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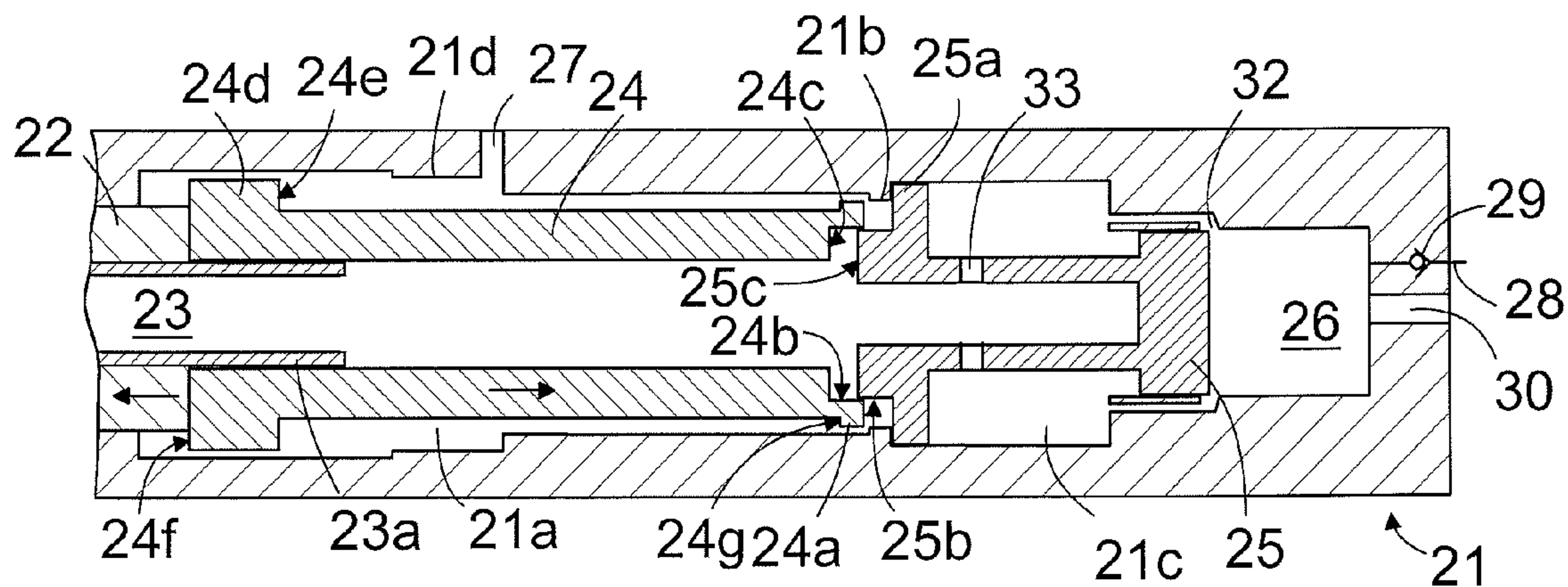
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(54) **Title: PNEUMATIC DOWN-THE-HOLE DRILL**



(57) **Abrégé/Abstract:**

A pneumatic down-the-hole drill having a frame (21), a pneumatic percussion piston (24) that moves in a reciprocating manner as pressurized air is fed into the DTH-drill and strikes a tool in the front end of the frame (21), mounted movably in the longitudinal direction of the frame (21), a feed channel for feeding compressed air to the DTH-drill, and shoulders in the frame (21) and in the percussion piston (24) for controlling compressed air to provide an impact movement. In the rear end of the frame (21) the DTH-drill comprises a combustion chamber (26) and an acceleration piston (25) which is arranged to push the percussion piston (24) during the impact movement for a portion of the percussion piston (24) travel, means for feeding combustion air and fuel into the combustion chamber (26), whereby the percussion piston (24) is arranged to push the acceleration piston (25) after the impact into the combustion chamber (26) and to compress the air in the combustion chamber (26) prior to feeding the fuel into the combustion chamber (26).

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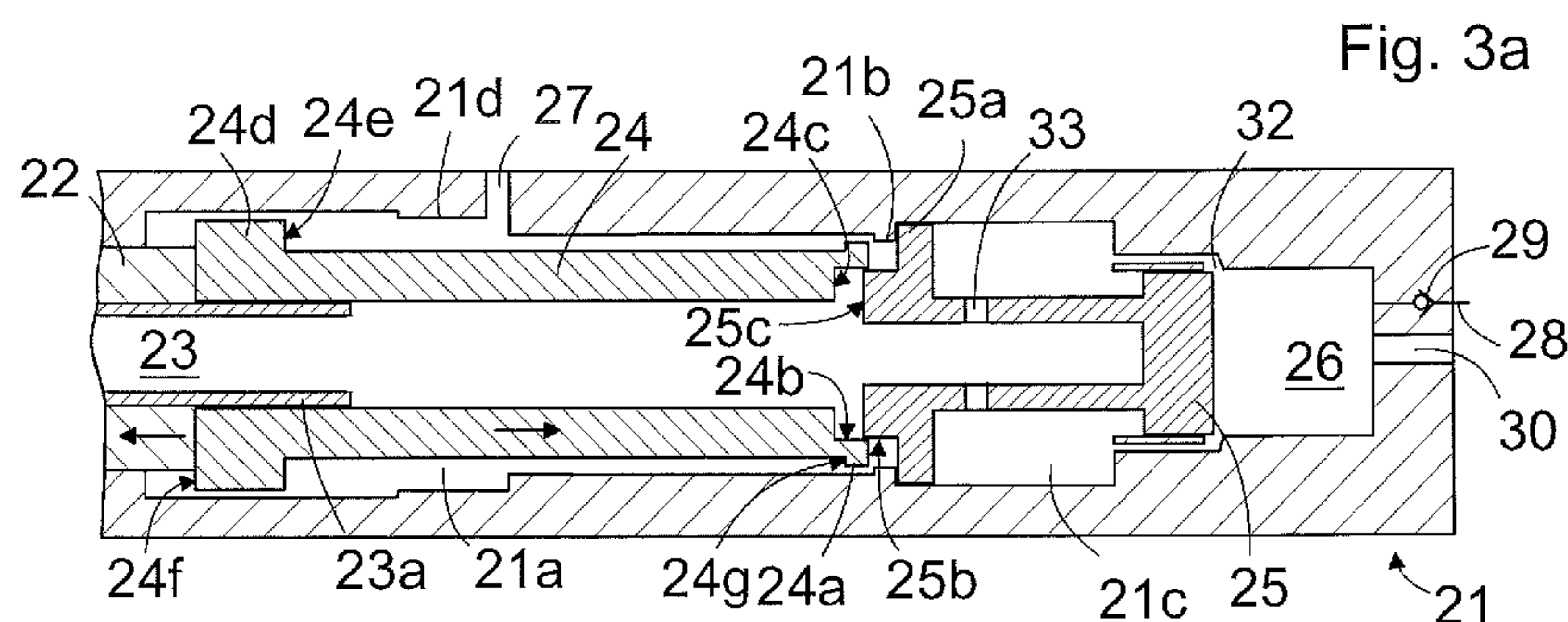
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(54) Title: PNEUMATIC DOWN-THE-HOLE DRILL



(57) **Abstract:** A pneumatic down-the-hole drill having a frame (21), a pneumatic percussion piston (24) that moves in a reciprocating manner as pressurized air is fed into the DTH-drill and strikes a tool in the front end of the frame (21), mounted movably in the longitudinal direction of the frame (21), a feed channel for feeding compressed air to the DTH-drill, and shoulders in the frame (21) and in the percussion piston (24) for controlling compressed air to provide an impact movement. In the rear end of the frame (21) the DTH-drill comprises a combustion chamber (26) and an acceleration piston (25) which is arranged to push the percussion piston (24) during the impact movement for a portion of the percussion piston (24) travel, means for feeding combustion air and fuel into the combustion chamber (26), whereby the percussion piston (24) is arranged to push the acceleration piston (25) after the impact into the combustion chamber (26) and to compress the air in the combustion chamber (26) prior to feeding the fuel into the combustion chamber (26).

Pneumatic down-the-hole drill

Prior art

[0001] The invention relates to a pneumatic down-the-hole drill having a frame and inside the frame a pneumatic percussion piston that moves in a reciprocating manner in the longitudinal direction of the frame when pressurized air is fed into the down-the-hole drill and at the end of its impact movement strikes a tool that is in the front end of the frame and mounted movably in the longitudinal direction of the frame, a feed channel for feeding pressurized air between the frame and the percussion piston, and shoulders in the frame and in the percussion piston to guide the pressurized air to provide the impact movement.

[0002] The down-the-hole drills are used for drilling holes in a rock. In these DTH-drills a tool is connected immediately in front of the DTH-drill and it is subjected to impacts with a percussion device of the DTH-drill.

[0003] Known solutions have a drawback that, for instance, their efficiency is relatively poor. A pneumatic percussion mechanism alone does not provide a sufficient efficiency, and hydraulic percussion devices are not readily used because of pollution risks.

[0004] The object of the present invention is to provide a pneumatic DTH-drill that is simple and works reliably.

[0005] The DTH-drill of the invention is characterized by comprising a combustion chamber at the rear end of the frame, and in the combustion chamber a separate acceleration piston between the frame and a percussion piston, moving in the longitudinal direction of the frame and operating by fuel combustion in the combustion chamber, which acceleration piston is arranged to push the percussion piston during the impact movement only for a portion of the percussion piston travel, an air channel for feeding combustion air into the combustion chamber, means for injecting fuel into the combustion chamber, an exhaust channel for exhausting combustion gases from the combustion chamber, whereby the percussion piston is arranged to push the acceleration piston by means of pressurized air back into the combustion chamber after each impact and thus to compress the air in the combustion chamber prior to feeding fuel into the combustion chamber.

[0006] The idea of the DTH-drill is that it includes a separate, pneumatic percussion piston that strikes the tool and a separate acceleration piston operating by fuel combustion, which accelerates the percussion piston

motion but will be off the percussion piston for the duration of the impact so that a working stroke will be performed by the percussion piston alone. Yet another idea of the DTH-drill is that the acceleration piston is returned to the initial position by pushing it with the percussion piston by means of the pressure
5 in compressed air.

[0007] An advantage with the invention is that the striking being performed with a percussion piston accelerated with a fuel-operated acceleration piston a required impact power will be provided. However, as the acceleration piston is off the percussion piston at the time of the impact, recoil forces reflecting from the tool do not affect the acceleration piston and do not stress it.
10

Brief description of the figures

[0008] The invention is now described in greater detail in the attached drawings, in which

Figure 1 shows schematically a rock drilling rig,
15 Figure 2 shows schematically another, different rock drilling rig, and
Figures 3a to 3f show schematically the structure of a down-the-hole drill and its operation in various phases of a working cycle.

Detailed description of the invention

[0009] Figure 1 shows a rock drilling rig 1 that may comprise a
20 movable carrier 2 provided with a drilling boom 3. The boom 3 is provided with a rock drilling unit 4 comprising a feed beam 5, a feed device 6 and a rotation unit 7. The rotation unit 7 may be supported to a carriage 8, or alternatively the rotation unit may comprise sliding parts or the like support members with which it is movably supported to the feed beam 5. The rotation unit 7 may be provided with drilling equipment 9 which may comprise one or more interconnected
25 drilling pipes 10, and a drill bit 11 at the outermost end of the drilling equipment. The drilling unit 4 of Figure 1 is intended for rotary drilling in which the rotation unit 7 is used for rotating the drilling equipment 9 about its longitudinal axis in direction R and, at the same time, the rotation unit 7 and the drilling
30 equipment 9 connected to it are fed with feed force F by means of a feed device 6 in drilling direction B. Thus, the drill bit breaks rock by the effect of rotation R and feed force F, and a drill hole 12 is formed. When the drill hole 12 has been drilled to a desired depth, the drilling equipment 9 can be pulled by means of the feed device 6 out of the drill hole 12 in return direction C, and the

drilling equipment can be disassembled by unscrewing connection threads between the drilling pipes 10 by means of the rotation unit 7.

[0010] Figure 2 shows a second drilling unit 4, which differs from the one in Figure 1 in such a way that the drilling equipment 9 is provided with a percussion device 13. The percussion device 13 is thus at the opposite end of the drilling equipment 9 in relation to the rotation unit 7. During drilling, the down-the-hole drill 13 is in the drill hole and the tool with the drill bit 11 may be connected directly to the down-the-hole drill 13.

[0011] Figures 3a to 3f show the down-the-hole drill of the invention and its operation in various phases of a working cycle. It comprises a frame 21 and, in the front end of the frame, a tool 22 that is mounted movably in the longitudinal direction thereof. In this application and the claims the front end refers to the end of the DTH-drill 13 where the tool is and in which direction the DTH-drill 13 advances in drilling, and the rear end refers to the opposite end of the DTH-drill 13.

[0012] In the middle of the tool 22 there is a flushing channel 23. Further, the DTH-drill 13 comprises a percussion piston 24 that is mounted movably in the longitudinal direction of the frame 21. Additionally, it includes an acceleration piston 25, which in relation to the percussion piston 24 is in the opposite end of the frame 21, i.e. rear end of the percussion piston, from the tool 22, and it is mounted movably in the longitudinal direction of the DTH-drill frame 21. Behind the acceleration piston, on the side away from the percussion piston 24 there is a combustion chamber 26. The DTH-drill includes a feed channel 27, through which pressurized air is fed into an annular space 21a between the percussion piston 24 and the frame 21. Further, the DTH-drill includes an air channel 28, through which compressed air is fed into the combustion chamber 26, and an inlet valve 29, by which the feed of compressed air is controlled. The inlet valve 29 may be any appropriate valve structure, or one known per se, and herein it is illustrated, by way of example, by a check valve. It further comprises a nozzle 30, included in fuel feeding means, through which fuel is fed into the combustion chamber 26. The DTH-drill further includes timing and feeding means, not shown and known per se, which control fuel feed into the combustion chamber 26 on the basis of the position of the acceleration piston 25 or the conditions, such as pressure, in the combustion chamber 26.

[0013] Figure 3a shows the DTH-drill in a situation where the percussion piston 24 has struck the tool 22. The frame 21 of the DTH-drill includes a counterpart shoulder 21b and the acceleration piston includes a stop shoulder 25a. In Figure 3a the acceleration piston 25 has stopped before the moment of impact, upon collision of its stop shoulder 25a with the counterpart shoulder 21b in the frame 21. For a portion of their lengths the percussion piston 24 and the acceleration piston 25 are nested in such a manner that there is never an open gap or a notable clearance therebetween.

[0014] Because high pressure still prevails in the combustion chamber 26, the inlet valve 29 remains closed despite the fact that the pressure of compressed air acts thereon via the channel 28. The pressure in the combustion chamber 26 becomes, however, lower and lower while the combustion gases therein will be discharged into the exhaust channel 32 and further into a space 21c around the acceleration piston, between said piston and the frame 21, and further through channels 33 in the acceleration piston 25, via a space in the middle of the pistons, into the flushing channel 23.

[0015] In Figure 3b the percussion piston 24 has started its reverse movement and the pressure in the combustion chamber 26 has decreased to enable the compressed air to push the check valve 29 open. At this stage, the air of high pressure, e.g. about 3 to 5 bar, from the air channel 28 flushes combustion gases from the combustion chamber 26 into the exhaust channel 32 and fills the combustion chamber with fresh air.

[0016] For a portion of their lengths the percussion piston 24 and the acceleration piston 25 are nested in such a manner that there is never an open gap or clearance therebetween. At the nested parts 24b and 25b they comprise working surfaces 24c and 25c which are in contact with one another, when the acceleration piston 25 pushes the percussion piston 24 towards the tool 22, or the percussion piston 24 pushes the acceleration piston 25 towards the combustion chamber 26. At the same time, a blocking shoulder 24a in the percussion piston 24, together with the inner surface of the counterpart shoulder 21b, has tightly closed the connection from the space between the stop shoulder 25a and the counterpart shoulder 21b. In this situation the space between the percussion piston 24 and the acceleration piston 25 forms a closed damping chamber 31, which is full of compressed air.

[0017] As the percussion piston 24 moves towards the acceleration piston 25, the pressure in the damping chamber 31 rises and the percussion

piston 24 starts pushing the acceleration piston 25 towards the combustion chamber by means of the formed, pressurized air cushion. In that case the acceleration piston 25, while moving, closes the exhaust channel 32, whereafter a pressure rise in the combustion chamber 26 pushes the inlet valve 29 closed, as the pressure rises higher than the pressure of air fed by the air channel 28. A so-called compression step thus takes place. The surface area 24 of the percussion piston, on which the pressure of the compressed air acts and thus generates a force reversing the pistons, is formed by the difference between the percussion piston surfaces 24f and 24g on the front end side of the frame 21 and the side 24e facing the rear end of the frame. Said surface area is larger than the surface area of the acceleration piston 25 on the side of the combustion chamber 26, whereby a sufficient compressive force is obtained for compressing the air in the combustion chamber.

[0018] Figure 3c further shows that the percussion piston 24 having moved a sufficient distance towards the acceleration piston 25, the blocking shoulder 24a at the upper end thereof passes by the counterpart shoulder 21b in the frame 21 in such a manner that a connection opens from the damping chamber 31 to the annular space 21a between the percussion piston 24 and the frame 21, whereby the pressure in the damping chamber 31 drops. As a result, the percussion piston 24 is able to move towards the acceleration piston 25 and to reach it in such a manner that the stop shoulder 25a of the acceleration piston 25 and the blocking shoulder 24a of the percussion piston 24, as well as the working surfaces 24c and 25c, will come into contact with one another and the pistons continue their travel towards the combustion chamber 26 at the same rate.

[0019] As the percussion piston 24 and the acceleration piston 25 move towards the combustion chamber 26, a working shoulder 24d in the lower end of the percussion piston 24 becomes in alignment with a control shoulder 21d in the frame and closes the connection from a reversing chamber 21f, which is at the end of the percussion piston 24 on the side of the tool 22, into the feed channel 27. At the same time the percussion piston 24 continues its motion with the acceleration piston 25 towards the combustion chamber 26. From this moment on, the pressure in the compressed air from the feed channel 27 starts acting on the percussion piston 24, on the working surface 24e of its working shoulder 24d, and produces a force that pushes the percussion pis-

ton towards the tool 22. This decelerates the motion of the percussion piston 24 and the acceleration piston 25 slightly.

[0020] In Figure 3d, the percussion piston 24 and the acceleration piston 25 have compressed the air in the combustion chamber 26 to have extremely high pressure and fuel is fed through a nozzle 30 into the combustion chamber, which fuel ignites because of the heated, compressed air causing a steep rise in pressure in the combustion chamber 26 in accordance with the operating principle of a diesel engine.

[0021] In the final part of the percussion piston motion, prior to said situation, the percussion piston 24 has passed by the end of a flushing pipe 23a in connection with the flushing channel 23 and thus opened a connection from the reversing chamber 21f to the flushing channel 23, whereby the pressurized air in the reversing chamber 21f discharges there. In that situation the percussion piston 24 and the acceleration piston 25 start an impact movement upon ignition of the fuel. At the same time, highly pressurized air from the feed channel 27 acts on the working surface 24e of the working shoulder 24d of the percussion piston 24, which tends to push the percussion piston 24 towards the tool 22.

[0022] Figure 3e shows a phase, in which the percussion piston 24 has closed the connection of the reversing chamber 21f into the flushing channel 23 by means of the flushing pipe 23a in association with the flushing channel 23. In the situation shown in the figure, a connection has opened from the compressed air feed channel 27 and the space 21a, around the working shoulder 24d, into the reversing chamber 21f, when the working shoulder 24d has passed by the control shoulder 21d. In this situation, the percussion piston 24 and the acceleration piston 25 further continue the motion at the same rate in the direction of the tool 22, still in contact with one another, but the force produced by the pressure in the compressed air acts against the travel direction of the percussion piston 24 because of the larger reversing surface 24f in the reversing chamber 21f, in front of the working shoulder 24d of the percussion piston 24, thus decelerating the percussion piston 24.

[0023] In Figure 3f the blocking shoulder 24a of the percussion piston 24, together with the counterpart shoulder 21b of the frame, has closed the connection from the damping chamber 31 to the space around the percussion piston, whereby the damping chamber 31 is formed into a closed space, and as the percussion piston 24 and the acceleration piston 25 proceed, the air

pressure in the damping chamber 31 rises. As a result, the pressure cushion formed as the pressure rises, decelerates the motion of the acceleration piston 25, whereby the percussion piston detaches from the acceleration piston 25, and thus the acceleration piston 25 no longer pushes the percussion piston 24 towards the tool 22.

[0024] As the acceleration piston 25 continues its movement towards the front end of the frame 21 a connection opens to the exhaust channel 32. As the pistons move onwards, negative pressure is formed in the space 21c around the acceleration piston 25, because the surface area of the stop shoulder 25a in the front end of the acceleration piston 25 is larger than the surface area of the acceleration piston 25 in the combustion chamber 26. Consequently, the produced negative pressure aspirates the combustion gases quickly into the space 21c, which enhances the flushing of the combustion chamber 26.

[0025] After this, the situation of Figure 3a occurs again, in which the percussion piston 24 has struck the tool 22 and the acceleration piston 25 has stopped to the shoulders 25a and 21b, whereafter the working cycle starts again from the beginning.

[0026] It is essential in the operation of the percussion piston 24 and the acceleration piston 25 that as the percussion piston 24 strikes the tool 22, the acceleration piston 25 is no longer in impact-direction contact with the percussion piston 24, but it has stopped prior to the impact moment. Thus the acceleration piston 25 does not receive any impact stress, nor the stress caused by a reflection impulse from the tool 22, but all the stress is exerted on the percussion piston alone. Further, it is essential in the operation that the acceleration piston 25 does not strike at full speed the stop shoulder 21b. Thus its impact rate is decelerated by a compressed air cushion in the damping chamber 31 in such a manner that the rate of the acceleration piston 25 on impact with the stop shoulder 21b of the frame 21 is sufficiently low so that the materials withstand the stresses caused by the impact.

[0027] Fuel feed for a DTH-drill may be implemented in various ways known per se by using fuel feed hoses, fuel tanks etc. Fuel injection may be implemented by several, different technical methods by using mechanical, electrical, pneumatic or other known solutions for timing fuel feed and for dispensing a quantity of fuel.

[0028] The DTH-drill may also be operated by compressed air alone, without feeding fuel into the combustion chamber, and naturally in that case its power is considerably lower. It may be used, for instance, when for one reason or another drilling is to be done very cautiously. Likewise, it allows
5 the operation of the acceleration piston to be started without separate ignition means, such as glow plugs or the like, just by striking the acceleration piston with the percussion piston until the air in the combustion chamber is sufficiently hot for igniting the fuel.

[0029] In Figures 3a to 3f the invention is only illustrated by way of
10 example and schematically. The shapes of the frame and the pistons, the positioning and shaping of various channels and shoulders may be implemented in a variety of ways within the scope of the general designing knowledge of a person skilled in the art.

Claims

1. A pneumatic down-the-hole drill having a frame and inside the frame a pneumatic percussion piston (24) that moves in a reciprocating manner in the longitudinal direction of the frame (21) when pressurized air is fed in-
5 to the down-the-hole drill and at the end of its impact movement strikes a tool that is in the front end of the frame (21) and mounted movably in the longitudinal direction of the frame (21), a feed channel for feeding pressurized air between the frame (21) and the percussion piston (24), and shoulders in the frame (21) and in the percussion piston (24) to guide the pressurized air to
10 provide the impact movement, wherein

the down-the-hole drill comprises a combustion chamber (26) at the rear end of the frame (21), and in the combustion chamber a separate acceleration piston (25) between the frame (21) and the percussion piston (24), moving in the longitudinal direction of the frame (21) and operating by fuel combustion in the combustion chamber (26), which acceleration piston is arranged to
15 push the percussion piston (24) during the impact movement only for a portion of the percussion piston (24) travel, an air channel for feeding combustion air into the combustion chamber (26), means for injecting fuel into the combustion chamber (26), an exhaust channel for exhausting combustion gases from the
20 combustion chamber (26), whereby the percussion piston (24) is arranged to push the acceleration piston (25) by means of pressurized air back into the combustion chamber (26) after each impact movement and thus to compress the air in the combustion chamber (26) prior to feeding fuel into the combustion chamber (26).

25 2. The down-the-hole drill of claim 1, wherein the acceleration piston (25) is arranged to close the exhaust channel before penetrating into the combustion chamber (26) and to open the exhaust channel before its forward motion ends.

3. The down-the-hole drill of claim 1 or 2, wherein the air channel
30 includes a blocking valve that opens as the pressure in the combustion chamber (26) drops below a predetermined pressure level and that from the air channel, the blocking valve being open, pressurized air is arranged to flow for flushing the combustion chamber (26) and for filling the combustion chamber (26) with fresh combustion air.

35 4. The down-the-hole drill of any one of claims 1-3, wherein the acceleration piston (25) comprises a stop shoulder and at the same point in the

frame (21), in the axial direction, a counterpart shoulder so that as the shoulders meet the acceleration piston (25) stops before the percussion piston (24) strikes the tool.

5 5. The down-the-hole drill of claim 4, wherein the percussion piston (24) and the acceleration piston (25) are for a portion of their length closely nested so that no clearance opens at any stage between them, that the percussion piston (24) comprises in its upper end a blocking shoulder which, as the pistons move in the impact direction, before the stop shoulder of the acceleration piston (25) hits the counterpart shoulder of the frame (21), together with
10 the counterpart shoulder closes a connection from a space between the stop shoulder and the counterpart shoulder in such a manner that a damping chamber is provided and while the acceleration piston (25) moves onwards its volume decreases and the pressure of the compressed air contained therein increases and decelerates the movement of the acceleration piston (25), and
15 correspondingly during the reversing movement of the percussion piston (24) pushes the acceleration piston (25) towards the combustion chamber (26) before the blocking shoulder opens a connection from the damping chamber so that the percussion piston (24) may displace air from the damping chamber and reach the acceleration piston (25) for pushing it back into the combustion
20 chamber (26).

6. The down-the-hole drill of any one of claims 1-5, comprising timing equipment for timing fuel feed in relation to the position of the acceleration piston (25).

7. The down-the-hole drill of any one of claims 1-6, wherein that the
25 percussion piston (24) comprises a working shoulder whose tool-side surface area is larger than the surface facing the acceleration piston (25) and that the frame (21) comprises an auxiliary shoulder so that in the rear position of the percussion piston (24), the shoulders being aligned, the pressure of the compressed air only acts on the surface facing the acceleration piston (25) producing
30 ing a force that pushes the percussion piston (24) towards the tool, and in the front position of the percussion piston (24), the shoulders being apart, the pressure of the compressed air acts on both surfaces producing a force that pushes the percussion piston (24) away from the tool.

8. The down-the-hole drill of any one of claims 1-7, wherein in the
35 percussion piston (24) the surface area of the surfaces which are facing the front end of the frame (21) and through which the pressurized air pushes the

percussion piston (24) and the acceleration piston towards the combustion chamber (26), is larger than the surface area of the acceleration piston (25) facing the combustion chamber (26).

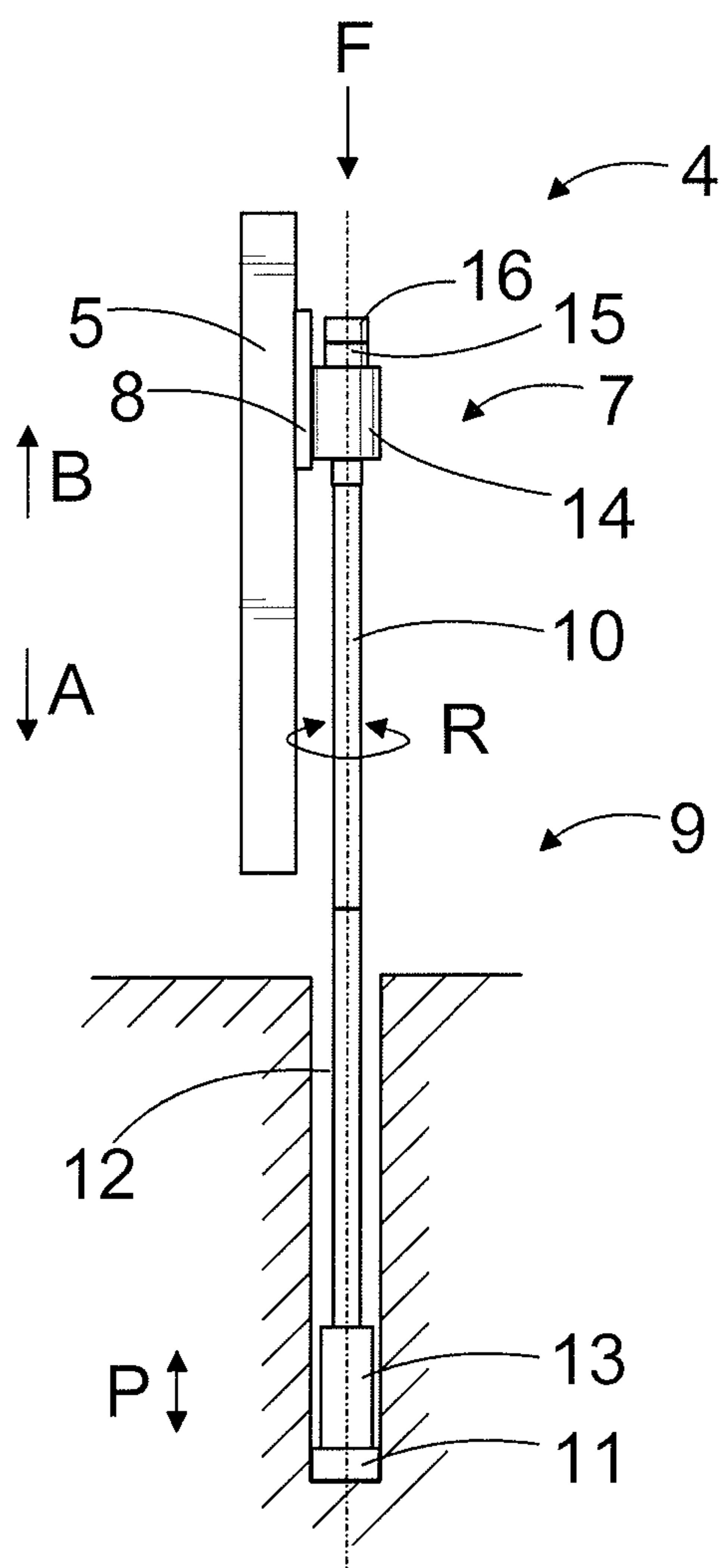
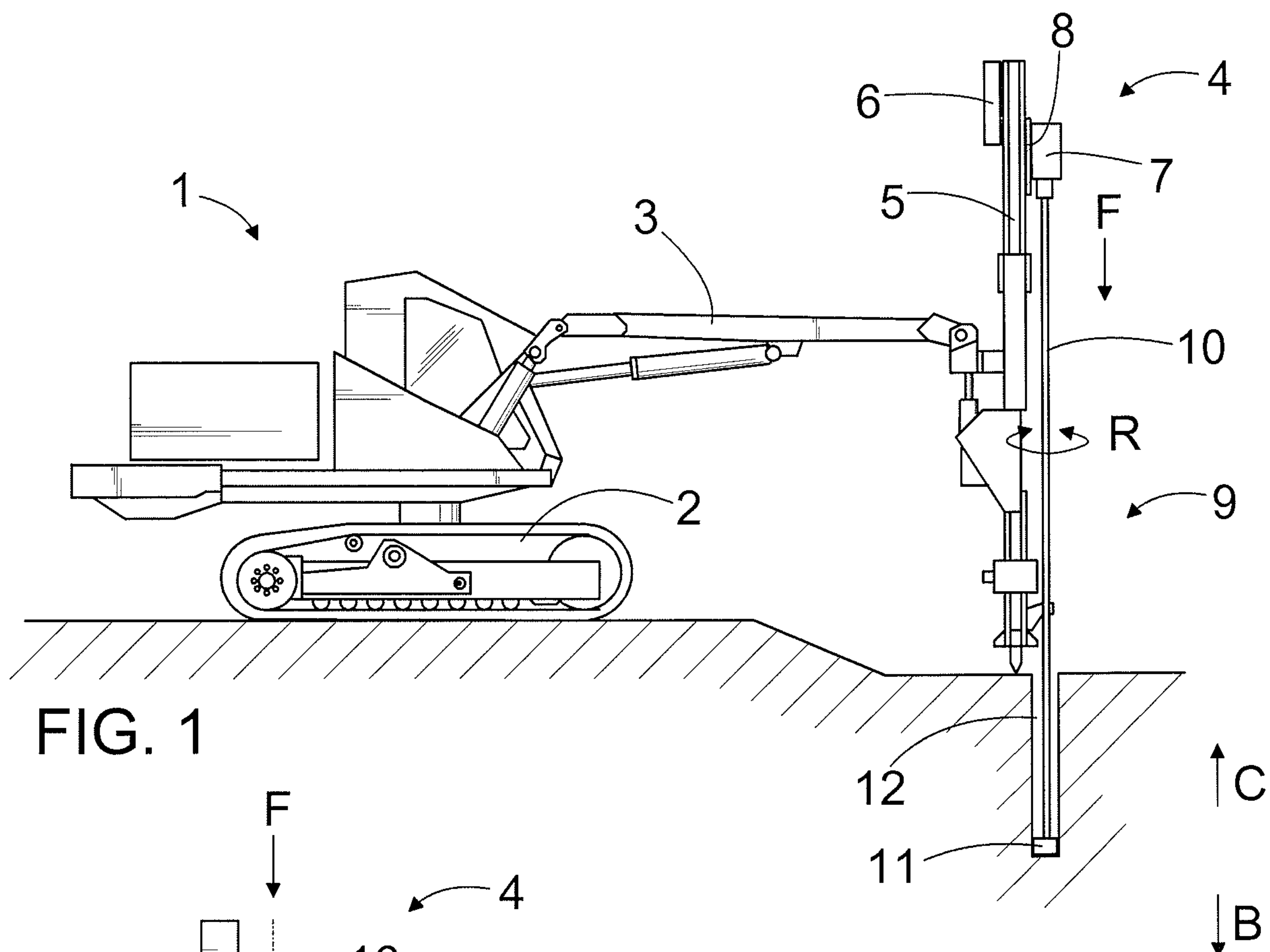


Fig. 3a

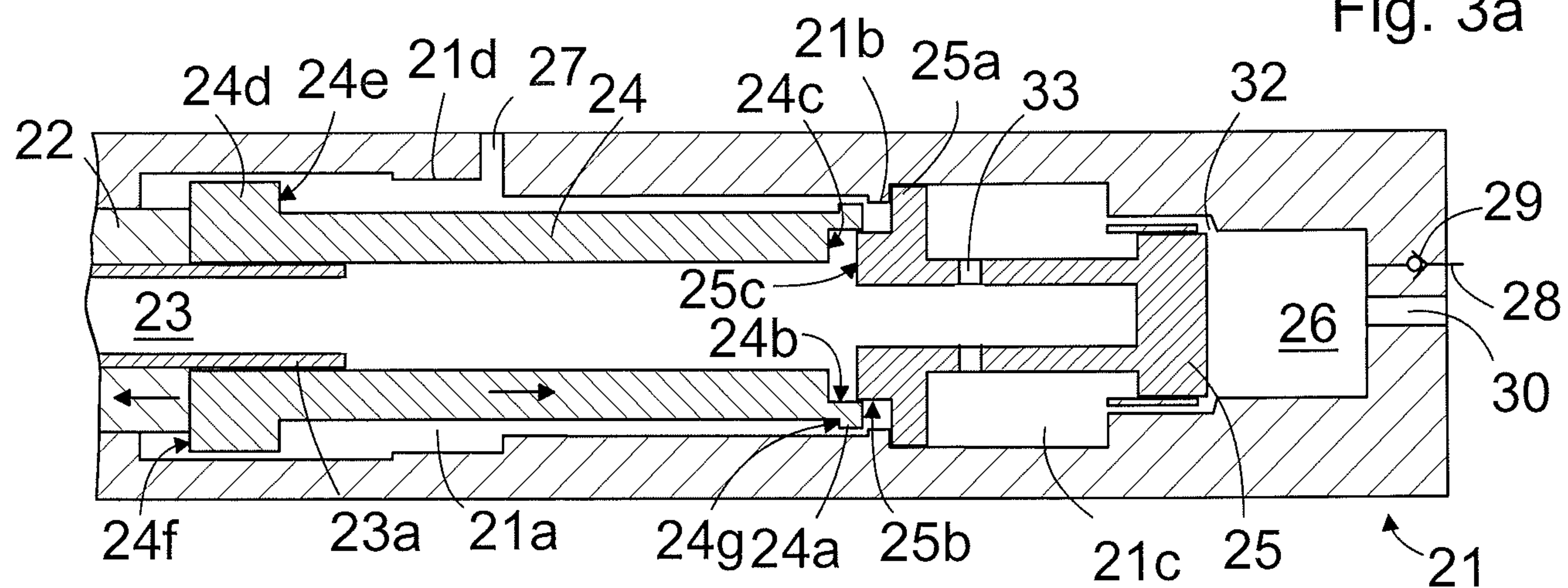


Fig. 3b

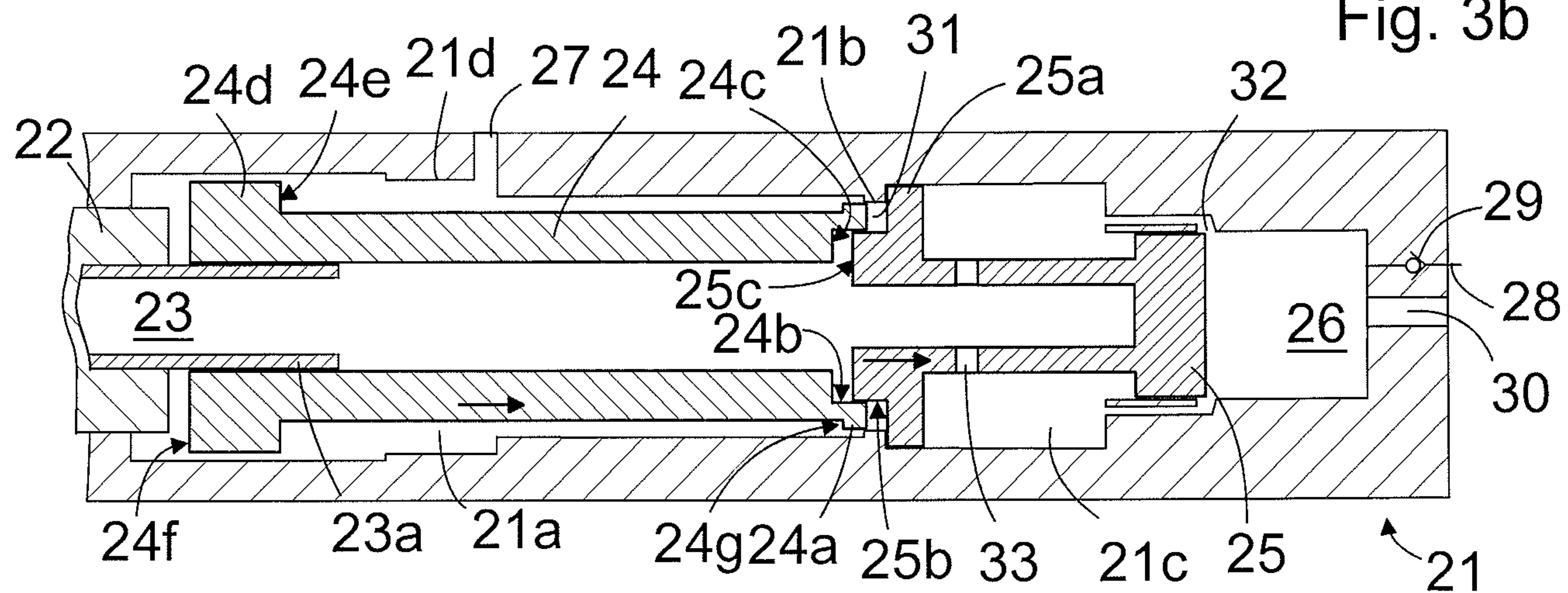


Fig. 3c

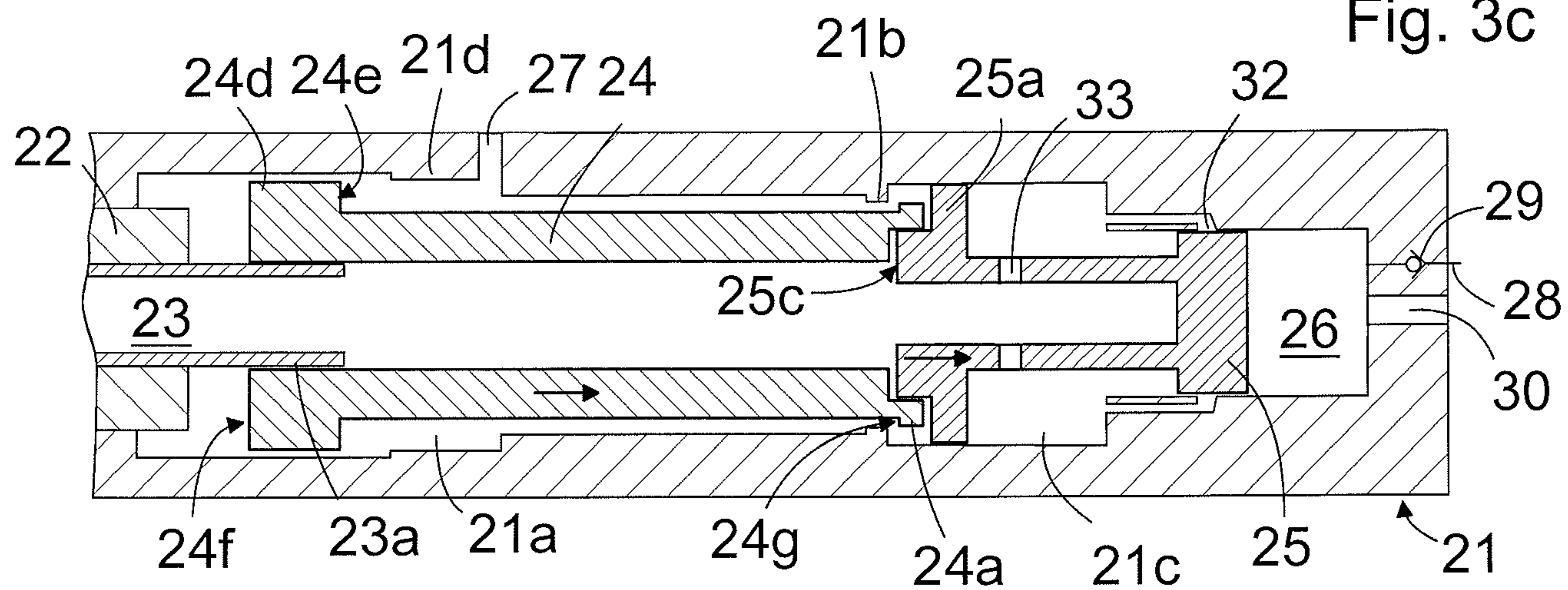


Fig. 3d

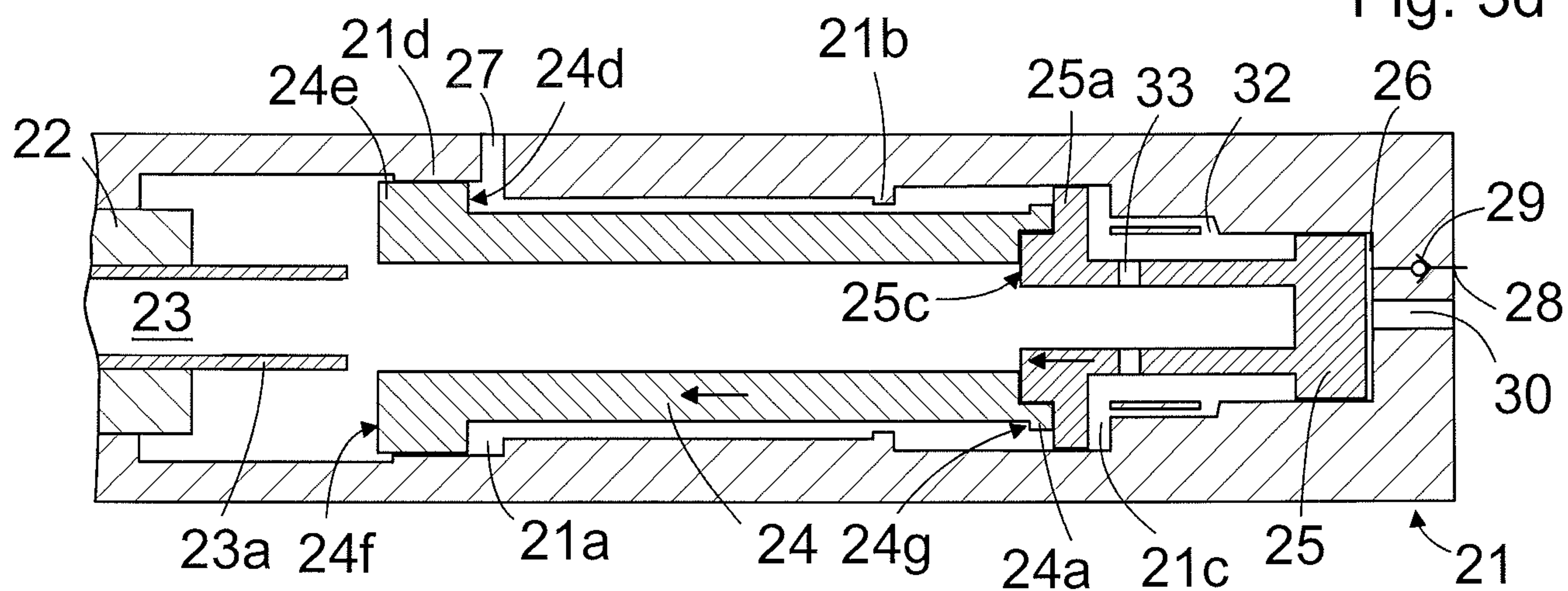


Fig. 3e

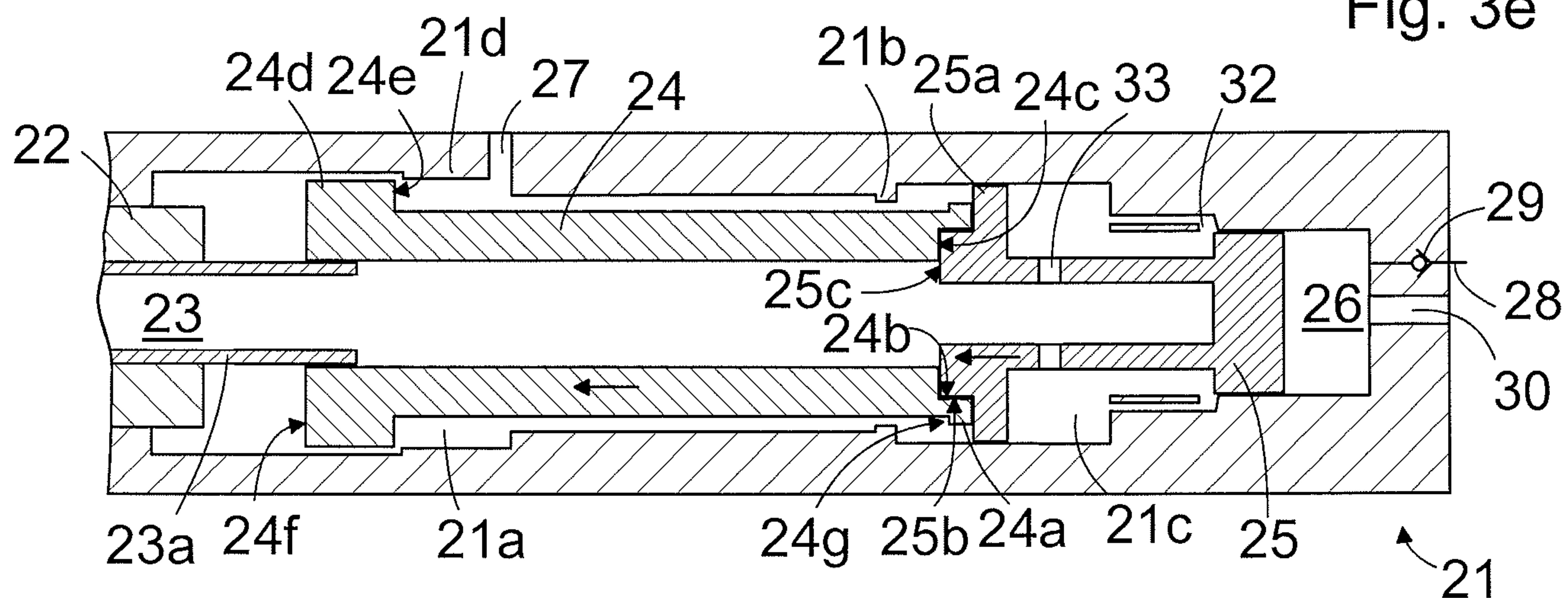


Fig. 3f

