinder, does not allow to reach considerable factors of increase in the cycle speed compared with the simple circuit (max 1.5). Moreover, since the load losses of the regenerative circuit constitute a valuable limit being amplified by a measure equal to the power of two of the ratio between the sections of the cylinder and the rod, it is necessary to over-size the hydraulic components affected by the regenerative flow.

[0008] A further solution, adopted in shears for the demolition of concrete, is to use a "pressure intensifier", consisting of a double section cylinder separated from the main cylinder, in which a quantity Q of fluid entering at pressure P determines a theoretic quantity Q/n of fluid emerging at pressure n·P. In these circuits, a group of valves feeds the jack at the pressure generated by the pump until contact with the piece; once contact has been made, the fluid pressure is sent to the intensifier whose outlet feeds the jack at the higher pressure. This technique requires to use numerous components designed to work at the intensified pressure, hence costly and critical components. This solution is therefore only indicated when the bulk sizes of the conventional components are excessive and it is therefore convenient to operate at high pressures, which are incompatible with normal hydraulic pumps.

[0009] As can be seen from this summary description of the state of the art, every solution known to us has defects in efficiency and/or economy which do not allow it to be used on small or average sized machines.

[0010] The present Applicant has devised and embodied this invention to overcome all these shortcomings and to obtain further advantages.

SUMMARY OF THE INVENTION

[0011] The invention is set forth and characterized in the main claim, while the dependent claims describe other characteristics of the invention.

[0012] The main purpose of the invention is to obtain a device or component and the relative circuit, able to move with greater speed during the approach step, that is, during the step where the resistant force is less than a determined threshold, and to move with a lesser speed and at maximum force when the resistant load generated by the working process requires it, and then continue to move at a greater speed when the working process is finished.

[0013] This component has been studied in particular for wood-cutting machines in which it is necessary to exert maximum force only in the initial phase when the trunk is broken, whereas in the step when the blade is brought near the trunk, and in the terminal phase when the broken pieces are separated, the force required is

particularly limited. The success obtained with this technique and its relative low cost have allowed to extend the field of application to other sectors as indicated in the summary in the background to the invention.

[0014] According to the invention, the linear actuator consists of two hydraulic cylinders, one inside the other and both equipped with a rod in common: the inner actuator, with a smaller section, represents the rapid movement system, while the outer actuator constitutes the component able to generate, under pressure from the pump, the force necessary to carry out the working process.

[0015] According to the invention, the bottom of the inner cylinder constitutes the piston of the outer cylinder and will be called hereafter in the description "bottom-piston".

[0016] A uni-directional valve is housed on said bottom-piston, and allows free passage from the rear chamber of the outer cylinder to the rear chamber of the inner cylinder and not vice versa. Said valve is kept mechanically open by the contact between the bottom-piston and the bottom of the outer cylinder, in which case the fluid will be free to emerge from the inner rear chamber to the outer rear chamber.

[0017] According to the invention, the front chamber of the inner cylinder communicates directly, by means of several holes, with the front chamber of the outer cylinder. By front chamber we mean the chamber on the rod side.

[0018] According to the invention, a valve is mounted on the pipe that feeds the front chamber and is piloted by the pressure present on the rear chamber to prevent the fluid from emerging freely until the pressure P_2 present in the front chamber exceeds the value given by the formula $P_2 \geq P_t - k \cdot P_1$ where P_t represents the setting value of the valve, k the pilot ratio of the valve, P_1 the pressure in the rear chamber of the outer cylinder. According to a preferred embodiment of the invention, the afore-mentioned valve is of uni-directional balancing type.

[0019] According to the invention, during the approach step, the fluid pressure conveyed into the rear chamber of the outer cylinder flows through the uni-directional valve inside the inner cylinder causing it to advance rapidly. During this step the rod meets a slight resistance to this advance and the counter-pressure in the front chambers is given by the solution of the following formulas of the geometry of the cylinder and the characteristics of the valve:

$$\begin{cases} F = P_1 \cdot S' - P_2 \cdot (S' - S_s) \\ P_2 = P_t - k \cdot P_1 \end{cases}$$

Where:

F represents the resistant force

S indicates the surface of the outer cylinder

S' indicates the surface of the inner cylinder

S_s indicates the surface of the rod

[0020] In this phase the bottom-piston remains thrust towards the bottom by the counter-pressure present in the front chambers with a force equal to

$$Ff = (P_1 - P_2) \cdot (S - S')$$

[0021] During the working step the fluid pressure, increased by the resistance to the advance, causes the bottom-piston to be distanced from the rest position and consequently the uni-directional valve located therein to be closed; in these conditions, the fluid pressure which acts on the bottom-piston determines an increase in the inner pressure of the minor actuator, which is totally closed by the uni-directional valve; in these conditions the pressure rises to values determined by the ratio of the respective areas of the cylinders in the same way as a pressure intensifier.

[0022] When a determined pressure value has been reached in the rear chamber given by the formula $Ps = Pt/k$, the balancing valve opens totally, annulling the counter-pressure P_2 in the front chambers. In these conditions the force exerted by the device becomes $Fmax = S \cdot P_1 max$ in the same way as a normal cylinder with a section S.

[0023] When the work is finished, the reduction in the pressure caused by the lesser resistance to advance causes the uni-directional valve located on the bottom-piston to open, the smaller cylinder will start again its respective advance at a higher speed while the bottom-piston will retreat due to the counter-pressure of the front chambers until it comes into contact with the bottom of the larger cylinder.

[0024] Or, if the resistant force does not go below the threshold value, the inner cylinder terminates its useful travel going into contact with the head of the outer cylinder; in this case the pressure in the rear chamber causes the uni-directional valve located on the bottom-piston to open, and the thrust of the device will be

$$F_{mant} = P_1 \cdot S'$$

Where F_{mant} indicates the maintenance force.

[0025] When the working cycle has finished, it is enough to invert the hydraulic flow so that the fluid pumped into the front chamber, if necessary, makes the bottom-piston retreat to the retreat position.

[0026] When contact has been achieved between the bottom-piston and the bottom of the outer cylinder, the uni-directional valve will be mechanically opened by such contact, allowing the oil contained in the rear chamber of the inner cylinder to flow freely to be discharged. The return force will therefore be:

$$F_{rit} = P_2 \cdot (S'-S_s)$$

Or the condition of maximum pressure

$$F_{rit(max)} = P_{max} \cdot (S'-S_s)$$

[0027] According to the invention, the preferential form of the uni-directional valve located on the bottom of the cylinder consists of a valve with a conical seating on whose rod, protruding from the base of the bottom-piston, a precharging spring will be mounted.

[0028] According to a variant of the invention, the uni-directional valve may consist of a ball embedded in the bottom-piston which is opened thanks to a pin solid with the bottom of the outer cylinder.

[0029] According to another variant, the piston of the outer cylinder may be not integrated with the bottom of the inner cylinder, but located in any position whatever of said cylinder. The piston and relative seal could even be integrated with the head of the inner cylinder.

[0030] According to another variant, the uni-directional balancing valve located in correspondence with the feed pipe of the front chambers can be replaced by a hydraulic release uni-directional valve.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] These and other characteristics will become clear from the description of the schematic hydraulic circuit and the preferential forms of embodiment, given as a non-restrictive example with reference to the attached drawings wherein:

- Fig. 1 is the diagram of the hydraulic principle with the symbols relating to the components used;
- Fig. 2 is a three-dimensional view of the complete device and the respective section, excluding the balancing valve;
- Fig. 3 is a three-dimensional sectional view of the details of the bottom-piston;
- Fig. 4 is a sectioned view of the device during the phases of the cycle;
- Fig. 4a shows the cylinder totally closed in the rest position;
- Fig. 4b shows the device during the approach step, characterised by the advance of the piston of the inner cylinder alone;
- Fig. 4c shows the working step characterized by the advance of the whole inner cylinder;
- Fig. 4d shows the step subsequent to working, characterized by the advance of the rod alone, with the inner cylinder at end-of-travel.

DESCRIPTION OF THE DRAWINGS

[0032]

Fig 1 is a diagram of the hydraulic principle and the hydraulic connections of the actuator according to the invention. To be more exact, a linear actuator 1, the embodiment of which will be described in more detail later, is connected to the hydraulic circuit by means of a uni-directional balancing valve 7 located at outlet from the pipe of the front chambers and piloted by the pressure in the rear chamber.

Fig. 1 also shows, with the sole purpose of facilitating comprehension, a direction valve 8 which does not belong to the invention, and which allows to control the linear actuator 1.

Fig. 2 shows both the linear actuator 1, as it appears when assembly is complete, both a longitudinal section thereof, in a form of embodiment supplied as an example only. In particular, the longitudinal section shows an outer cylinder 9 constituted by a pipe 11, a head wall 12 and a bottom wall 13 of the. A piston 16 of the outer cylinder 10 constitutes, in turn, the bottom-piston of an inner cylinder 20 which comprises also a pipe 21, a head 22 and an inner piston 26. A rod 10, solid with the inner piston 26, is common both to the inner cylinder 20 and the outer cylinder 9.

Fig. 2 also shows two pipes 14 and 15 which connect the hydraulic circuit respectively to the rear chamber 2 and the front chamber 3 of the device. It can be also seen how the front chamber 3 of the outer cylinder 9 is connected, by means of holes 25 made on the pipe 21, with the front chamber of the inner cylinder 20. The head 22 of the inner cylinder 20 therefore does not perform any hydraulic sealing function, but functions only as a guide for the pipe 21 on the rod 10. The head 22, in this example, is screwed to the pipe 21.

Fig. 3 shows better the details which characterize the zone of the bottom of the linear actuator 1. We can observe the bottom-piston 16 made solid with the pipe 21 of the inner cylinder 20 by welding.

[0033] In the bottom-piston 16 a conical seating is provided for lodging the uni-directional valve 30, a stem 31 of which protrudes from the rear part of the same bottom-piston 16. The valve 30 is normally closed by a spring 32 coaxial with the stem 31. The hydraulic fluid can therefore pass freely from the rear chamber 2 of the outer cylinder 9 to the rear chamber 4 of the inner cylinder 20 through holes 33, but not vice versa, except when the bottom-piston 16 is totally retreated; in this condition the stem 31 of the uni-directional valve 30 hits the bottom wall 13 and causes the forced opening of said valve 30.

[0034] Fig. 4 represents the operating sequence of the device. In particular, Fig. 4a shows the bottom-piston

16 totally retreated. The fluid pressure applied to the outer rear chamber 2 through the pipe 14 passes through the valve 30 and is transmitted to the inner rear chamber 4 of the inner cylinder 20, generating a thrust both on the inner piston 26 and also on the bottom-piston 16; the counter-pressure generated in the front chambers 3 and 5, thanks to the uni-directional balancing valve 7 (not shown in Fig. 4a), opposes the advance both of the piston 26 and the bottom-piston 16, particularly, due to the geometries and setting values of the uni-directional balancing valve 7, the action of reaction is greater on the bottom-piston 16 which is kept in contact with the bottom wall 13 while the rod 10 emerges freely as indicated in Fig. 4b.

[0035] When the rod 10 meets the resistance of the working process, the pressure in the rear chambers 2 and 4 increases and, as a consequence, thanks to the uni-directional balancing valve 7, the counter-pressure in the front chambers 3 and 5 diminishes, allowing the bottom-piston 16 to advance. The advance of the bottom-piston 16 allows to close the uni-directional valve 30 as shown in Fig. 4c, making the rear chamber 4 of the inner cylinder 20 absolutely sealed. The force acting on the bottom-piston 16 is then transmitted to the inner piston 26 due to the fact that the fluid contained therein cannot be compressed; the fluid in these conditions reaches much higher pressure values than those of the feed fluid.

[0036] This is the phase when the maximum force is developed, and can finish in two different ways:

1) if the resistant force goes below the threshold which has generated the movement of advance of the bottom-piston 16, then the latter will retreat due to the counter-pressure in the front chamber 3,
2) if the resistant force remains high, the inner cylinder 20 will terminate its travel against the head 12 of the outer cylinder 9.

[0037] In this second hypothesis as shown in Fig. 4d, the rod 10 will be able to continue to advance only if the resistant force is overcome by the force generated by the inner cylinder 20 at the maximum pressure of feed of the circuit.

Claims

1. Linear actuator of cylindrical type based on differentiated thrust fluid pressure and comprising on outer cylinder (9) coaxial to an inner cylinder (20), wherein said inner cylinder (20) comprises a pipe (11), **characterized in that** said outer cylinder (9) is provided with a piston (16) solid with said pipe (11) of said inner cylinder (20) and **in that** the heads (12, 22) of both said two cylinders (9, 20) are able to slide on a same rod (10).

2. Actuator as in claim 1, **characterized in that** the rear chamber (2) of said outer cylinder (9) is in communication with the rear chamber (4) of said inner cylinder (20) by means of a uni-directional valve (30) able to actuated mechanically and actuated by the reciprocal position of said two cylinders (9, 20).

3. Actuator as in claim 2, **characterized in that** the front chambers (3, 5) of both said two cylinders (9, 20) are in communication through appropriate passages (33) and **in that** the pressure in said front chambers (3, 5) is able to be controlled by means of an external valve (7, 8) able to generate a counter-pressure sufficient to impede the feeding of said piston (16) when no resisting force is applied thereto.

4. Actuator as in claim 3, **characterized in that** said front chambers (3, 5) of both cylinders are able to be fed by the fluid pressure by means of a uni-directional valve (7).

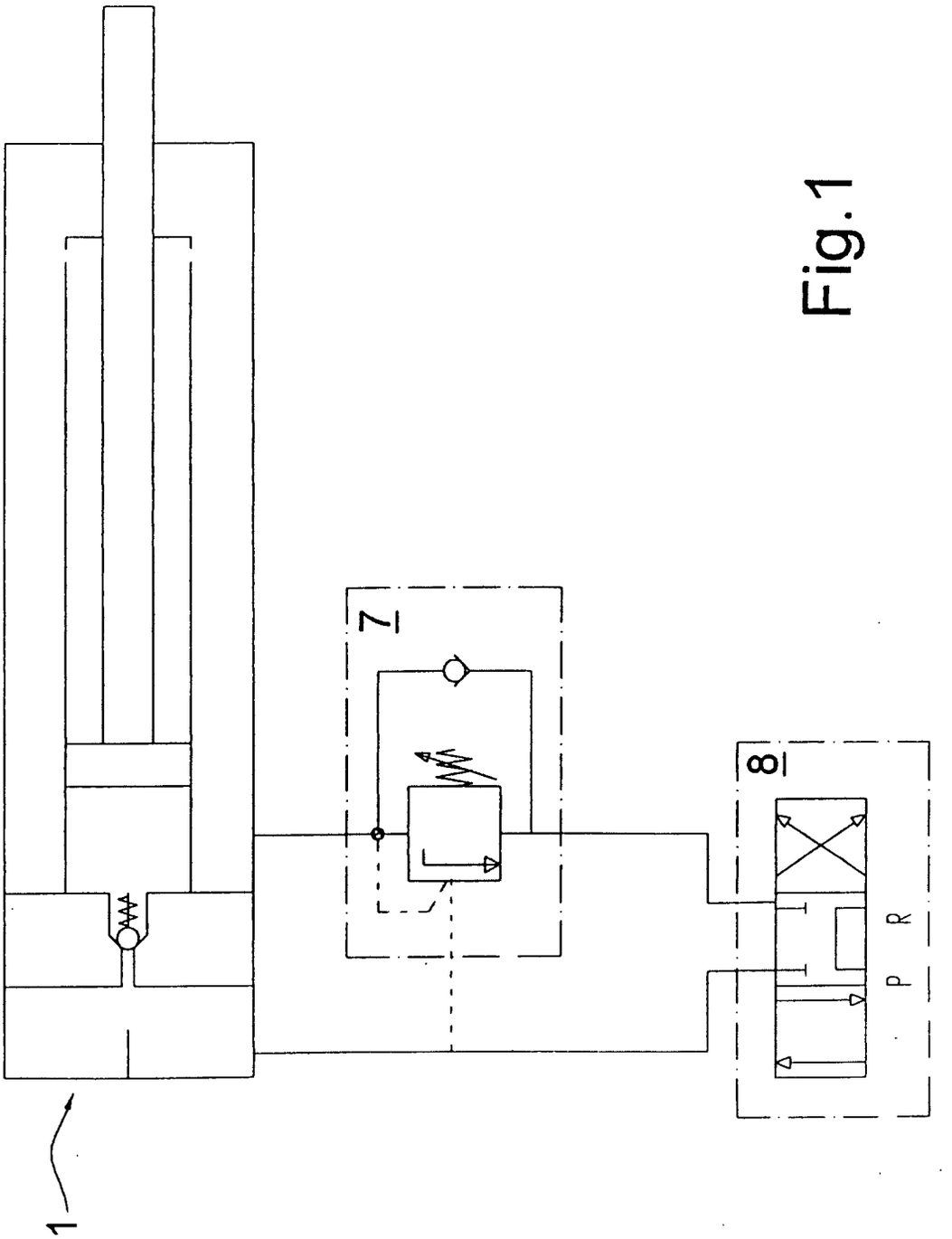


Fig.1

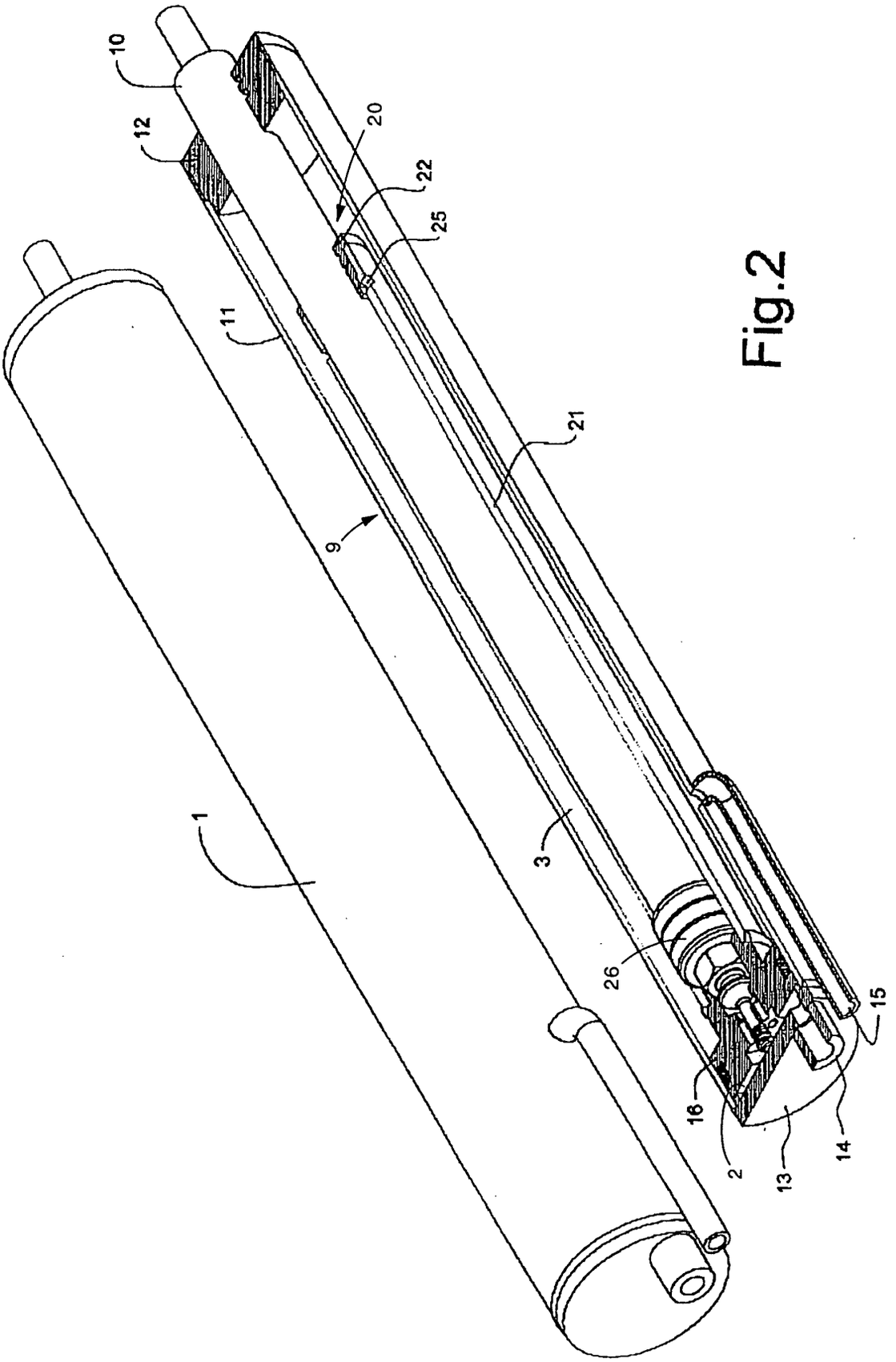


Fig.2

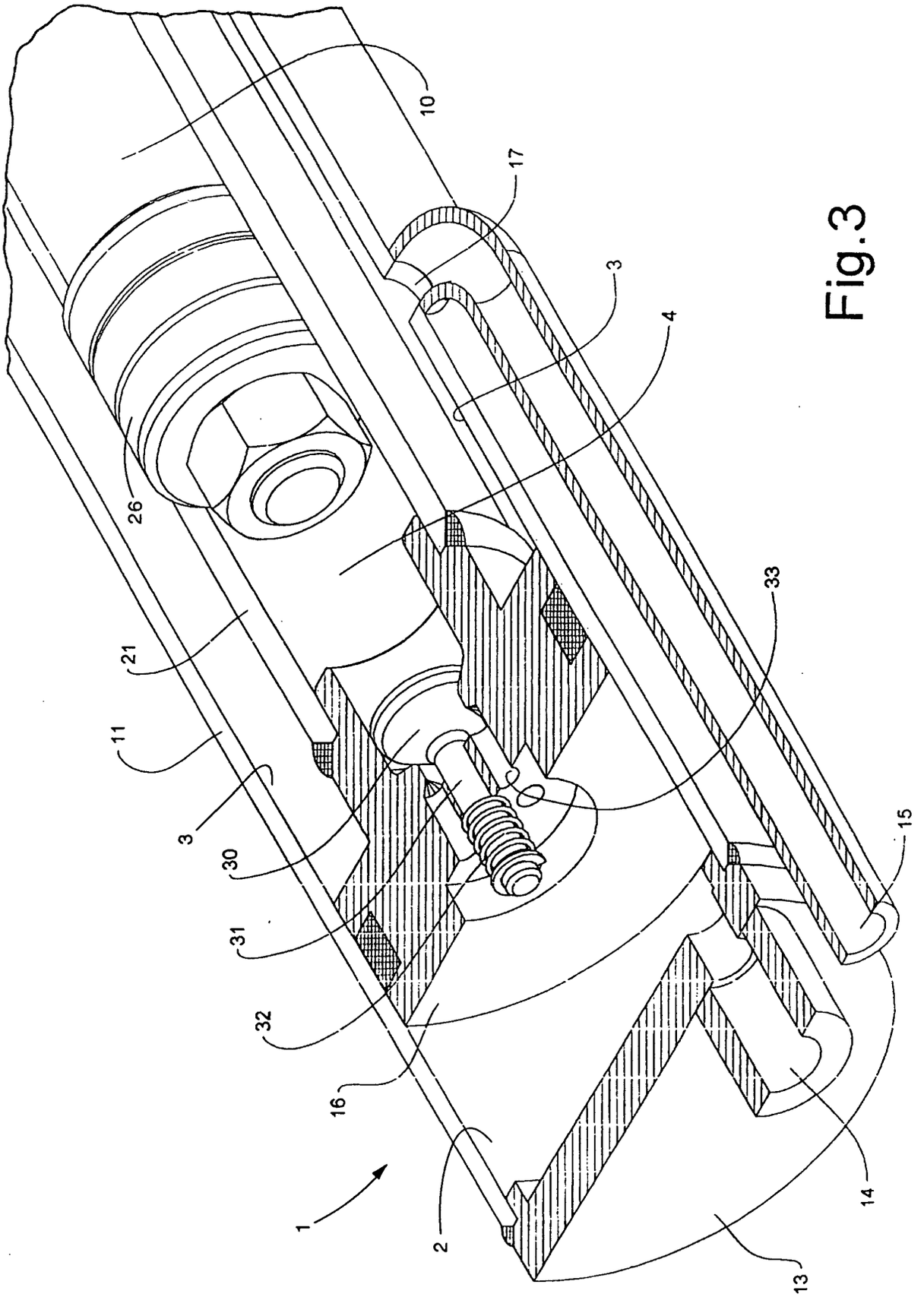
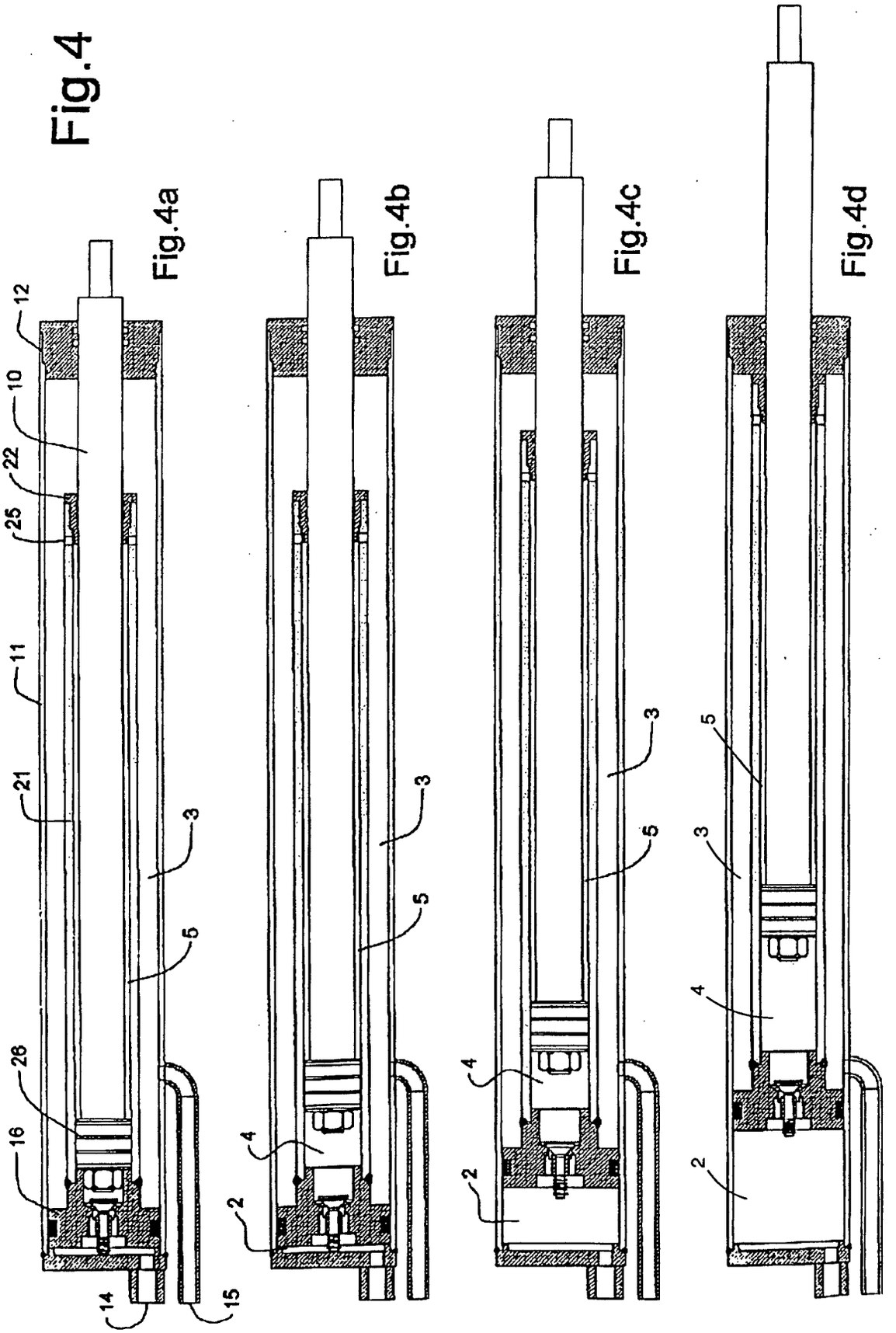


Fig.3

Fig.4



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EUROPEAN SEARCH REPORT

Application Number
EP 02 00 4445

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.7)
X	DE 14 26 506 A (HICK, DR WALTER, BREGENZ) 13 March 1969 (1969-03-13) * page 17, paragraph 1; figures 2,4 *	1-4	F15B15/20 F15B11/036
X	DE 19 64 076 A (REXROTH GMBH G L) 24 June 1971 (1971-06-24) * page 4, paragraph 2 - page 6, paragraph 2 *	1,2	
X	EP 0 914 896 A (NIMAK AUTOMATISIERTE SCHWEISST) 12 May 1999 (1999-05-12) * paragraph '0028! - paragraph '0037! *	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			F15B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	18 June 2002	Toffolo, O

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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18-06-2002

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