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(54) **Tunnelling system**

(57) The present invention relates to a tunnelling system (10) including a tunnelling device (12) comprising a hollow body (10) having a longitudinal axis and a cutter blade (22) mounted to a forward end of the body (18) and rotatable about said axis, a traction member (36) extending from the forward end of the tunnelling device (12), a jacking unit (14) operable to pull and rotate the traction member (36) to advance the tunnelling device (12), and a vacuum source (16) connected operable to remove material excavated by the tunnelling device (12).

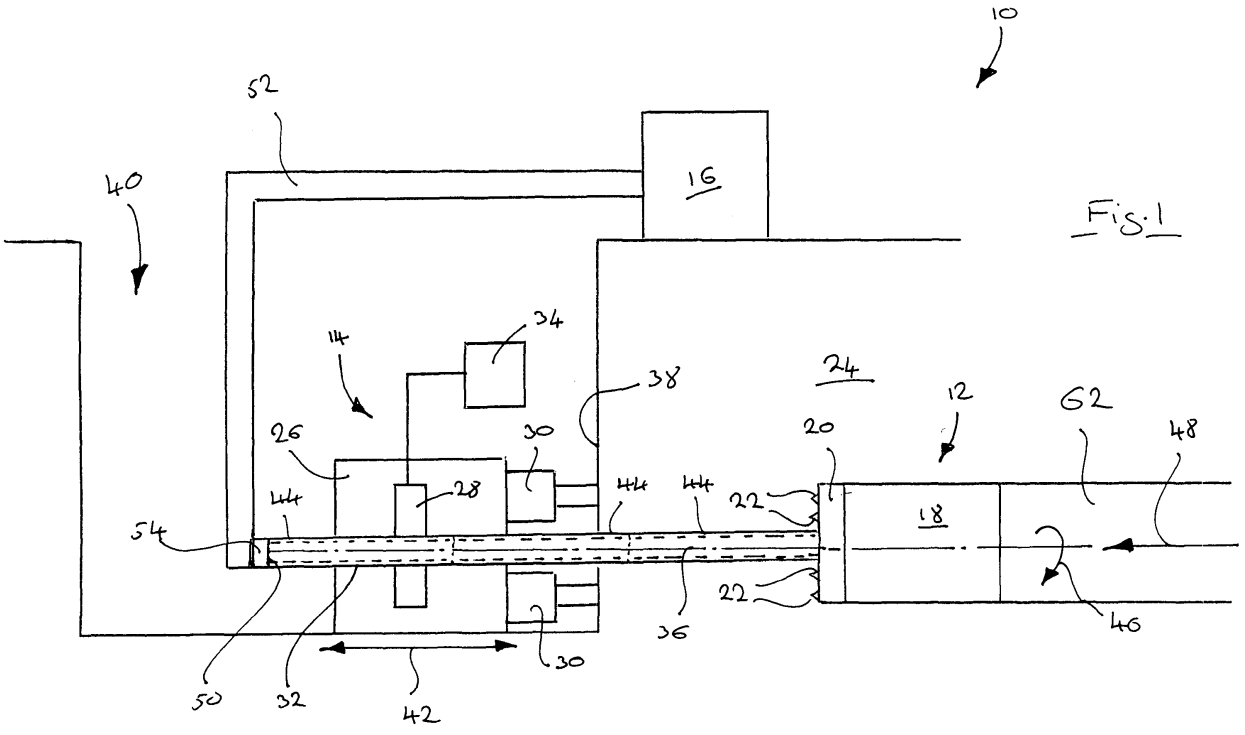


Fig.1

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Description

[0001] The present invention relates to a tunnelling system and in particular to a tunnelling system where a tunnelling device is pulled through the ground. The present invention also relates to a tunnelling device suitable for use with such a system.

[0002] It is known to excavate a tunnel using a cutter apparatus or head which is advanced through the ground by pressure applied to the rear of the head by a hydraulic jack or ram. The pressure may be applied directly to the head or via on or more spacers positioned between the head and the ram. The cutter head typically comprises a hollow cylindrical body which is provided at its forward end with a rotatable cutter blade. In use, the blade breaks up the ground ahead of the of the cutter head. The broken up ground is typically removed by the recirculation of bentonite slurry through the cutter head. The slurry entrains the broken up ground and permits its removal from the tunnel. In order to circulate the slurry in the required manner, a relatively complex slurry supply system must be provided. For example, the cutter head, and any intermediate spacers, require internal supply and return pipe work, and the slurry supply means require adequate filtration means to remove material entrained within the slurry.

[0003] According to the present invention there is provided tunnelling system including a tunnelling device comprising a hollow body having a longitudinal axis and a cutter blade mounted to a forward end of the body and rotatable about said axis, a traction member extending from the forward end of the tunnelling device and a jacking unit operable to pull and rotate the traction member to advance the tunnelling device, and a vacuum source connected to the tunnelling device and operable to remove material excavated by the tunnelling device.

[0004] In one embodiment the traction member is hollow and the vacuum source is connected to the traction member such that material excavated by the tunnelling device is removed through the traction member. The excavated material is thus removed through the traction member in the direction of travel of the tunnelling device. In an alternative embodiment the vacuum source is connected to a material removal conduit which extends from the rear of the tunnelling device. In such an embodiment the excavated material is removed through the material removal conduit in a direction opposite to the direction of travel of the tunnelling device.

[0005] The jacking unit preferably includes a clamp arrangement operable to releasably grip the traction member. The jacking unit may also include a drive means arranged to rotate the traction member when said member is gripped by the clamp arrangement. The drive means may be arranged to rotate the clamp arrangement. The jacking unit is preferably provided with at least one extensible ram. The ram is operable to move the jacking unit in a direction substantially parallel to a pulling axis. The pulling axis is aligned with a longitudinal axis of the traction member.

[0006] The traction member preferably includes a plurality of tubular members which are releasably connectable to one another. In the embodiment where material is removed from the tunnelling device through a material removal conduit, the jacking unit may be provided with a draw bar which is releasably connectable to the traction member. The draw bar is arranged to be gripped and rotated by the clamp arrangement and drive means of the jacking unit respectively.

[0007] The tunnelling device may include a hollow body having a longitudinal axis and a shaft mounted cutter blade provided at a forward end of the body and rotatable about said axis, the body being provided with an end face wall at the forward end of the body having at least one aperture therein, the body further being provided with an internal chamber behind the end face wall having an outlet connectable, in use, to a vacuum source, wherein the outlet is defined by an aperture of the cutter blade shaft which is connectable to the traction member. Alternatively, the outlet may be defined by an aperture in a wall of the internal chamber. In such an embodiment, the outlet may be connected to a conduit extending to the rear of the tunnelling device.

[0008] In a preferred embodiment the chamber is defined between the end face wall and an internal partition wall of the body. The partition wall may be provided with an aperture to permit air to enter the chamber from the rear of the device. The shaft may be provided with a blade or paddle operable to agitate material present within the chamber. The device may be provided with a liquid conduit operable to convey liquid through the hollow body to the cutter blade. The liquid conduit may be connected to a port or aperture provided in front end face of the body.

[0009] According to a second aspect of the present invention there is provided a tunnelling device including a hollow body having a longitudinal axis and a shaft mounted cutter blade provided at a forward end of the body and rotatable about said axis, the body being provided with an end face wall at the forward end of the body having at least one aperture therein, the body further being provided with an internal chamber behind the end face wall having an outlet connectable, in use to a vacuum source, and the cutter blade shaft is provided at its forward end with a connector arrangement to permit the releasable connection of a traction member thereto.

[0010] In one embodiment the cutter blade shaft amy be hollow and the outlet by an aperture of the cutter blade shaft. In an alternative embodiment, the outlet may be defined by an aperture in the wall internal chamber. In such an embodiment, In such an embodiment, the outlet may be connected to a conduit extending to the rear of the tunnelling device.

[0011] In a preferred embodiment the chamber is defined between the end face wall and an internal partition wall of the body. The partition wall may be provided with an aperture to permit air to enter the chamber from the rear of the device. The shaft may be provided with a blade

or paddle operable to agitate material present within the chamber. The device may be provided with a liquid conduit operable to convey liquid through the hollow body to the cutter blade. The liquid conduit may be connected to a port or aperture provided in front end face of the body.

[0012] According to a further aspect of the present invention there is provided a method of excavating a tunnel, the method comprising the steps of:

providing a tunnelling device having a hollow body having a longitudinal axis and a cutter blade mounted to a forward end of the body and rotatable about said axis;
providing a jacking unit;
providing a traction member;
providing a vacuum source;
positioning the tunnelling device at a starting location;
positioning the jacking unit at a finishing location for the tunnelling device;
connecting the traction member between the jacking unit and tunnelling device;
connecting the vacuum source to the jacking unit;
operating the jacking unit to draw the tunnelling device from the starting location to the finishing location; and
operating the vacuum source to remove material excavated by the tunnelling device.

[0013] In one embodiment the traction member is hollow and the vacuum source is connected to the tunnelling device through the traction member such that material excavated by the tunnelling device is removed through the traction member in the direction of travel of the tunnelling device. In an alternative embodiment the tunnelling device is provided with a material removal conduit which extends from the rear thereof and to which the vacuum source is connected, the material being excavated by the tunnelling device being removed through the material removal conduit in a direction opposite to the direction of travel of the tunnelling device.

[0014] Embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Figures 1 and 2 show schematic side views of a tunnelling system according to a first embodiment of the present invention;
Figure 3 shows a cross-sectional side view of a tunnelling device according to the first embodiment of the present invention;
Figures 4 and 5 show schematic side views of a tunnelling system according to a second embodiment of the present invention; and
Figure 6 shows a cross-sectional side view of a tunnelling device according to the second embodiment of the present invention;

[0015] A schematic representation of a system according to the present invention, generally designated 10, is shown in figure 1. The system 10 includes a tunnelling device 12, an extraction unit 14 and a vacuum source 16. The tunnelling device includes a substantially cylindrical body 18 having a cutter head 20 rotationally mounted thereto. The cutter head 20 is cylindrical and of a diameter substantially equal to that of the body 18. The cutter head 20 is provided with a plurality of teeth and/or blades 22 which are configured so as to break up earth ahead of the tunnelling device 12 as it moves through the ground 24.

[0016] The extraction unit 14 includes a body 26 having a clamp arrangement 28 and a pair of extensible rams 30. The clamp arrangement 28 includes a drive means 34 which is operable to both open and close the clamp arrangement 28 and rotate the clamp arrangement 28 relative to the extraction unit body 26. The body 26 is further provided with a conduit 32 extending therethrough. The conduit 32 is configured so as to be able to receive therethrough a tube 36 extending from the tunnelling device 12 and hereinafter referred to as the traction member or tube 36. The clamp arrangement 28 is positioned such that the conduit 32 and traction tube 36 extend therethrough. The extensible rams 30 are provided on a side of the body 26 adjacent a wall 38 of a pit 40 within which the extraction unit 14 is located. The rams 30 are connected to the to the wall 38 such that extension and retraction of the rams 30 causes movement of the extraction unit body 26 towards and away from the wall 38 as indicated by arrow 42.

[0017] The traction tube 36 is comprised of a number of tube sections 44 which are releasably secured to one another, for example by the provision of complementary male and female threaded connections between the tube sections 44. The traction tube 36 is connected to the tunnelling device 12 such that rotation of the traction tube 36 causes rotation of the cutter head 20 as indicated by arrow 46. It will be appreciated that the cutter head 20 may also be rotated in the opposite direction. The traction tube 36 is also connected to the tunnelling device such that the extraction unit 14 is able to draw the tunnelling device 12 through the ground 24 in the direction indicated by arrow 48. Operation of the extraction unit 14 will be described in greater detail below.

[0018] The vacuum source 16 is connected to the end 50 of the traction tube 36 remote from the tunnelling device 12 via a suction tube 52. The suction tube 52 is connected to the traction tube 36 via a coupling 54 which is able to accommodate the rotation of the traction tube 36 resulting from the operation of the extraction unit 14. The suction tube 52 is also movable so as to be able to accommodate the longitudinal movement of the traction tube end 50 as a result of the operation of the extraction unit 14. For example, the suction tube 52 may comprise a flexible hose.

[0019] Operation of the system will now be described. Firstly, two pits 40, 56 are dug at positions corresponding

to the ends of a tunnel it is proposed to excavate through the ground 24. The pits comprise a launch pit 56 and a retrieval pit 40. The launch pit 56 is arranged to receive and accommodate the tunnelling device 12, while the retrieval pit 40 accommodates the extraction unit 14. A pilot tunnel 58 having a diameter slightly greater than the traction tube 36 is excavated between the pits 40, 56. The traction tube 36 is then fed through the pilot tunnel 58 from the retrieval pit 40 to the launch pit 56 and connected to the tunnelling device 12. The traction tube 36 is also connected to the suction tube 52. The retrieval pit end of the traction tube 36 is gripped by the clamp arrangement 28 of the extraction unit 14 and the drive means 34 operated to rotate the clamp arrangement 28 and traction tube 36. In this manner the cutter head 20 of the tunnelling device 12 is caused to rotate.

[0020] As the traction tube 36 is rotated, the extensible rams 30 of the extraction unit 14 are then operated to move the unit 14 away from the wall 38 of the retrieval pit 40 and draw the traction tube 36 through the pilot tunnel 58. The tunnelling device 12 is thus drawn towards the wall 60 of the launch pit 56 in the direction of the retrieval pit 40. As the device 12 makes contact with the wall 60 the rotation of the cutter head 20 causes the break up of the ground 24 ahead of the device 12.

[0021] It will be appreciated that the stroke of the extensible rams 30 is significantly less than the length of the pilot tunnel 58. Once the rams 30 have fully extended the clamp arrangement 28 is disengaged. The rams 30 are then retracted and the extraction unit 14 moved back towards the pit wall 38. The clamp arrangement 28 is reengaged and the rams 30 re-extended to draw the traction tube 36 and tunnelling device 12 through the ground 24. The above described steps are repeated until the tunnelling device 12 reaches the retrieval pit 40 and a tunnel 62 having the diameter of the device 12 is provided between the pits 40,56

[0022] The vacuum source 16 is operable in order to remove the ground broken up by the cutter head 20. The source is activated shortly before the cutter head 20 contacts the launch pit wall 60. Material is drawn through the traction tube 36 and into the suction tube 52 before being either stored in or ejected from the vacuum source 16. It will be appreciated that continued operation of the extraction unit 14 results in the traction tube 36 extending rearwardly of the extraction unit 14. Redundant sections 44 of the traction tube 26 can be removed once they have cleared the rear of the extraction unit 14. It will be understood that this will necessitate the disconnection and subsequent reconnection of the suction tube coupling 54 to the traction tube 36.

[0023] Figure 3 shows a cross-sectional view of a cutter apparatus, generally designated 12, according to an aspect of the present invention. The apparatus 12 includes a substantially circular tubular body 18 having a substantially circular front end face wall 62. The apparatus 12 further includes a rotatable cutter 20 mounted ahead of the end face wall 62. The cutter 20 is mounted to a shaft 64 which extends through the end face wall 62 and is axially aligned with the longitudinal axis of the body 18. The shaft 64 is provided at its forward end 66 with a drive connection to which a section of traction tube 36 can be connected to effect rotation of the cutter 20. Within the body 18 there is provided a chamber 68 which is defined between the end face wall 62 and an internal partition wall 70 of the body 18.

[0024] The front end face wall 62 is provided with a plurality of apertures 72 through which material loosened by the cutter 20 can pass as indicated by arrows 74. The partition wall 70 is provided with a plurality of apertures 76 through which air can pass as indicated by arrows 78. The shaft 64 has a hollow core 80 and is provided with apertures 82 which are open to the chamber 68.

[0025] In use, material dislodged by the cutter 20 passes through the apertures 74 and into the chamber 68. The material is removed from the chamber 68 through the hollow core 80 of the shaft 64 and the traction tube 36 by the airflow induced by the vacuum pump as indicated by arrows 84 and 86. The presence of apertures 76 in the partition wall 70 permits air to enter the chamber 68 from behind the cutter apparatus 12 to replace the air removed from the chamber 68 by the pump.

[0026] The apparatus 12 may optionally be provided with a water feed line 88 to the front end face wall 62 as indicated by broken lines. The feed line 88 may be utilised to inject water onto and around the cutter 66 to assist in excavation work. The shaft 64 may optionally be provided with a stirrer or paddle 90 located within the chamber 68 to agitate material contained therein and hence reduce the possibility of blockages forming in the chamber 68 or further downstream in the shaft 64 or traction tube 36.

[0027] Referring now to figures 4 to 6 there are shown alternative embodiments of a tunnelling system, generally designated 100, and a tunnelling device generally designated 120. features common to the system and device described with reference to figures 1 to 3 are identified with like reference numerals. The system 100 differs in that the vacuum source 16 is connected to the rear of the tunnelling device 120. The connection between the device 120 and the source 16 is made via a hose or tube 102. The hose or tube 120 connects to a conduit 104 provided in the tunnelling device 120 which extends rearwardly from the chamber 68. The conduit 104 extends rearwardly from an aperture 106 provided in the partition wall 70 of the chamber 68.

[0028] The extraction unit 14 differs in that it is provided with a draw bar 108 which is arranged to be gripped by the clamp arrangement 28 and rotated by the drive means 34. The draw bar 108 may be arranged to be moved internally by the extraction unit 14 in the directions indicated by arrow 42. The operative stroke of the extraction unit 14 and draw bar 108 is at least equal to the length of one of the tube sections 44 of the traction tube 36. In use, a full section 44 can be drawn into the pit 40 and then disconnected from the tube 36 and draw bar 108. The draw bar 108 is then reattached to the tube 36

and the extraction unit 14 operated to extract another pipe section 44. It will be appreciated that in the system 100 of figures 4 to 6 the material excavated by the tunnelling device 120 is removed from the device 120 in a direction opposite to the direction of travel of the device 120.

Claims

1. A tunnelling system including a tunnelling device comprising a hollow body having a longitudinal axis and a cutter blade mounted to a forward end of the body and rotatable about said axis, a traction member extending from the forward end of the tunnelling device, a jacking unit operable to pull and rotate the traction member to advance the tunnelling device, and a vacuum source connected operable to remove material excavated by the tunnelling device.

2. A tunnelling system as claimed in claim 1 wherein the traction member is hollow and the vacuum source is connected to the traction member.

3. A tunnelling system as claimed in claim 1 wherein the vacuum source is connected to a material removal conduit extending from the rear of the tunnelling device.

4. A tunnelling system as claimed in any preceding claim wherein the jacking unit includes a clamp arrangement operable to releasably grip the traction member.

5. A tunnelling system as claimed in claim 4 wherein the jacking unit includes a drive means arranged to rotate the traction member when said member is gripped by the clamp arrangement.

6. A tunnelling system as claimed in claim 5 wherein the drive means is arranged to rotate the clamp arrangement.

7. A tunnelling system as claimed in any preceding claim wherein the jacking unit is provided with at least one extensible ram operable to move the jacking unit in a direction substantially parallel to a pulling axis of the traction member.

8. A tunnelling system as claimed in any preceding claim wherein the traction member includes a plurality of tubular members which are releasably connectable to one another.

9. A tunnelling system as claimed in any preceding claim wherein the tunnelling device includes a hollow body having a longitudinal axis and a shaft mounted cutter blade provided at a forward end of the body and rotatable about said axis, the body being provided with an end face wall at the forward end of the body having at least one aperture therein, the body further being provided with an internal chamber behind the end face wall having an outlet connectable, in use, to a vacuum source.

10. A tunnelling system as claimed in claim 9 wherein the cutter blade shaft is hollow and the outlet is defined by an aperture of the cutter blade shaft.

11. A tunnelling system as claimed in claim 9 wherein the outlet is provided in a wall of the chamber.

12. A tunnelling system as claimed in any of claims 9 to 11 wherein the chamber is defined between the end face wall and an internal partition wall of the body.

13. A tunnelling system as claimed in claim 12 wherein the partition wall is provided with an aperture to permit air to enter the chamber from the rear of the device.

14. A tunnelling system as claimed in any of claims 9 to 13 wherein the shaft is provided with a blade or paddle operable to agitate material present within the chamber.

15. A tunnelling system as claimed in any of claims 9 to 14 wherein the device is provided with a liquid conduit operable to convey liquid through the hollow body to the cutter blade.

16. A tunnelling device including a hollow body having a longitudinal axis and a shaft mounted cutter blade provided at a forward end of the body and rotatable about said axis, the body being provided with an end face wall at the forward end of the body having at least one aperture therein, the body further being provided with an internal chamber behind the end face wall having an outlet connectable, in use, to a vacuum source, and the cutter blade shaft is provided at its forward end with a connector arrangement to permit the releasable connection of a traction member thereto.

17. A tunnelling device as claimed in claim 16 wherein the cutter blade shaft is hollow and the outlet is defined by an aperture of the cutter blade shaft.

18. A tunnelling device as claimed in claim 16 wherein the outlet is provided in a wall of the chamber.

19. A tunnelling device as claimed in any of claims 16 to 18 wherein the chamber is defined between the end face wall and an internal partition wall of the body.

20. A tunnelling device as claimed in claim 19 wherein the partition wall is provided with an aperture to permit air to enter the chamber from the rear of the device.

21. A tunnelling device as claimed in any of claims 16 to 20 wherein the shaft is provided with a blade or paddle operable to agitate material present within the chamber.

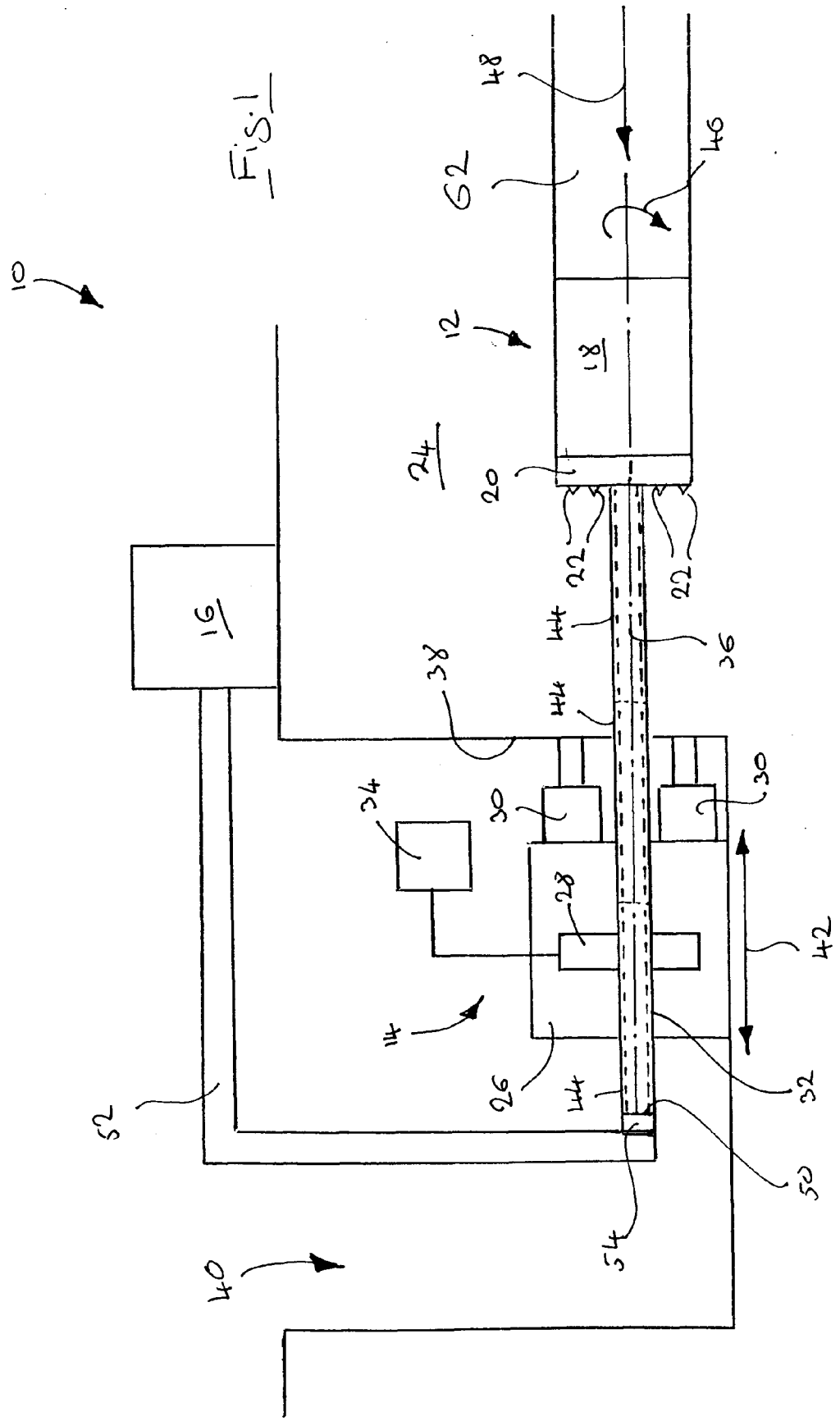
22. A tunnelling device as claimed in any of claims 16 to 21 wherein the device is provided with a liquid conduit operable to convey liquid through the hollow body to the cutter blade.

23. A method of excavating a tunnel, the method comprising the steps of:

providing a tunnelling device having a hollow body having a longitudinal axis and a cutter blade mounted to a forward end of the body and rotatable about said axis;
providing a jacking unit;
providing a traction member;
providing a vacuum source;
positioning the tunnelling device at a starting location;
positioning the jacking unit at a finishing location for the tunnelling device;
connecting the traction member between the jacking unit and tunnelling device;
connecting the vacuum source to the jacking unit;
operating the jacking unit to draw the tunnelling device from the starting location to the finishing location; and
operating the vacuum source to remove material excavated by the tunnelling device.

24. A method as claimed in claim 23 wherein the traction member is hollow and the vacuum source is connected to the tunnelling device through the traction member such that material excavated by the tunnelling device is removed through the traction member in the direction of travel of the tunnelling device.

25. A method as claimed in claim 23 wherein the tunnelling device is provided with a material removal conduit which extends from the rear thereof and to which the vacuum source is connected, the material being excavated by the tunnelling device being removed through the material removal conduit in a direction opposite to the direction of travel of the tunnelling device.


Fig. 1
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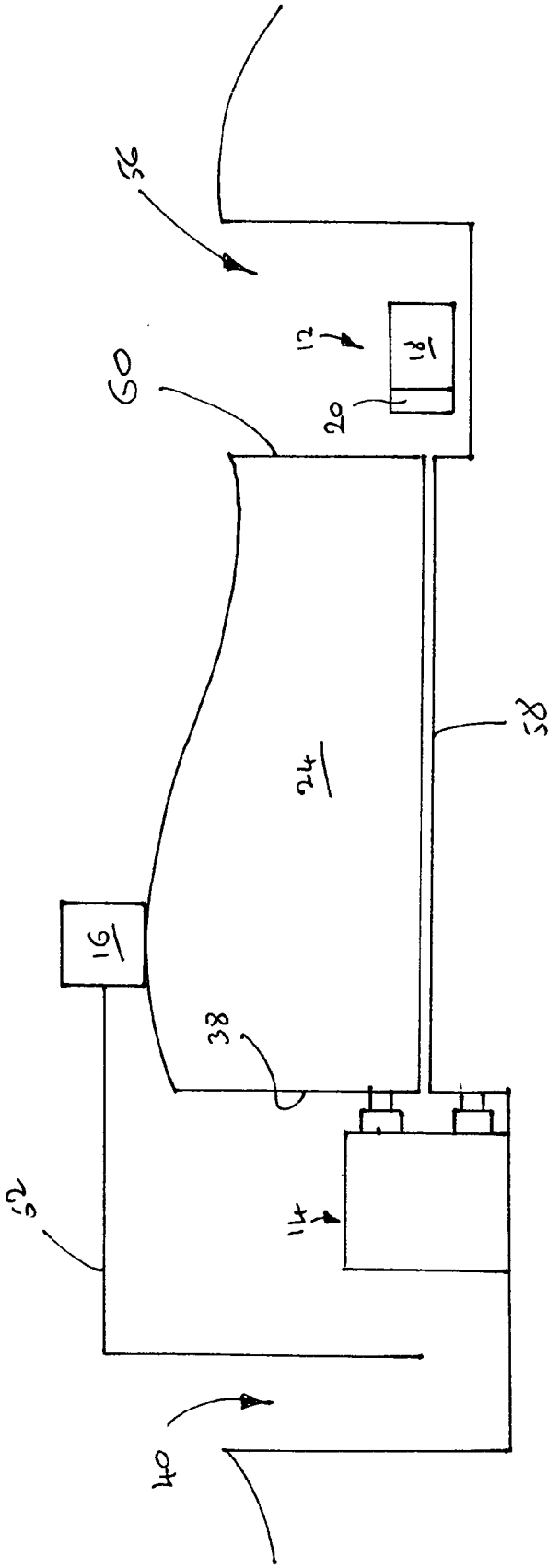


Fig. 2

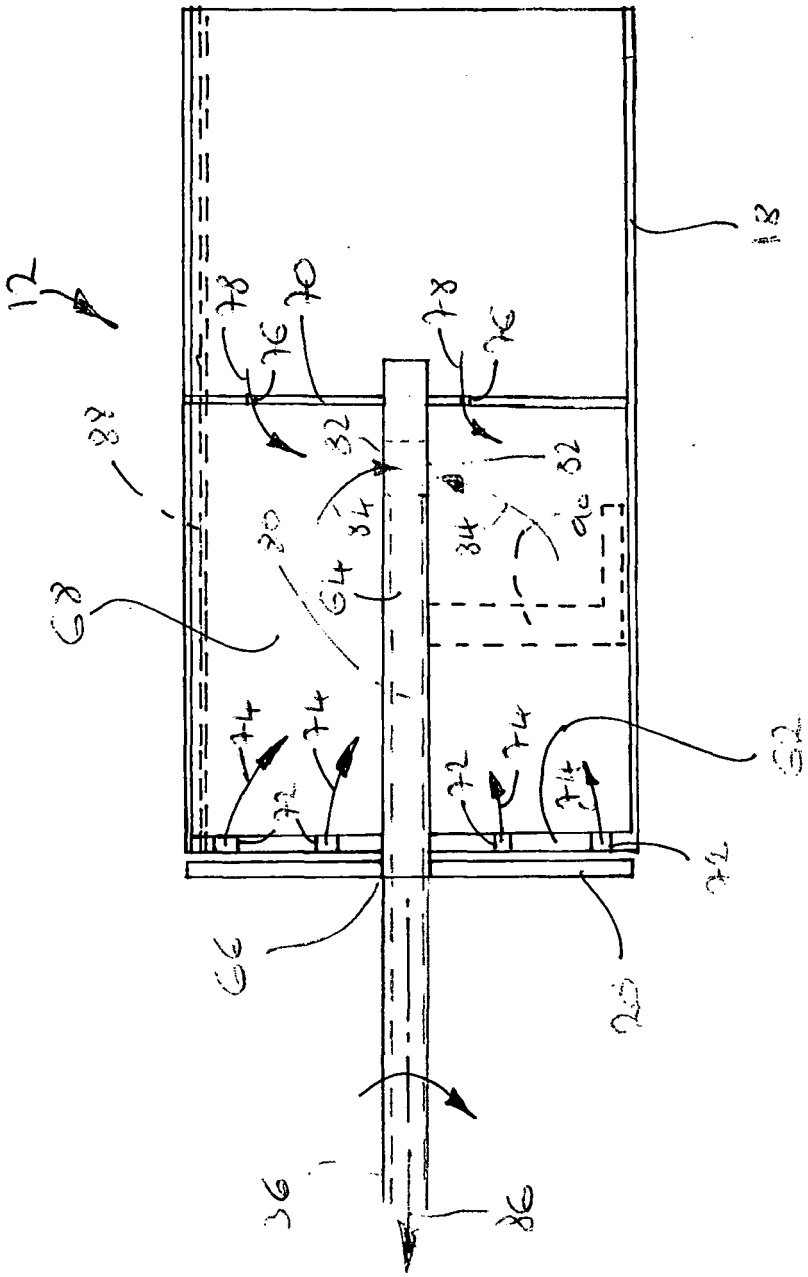
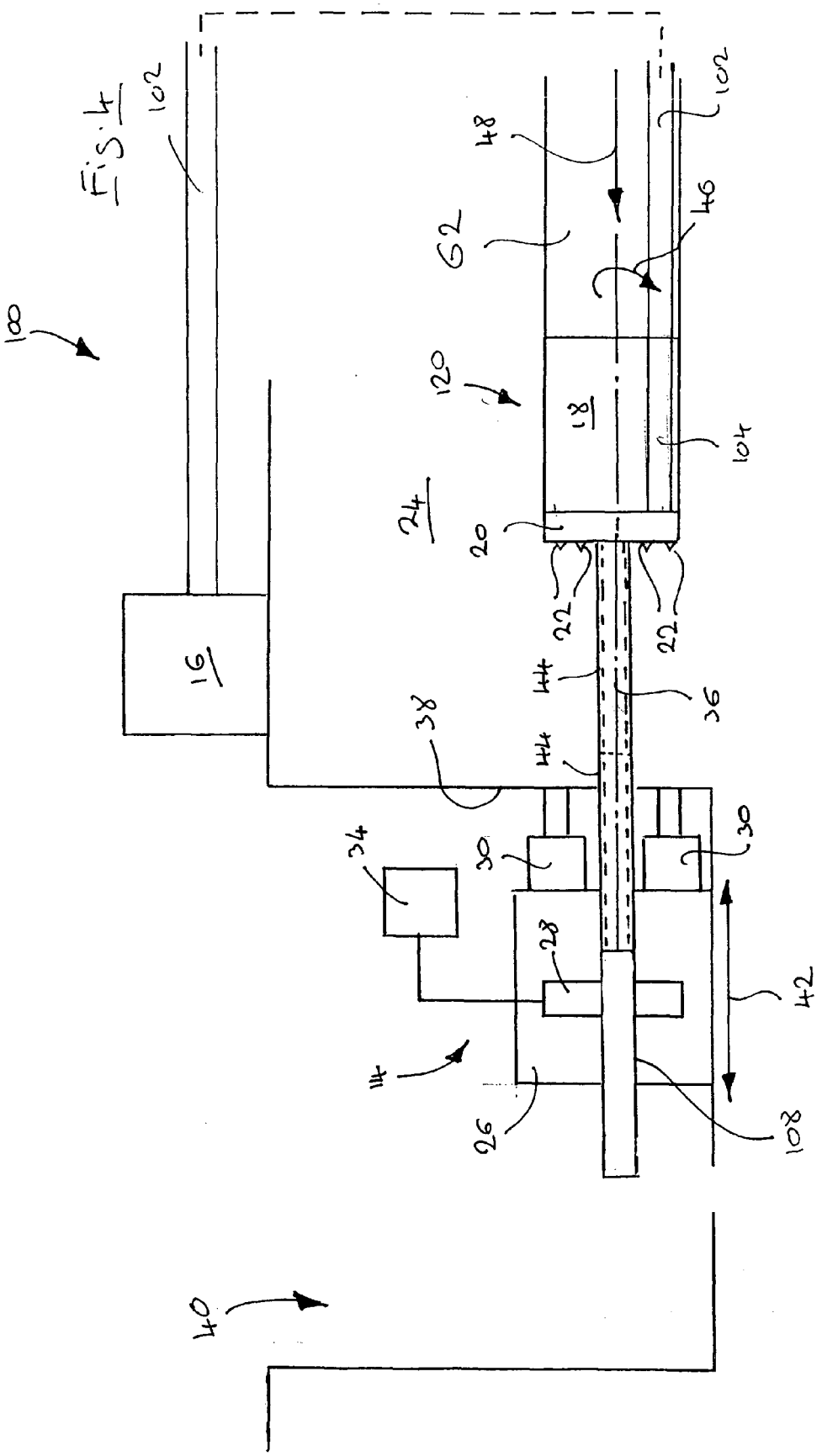

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Fig. 2

Fig. 4


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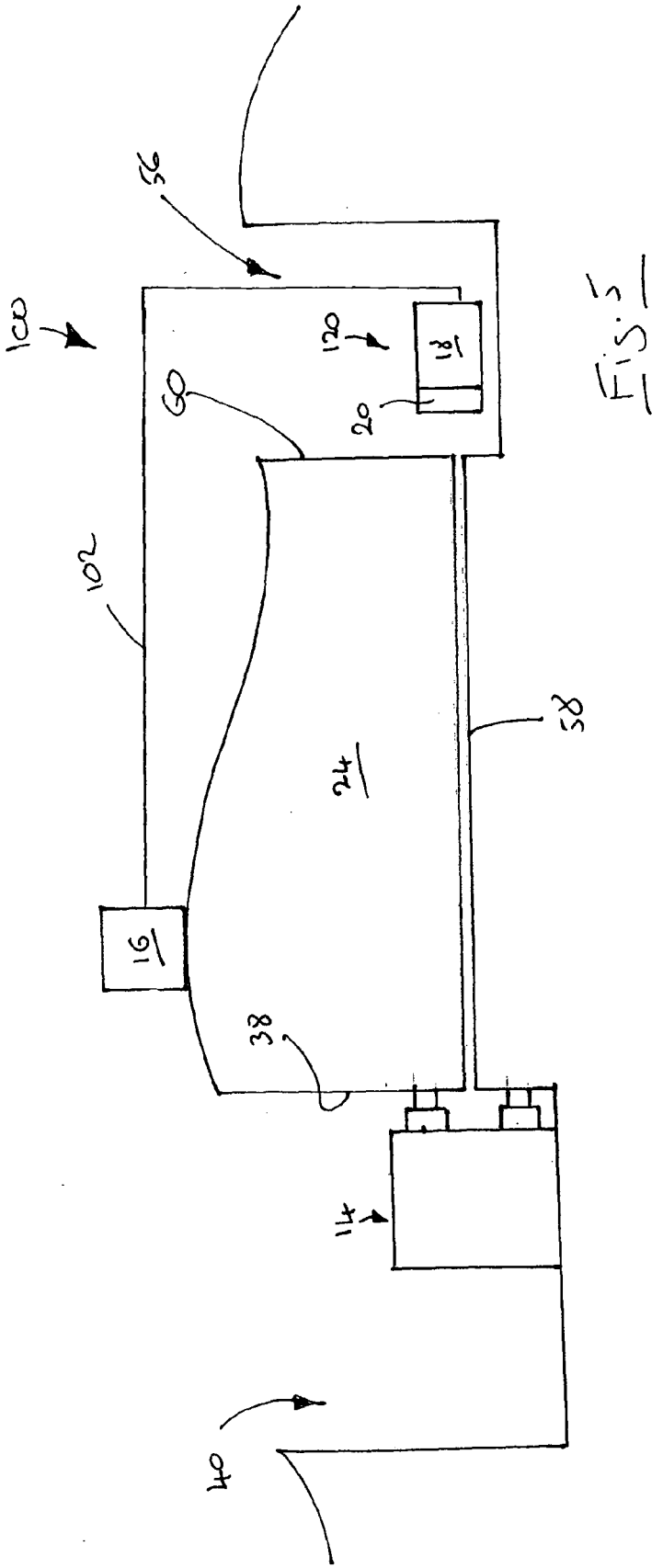


Fig. 1

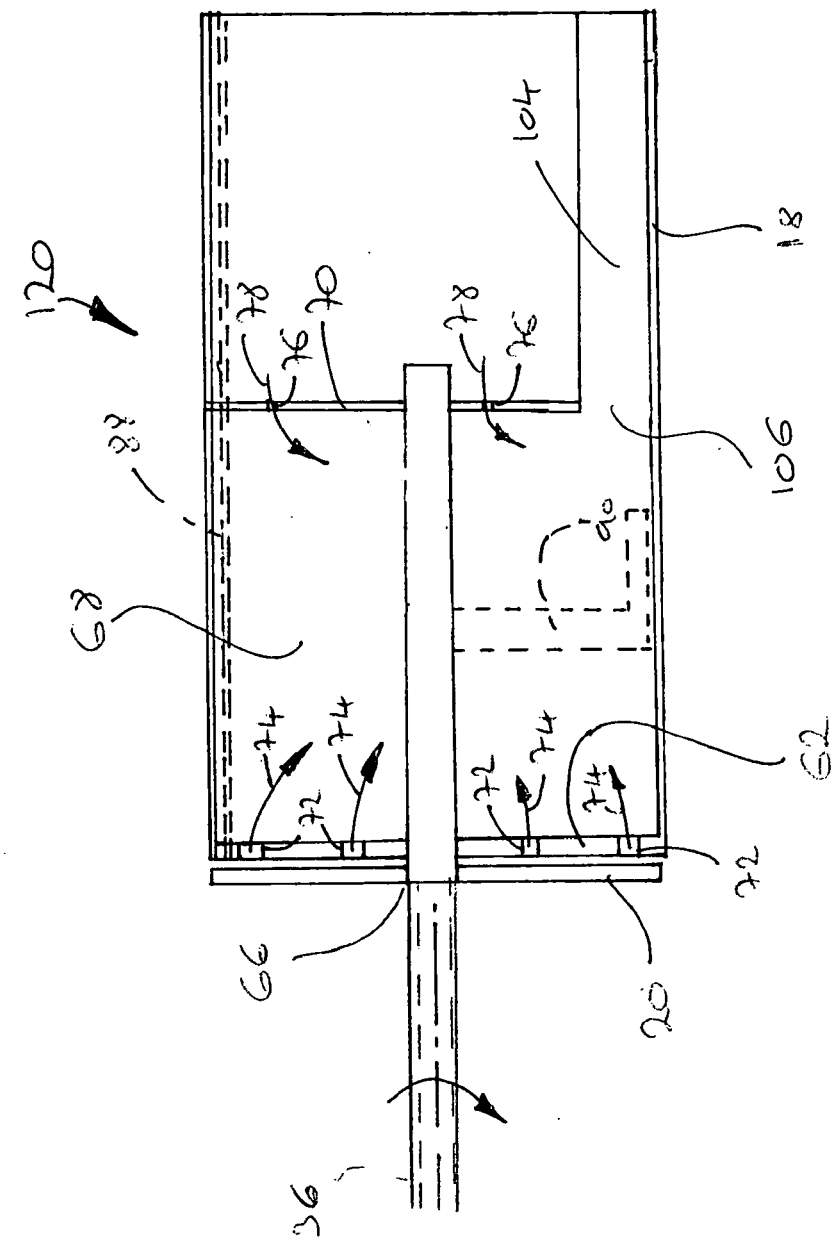


FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 25 0701

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	24 May 2007	Morrish, Susan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 25 0701

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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