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(54) **Method and device for constructing an underground tunnel**

(57) In a method and device for constructing a tunnel in the ground along a predetermined path, a rod is positioned in the ground. The rod is fixed with respect to the ground at at least one location. An earth removing device is displaced along the rod for the purpose of constructing the tunnel. A drive device which acts on the rod and the earth removing device is provided for the

purpose of supplying at least part of the force for displacing the earth removing device. Tunnel wall sections are displaced along the rod with the aid of a second drive device which acts on the rod and the tunnel wall sections.

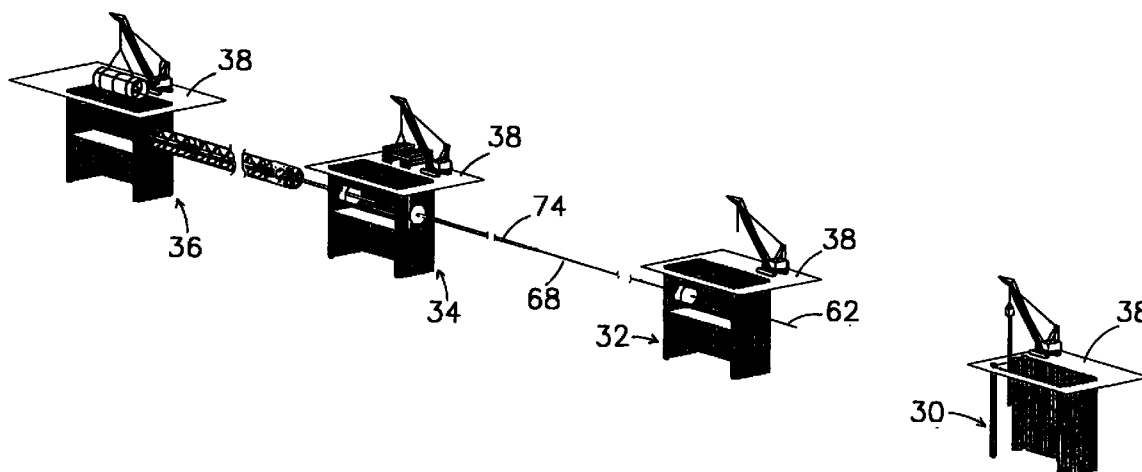


Fig 2

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Description

[0001] The invention relates to a method and device for constructing a tunnel in the ground along a predetermined path.

[0002] Existing methods for constructing a passage or tunnel in the ground include, in addition to the standard controlled horizontal drilling techniques for relatively small diameters, for relatively large diameters, firstly, techniques in which a suitable drilling, jetting or reaming tool which is pulled or pushed through the ground is used and, secondly, techniques in which tunnel building devices are used.

[0003] The known techniques for drilling, jetting and/or reaming a passage in soft ground using a tool which is pulled or pushed through the ground are limited to small-scale projects. These may, for example, include reaming of a passage using a pulled reamer with a metal or plastic pipe pulled along immediately behind it. To keep the friction forces at a low level and to limit risks, the reaming of the passage and the positioning of the pipe may also be carried out as separate steps, in which case the reamed passage is temporarily supported by a bentonite mixture. In the case of larger diameters, the passage may also be reamed by pulling successive reamers with increasing diameters through the passage.

[0004] In hard ground, passages with a relatively large diameter can be obtained using a drilling and/or reaming device which is pulled through the ground. Due to the structure of the ground, a reamed passage does not have to be supported immediately; for example, it is possible for a concrete lining to be formed on the wall of the passage at a subsequent time. Pulling a large-diameter reamer in a vertical direction is known in the mining industry. Furthermore, it is known that a passage running in the horizontal direction can be reamed using a machine which is pulled by a tool which rests against the wall of the (unreamed) passage.

[0005] The existing technique based on reamers cannot readily be scaled up to construct passages with very large transverse dimensions. If the transverse dimensions of the passage which is to be formed become larger, the tensile force in and (usually as a consequence of this) the cross section of a pull rod connected to a reamer increase. In this context, it needs to be considered that the tensile force which has to be supplied is not limited to the resistance and digging force of the reamer, but rather the frictional force on the outer surface of the pull rod moving through the ground also has to be applied. This friction is increased still further if the length of the path which has to be reamed, and consequently the length of the pull rod, increases. A further drawback of the use of a pull rod moving through weak ground is that the bends in the path are flattened, owing to the fact that at these locations the pull rod works into the wall of the pull-rod passage owing to the tensile force (what is known as the "sawing effect"). The

results are deviations in the desired path of the passage. Finally, if the passage has large transverse dimensions, problems arise if the passage needs to be supported by means of a bentonite mixture: in the case of tunnels which are to be formed at a relatively shallow level in the ground, the bridge action required from ground situated above the tunnel is insufficient. In addition, in practical terms the quantities of bentonite required are excessive. A further drawback is that the digging process to be carried out using a reamer has to be interrupted periodically in order for sections of the pull rod which have been pulled in at the end of this pull rod to be uncoupled.

[0006] When employing tunnel building devices, use is generally made of a tunnel wall lining comprising annular, prefabricated concrete or iron elements or a lining produced by extruding concrete. This tunnel wall lining has to be able to absorb the mechanical loads which occur when constructing a tunnel. If the tunnel wall lining is positioned in situ, an earth removing device must be able to support itself on the tunnel wall lining in order to generate the digging forces required. If, when constructing the tunnel, the tunnel wall lining is pressed into the tunnel and thus moves with respect to the ground, it is necessary for, in particular, the rear part of the tunnel wall lining to be able to withstand the high compressive forces which arise, plus by the forces which are required for the necessary digging action. The loads which arise in the tunnel wall lining in the latter two cases are generally considerably higher than those which occur during normal use of the tunnel, so that the tunnel wall lining in fact has to be excessively heavy from the general use perspective. Another drawback which arises when using tunnel building devices is that the composition of the soil along the path of the tunnel is often not known in detail, a fact which may lead to unforeseen problems and deviations from the planned path during construction of the tunnel. In general, a reasonable distance will generally be maintained between the path of the tunnel and known or assumed underground obstacles, a fact which often imposes considerable limitations on the tunnel path selected.

[0007] The object of the invention is to provide a device which makes it possible to scale up existing techniques which make use of an earth removing device, such as a drilling, jetting or reaming device, to produce larger tunnel transverse dimensions and a greater length of path than those which are possible in practice given the prior art. At the same time, the invention aims to eliminate or at least substantially reduce the above-mentioned drawbacks and limitations of the conventional techniques.

[0008] These objects are achieved using the method according to the invention for constructing a tunnel in the ground along a predetermined path, comprising the steps: positioning at least a first base rod in the ground along the path; fixing the at least one base rod with respect to the ground at at least one location;

displacing an earth removing device along the at least one base rod for the purpose of constructing the tunnel, at least a first drive device, which acts on the at least one base rod and the earth removing device, being provided for the purpose of supplying at least part of the force for displacing the earth removing device. The abovementioned objects are also achieved with the method according to the invention for constructing a tunnel in the ground along a predetermined path, comprising the steps: displacing an earth removing device in the ground for the purpose of constructing the tunnel; positioning at least a second base rod in the ground; fixing the at least one base rod with respect to the ground at at least one location; and displacing at least one tunnel wall section along the at least one base rod, at least one second drive device, which acts on the at least one base rod and the at least one tunnel wall section, being provided for the purpose of supplying at least part of the force for displacing the at least one tunnel wall section.

[0009] The two abovementioned methods according to the invention are based on the common inventive idea of moving an element (in the present case: an earth removing device or a tunnel wall section) in the ground with the aid of a drive device which propels itself on a rod which (at that moment) is stationary and fixed with respect to the ground.

[0010] In the two abovementioned methods according to the invention, the section of the base rod between the fixing location, for example at the end of the base rod, and the earth removing device or the tunnel wall section will be subjected to a tensile load if the earth removing device or the tunnel wall section is moving towards the fixing location, and that the section of the base rod which is between the fixing location and the earth removing device or the tunnel wall section will be subjected to compressive load if the earth removing device or the tunnel wall section is moving away from the fixing location. It is also possible for the base rod to be fixed with respect to the ground on either side of the earth removing device or the tunnel wall section, that section of the base rod which lies between one of the fixing locations and the earth removing device or the tunnel wall section being subjected to a tensile load if the earth removing device or the tunnel wall section is moving towards this fixing location, and that section of the base rod which lies between the other fixing location and the earth removing device or the tunnel wall section being subjected to a compressive load. To prevent that section of the base rod which is subjected to a compressive load from buckling, it is preferably supported at predetermined intervals with respect to the wall of the tunnel.

[0011] In contrast to the conventional technique, in which one or more reamers are used and are pulled along by means of a pull rod moving through the ground, the earth removing device and/or each tunnel wall section according to the invention move with respect to a base rod which is stationary with respect to

the ground. The base rod does not have to be permanently stationary or fixed with respect to the ground; during periods in which the earth removing device and/or the tunnel wall section is not moving with respect to the ground, and therefore there is no need to generate movement forces therefor, the base rod, after it has been uncoupled from the fixing means and the drive device for the earth removing device and/or the tunnel wall section, can be displaced with respect to the ground with the aid of pushing and/or pulling forces exerted on the base rod, for example in order for a section of this rod to be assembled or dismantled in an building pit or the like. The force which the base rod has to apply during the displacement of the earth removing device and/or the tunnel wall section is limited to the force which is required to move the earth removing device and/or each tunnel wall section along; the frictional force between the base rod and the ground is then advantageously used to fix the base rod in the ground. The pulling or pushing force which is to be supplied by the base rod is independent of the length of the path. It is possible to increase the transverse dimensions of the base rod without this leading as quickly as in the case of a moving pull or push rod to limits in the transverse dimensions of the tunnel or its length. Furthermore, due to the fact that the base rod, apart from its elastic deformation, does not move in the ground means that bends in the path can be produced much more accurately due to the absence of the abovementioned sawing effect. Yet another advantage of the method according to the invention is that the base rod, following completion of the tunnel path, can in principle remain entirely intact and is therefore immediately ready for use after it has been moved to the next section of tunnel.

[0012] If the methods according to the invention are compared with the construction of a tunnel by means of a conventional tunnel building device, it is firstly apparent that, in the context of the invention, the composition of the soil along the path of the tunnel to be constructed can be accurately charted using known surveying techniques prior to the actual digging work, while the base rod is being positioned in the ground. This in turn leads to fewer risks during the digging work. In addition, a desired path can be followed very accurately if the base rod is accurately positioned in the ground. The digging process can take place continuously and is to a large extent independent of the construction of the lining of the tunnel wall. In its longitudinal direction, the tunnel wall only has to be subjected to the desired in-use strength, since the earth removing device does not exert cumulative propulsion forces on the lining. Consequently, the choice of possible materials and compositions of the tunnel wall also becomes considerably wider. It is also possible to utilize relatively long tunnel wall sections.

[0013] It should also be noted, with regard to conventional tunnel building devices, that they have an

outer casing which, at its rear side, has to be able to absorb the propulsive force supplied by the tunnel wall lining. For this purpose, the outer casing has to be sufficiently rigid to prevent buckling. In order for it also to be possible to construct bends, the outer casing is conical in longitudinal section. The space which is consequently formed between the outer casing and the ground is filled with a bentonite mixture. The rigid outer casing of the tunnel-drilling device in combination with the bentonite mixture forms a passive support for the ground and causes the ground to subside. The earth removing device to be used in the method according to the invention may be provided with a flexible outer casing which is suitable for following bends, since the outer casing of the earth removing device is not subjected to any compressive loads. This flexible outer casing forms an active support for the soil, so that the incidence of subsidence in the ground is reduced.

[0014] In the method according to the invention, the propulsive force required for the earth removing device can be transferred to the base rod at one or more locations. Furthermore, the propulsive force required for the tunnel wall sections at one or more locations can be transferred to the base rod, to a large extent independently of the movement of the earth removing device. If the tunnel wall sections are each coupled to a frame and propulsive forces are transferred to individual tunnel wall sections via interlinked frames, these sections may, if desired, be arranged flexibly with respect to one another. If the lining of the tunnel wall is formed with the aid of sliding formwork for extrusion of concrete, the base rod can also be used for the sliding formwork to move along, largely independently of the movement of the earth removing device. Moreover, the position of the earth removing device in the ground can be established with a very high level of accuracy with the aid of the known length of the base rod, taking into account changes in length caused by forces acting on the base rod. It is also possible for the distance between parallel tunnels and the clearance between underground obstacles and the paths of the tunnel to be determined with a particularly high level of accuracy.

[0015] The invention is explained in more detail below with reference to the appended drawing, in which:

Fig. 1 diagrammatically shows various stages (a) to (e) of the construction of a tunnel using the method according to the invention;

Fig. 2 diagrammatically shows a partially cut-away, perspective view of various building pits located along a path, for the purpose of illustrating various steps for the construction of a tunnel using the method according to the invention;

Fig. 3 diagrammatically shows a partially cut-away, perspective view of a detail from Fig. 2 on an enlarged scale;

Fig. 4 diagrammatically shows a partially cut-away, perspective view of another detail from Fig. 2 on an

enlarged scale;

Fig. 5 shows a partially cut-away, perspective view of a detail from Fig. 4 on an enlarged scale;

Fig. 6 diagrammatically shows a partially cut-away, perspective view of another detail from Fig. 2, on an enlarged scale;

Fig. 7 diagrammatically shows a partially cut-away, perspective view of a tunnel wall section, provided with a frame, in assembled form and in exploded form;

Fig. 8 diagrammatically shows a partially cut-away, perspective view of another detail from Fig. 2, on an enlarged scale;

Figs. 9a, 9b and 9c show side views, partially in cross section, of various operating positions of a drive device for an earth removing device;

Figs. 10a and 10b show side views, partially in cross section, of various operating positions of a drive device for one or more tunnel wall sections;

Fig. 11a shows a plan view, on an enlarged scale, of a clamping device of the drive device shown in Figs. 10a and 10b;

Figs. 11b and 11c show cross sections on line Xlc-Xlc of the clamping device from Fig. 11a, in two different operating positions;

Figs. 11d and 11e show cross sections on line Xle-Xle of the clamping device from Fig. 11a, in two different operating positions;

Fig. 11f shows a cross section on line Xlf-Xlf of the clamping device in accordance with Fig. 11a;

Fig. 12 shows a side view, partially in cross section, of a drive device for tunnel wall sections;

Fig. 13 shows a diagrammatic side view, partially in cross section, of a device for the construction of a tunnel;

Fig. 14 shows a diagrammatic side view, partially in cross section, of another device for the construction of a tunnel;

Fig. 15 shows a diagrammatic, partially cut-away, perspective view of a few principal components of yet another device for the construction of an underground tunnel; and

Fig. 16 shows a diagrammatic side view of a detail of a frame shown in Fig. 15.

[0016] Throughout the various figures, identical reference numerals denote identical components or components with an identical function.

[0017] In the figures and the subsequent description, no attention is paid to logistics facilities, such as measures for supplying drilling liquid, measures for removing excavated earth, power supply or the like.

[0018] In stage (a), Fig. 1 shows three building pits 2, 4 and 6. Drilling machines 8, 10, 12 and 14 are arranged in the building pits 2 and 6 for the purpose of carrying out controlled horizontal drilling from the building pits 2 and 6 to the building pit 4 along the paths 8a, 10a, 12a and 14a, in the directions indicated by the

arrows.

[0019] Stage (b) shows how rods 8c, 10c, 12c, and 14c are pulled into the ground, in the direction indicated by arrows, along the paths 8a, 10a, 12a and 14a, respectively, with the aid of drilling rods 8b, 10b, 12b and 14b used for the controlled horizontal drilling. For this purpose, a reamer (not shown) can be used at the location of coupling between the drilling rods 8b, 10b, 12b and 14b and the rods 8c, 10c, 12c, and 14c. As shown in stage (c), the rods 8c, 10c, 12c and 14c which extend between the building pits 2 and 4 and 4 and 6, respectively, are fixed at one end, in a manner not shown in more detail, with the aid of fixing means 8d, 10d, 12d and 14d, respectively. Then, four tunnel-drilling operations take place from the building pit 4 with the aid of drilling devices 8e, 10e, 12e and 14e, which are not shown in more detail, the walls of the tunnels constructed in this way being lined with a suitable material, such as concrete. The propulsive force required for the drilling devices 8e, 10e, 12e and 14e is supplied via the rods 8c, 10c, 12c and 14c which are fixed in the ground. During or prior to the drilling of the tunnels, controlled horizontal drilling operations are carried out, in the manner which has already been explained in the description of stage (a), from new building pits 16 and 18 towards the building pits 2 and 6, respectively, with the aid of drilling machines 20, 22, 24 and 26 along paths 20a, 22a, 24a and 26a, in the direction indicated by arrows, in order to prepare for the drilling of additional tunnel sections.

[0020] As shown in stages (d) and (e), the rods 8c and 10c are pulled completely out of the finished tunnel sections between the building pits 2 and 4, by drill rods 20b and 22b, respectively, until they extend between the building pits 16 and 2. A similar operation is carried out between the building pits 4, 6 and 18. It is then possible, with the aid of the drilling devices 8e, 10e, 12e and 14e, to bore tunnel sections between the building pits 2 and 16 and the building pits 6 and 18, as already explained with reference to stage (c).

[0021] Fig. 2 shows four building pits 30, 32, 34, 36 which are/have been laid below ground level 38. In Fig. 2, one wall has always been omitted from the substantially rectangular building pits 30-36, so that the interior of the building pit can be shown.

[0022] As shown in more detail in Fig. 3, each of the building pits 30-36 is formed with the aid of a hoisting machine 40 which bears a vibrating device 42, which is not shown in detail and is known per se, and introduces pile planking 44 into the ground until a space which is completely surrounded by the pile planking 44 and is substantially rectangular is formed in the ground. This space is then at least partially excavated, and may possibly be provided with means for controlling the groundwater level in the space.

[0023] As shown in Figs. 2 and 4, an building pit (in this case illustrated on the basis of building pit 32), after they pile planking 44 has been driven in, is excavated

down to a base 46, and longitudinal bars 48, 50, 52, 54 and transverse bars 56, 58 are arranged therein. The transverse bar 58 can be displaced along the longitudinal bars 48, 50 with the aid of bar drives 57. With the aid of a drilling device 60, a pull rod 62 is moved into the ground between the building pit 32 and the building pit 30 in a controlled horizontal drilling operation. Controlled horizontal drilling is known per se, and the pull rod 62 is pushed through the ground in the direction of arrow 64 by the drilling device 60, one end 62a of the pull rod 62 being provided with means (not shown in more detail) for displacing ground and guiding the end 62a in a predetermined direction. No further details of the way in which the pull rod 62 is guided through building pit 32a are shown in Fig. 4; in a practical situation, the requisite technical features will have to be provided for this purpose.

[0024] Furthermore, with the aid of a drilling device 66, a pull rod 68 is moved from the building pit 32 to the building pit 34, after which one end 68a of the pull rod 68 is connected in the building pit 34 to a reamer 70, a decoupling device 72 and a base rod 74. The assembly comprising the pull rod 68, the reamer 70, the decoupling device 72 and the base rod 74 is pulled towards the building pit 32, in the direction of arrow 76, with simultaneous rotation of the pull rod 68, as illustrated by Figs. 2 and 4.

[0025] To generate the tensile force required, the drilling device 66 is supported on the base 46 of the building pit 32. If desired, the drilling device 66 can be connected to the transverse bar 58 or one of the longitudinal bars 48-54 if the tensile force required should necessitate this.

[0026] Fig. 5 shows the reamer 70 with a substantially cylindrical body 70a which, at the front end, merges into a truncated cone 70b on which spray nozzles 70c are arranged. When the rod 68 rotates in one of the directions of double arrow 78 and is displaced in the direction of the arrow 76, the reamer 70 forms a passage in the ground for the components located behind it. In the process, the decoupling device 72, which comprises two parts 72a and 72b which can rotate freely with respect to one another, ensures that the rotation of the pull rod 68 is not transmitted to the base rod 74, but the tensile force exerted by the pull rod 68 is transmitted to the base rod 74.

[0027] Returning to Fig. 4, a passageway 80 (not shown in more detail) is shown in the building pit wall 32b, in order for the base rod 74 to be introduced into the building pit 32.

[0028] In a similar manner to that explained with reference to pull rod 68 and building pits 32 and 34, a base rod is introduced into the ground between the building pits 30 and 32 with the aid of a pull rod 62.

[0029] Figs. 2 and 6 show the building pit 34 with the rear end of the base rod 74 passing through a passageway 82 in building pit wall 34a. Building pit wall 34b is provided with a passageway 84 through which a base

rod 86 passes. One end 86a of the base rod 86 is attached, in a manner not shown in more detail, to the transverse bar 58, which in turn is attached to the longitudinal bars 48, 50 which, at their ends, are supported against the building pit walls 34a, 34b. The base rod 86 is thus fixed in the ground. An earth removing device 88 is provided with a drive device, which is shown in more detail in Figs. 9a, 9b and 9c, for displacing the earth removing device 88 along the base rod 86, the drive device being supported on the base rod 86. Tunnel wall sections 92, which are to be described in more detail with reference to Fig. 7 and Fig. 8, are introduced into the passage which is formed by the earth removing device 88 when it moves in the direction of arrow 90, with the aid of drive devices which are to be discussed in more detail below with reference to Figs. 10a, 10b and 12. It will be clear that, after the base rod 74 has been laid between the building pits 34 and 32 - and ultimately also after a base rod has been positioned between the building pits 30 and 32 - the earth removing device 88 can be displaced further from the building pit 34 to the building pit 32, and from the building pit 32 to the building pit 30. It will also be clear that, in the situation shown in Fig. 6, the earth removing device 88 exerts a tensile force on that part of the base rod 86 which is located between its end 86a and the earth removing device 88. Obviously, it is also possible to fix one end of the base rod in the building pit 36 instead of or in addition to fixing the base rod 86 at the end 86a, in which case a compressive load will be exerted on that section of the base rod 86 which lies between the end fixed in the building pit 36 and the earth removing device 88.

[0030] Fig. 7 shows a frame 100 which comprises a central pipe 102 and a number of arms 104 extending from the pipe 102. Furthermore, Fig. 7 shows tunnel wall subsections 106 which are intended to be coupled to one another and to the free ends of the arms 104. It is thus possible to construct a tunnel wall section 108 provided with a frame 100.

[0031] Each tunnel wall subsection 106 is per se constructed from a metal frame 110 which encloses cylinder segments of reinforced concrete. By way of example, the tunnel wall subsections 106 are connected to one another and to the arms 104 of the frame 100 by means of welding.

[0032] The internal diameter of the pipe 102 is greater than the external diameter of the base rod over which the pipe 102 is intended to slide. On the one hand, this is necessary in order to allow the frame 100 to be displaceable with respect to the base rod, and on the other hand the clearance between the pipe 102 and the base rod must be sufficiently great for it also to be possible for the frame 100 to move along a curved base rod. In this case, the pipes 102 may be hinged to one another.

[0033] The pipe 102 is provided with three sets of four arms 104, each set of arms 104 being attached to

a ring 112 which is at a radial distance from the pipe 102. The two rings 112 in the vicinity of the two ends of the pipe 102 are fixed with respect to the pipe 102, in the longitudinal direction of the latter, by means of collars 114 which are located on either side of the rings 112 and are fixed to the pipe 102.

[0034] At its two ends, the pipe 102 is provided with means (not shown in more detail) for coupling the pipe 102 to that of an adjoining frame 100.

[0035] Figs. 2 and 8 show the way in which tunnel wall sections 108 which are provided with a frame 100 are installed in the building pit 36 using a hoisting device 116. The transverse bar 58 and another transverse bar 59 are displaced sufficiently far towards side wall 36b of the building pit 36 for it to be possible for the tunnel wall section 108 which is provided with a frame 100 to be brought into line with tunnel wall sections 118, 120, 122 and 124 which are already in the ground. Then, that end of the pipe 102 which faces towards the tunnel wall section 118 is coupled to the pipe situated in the tunnel wall section 118, and the tunnel wall section 108, which is provided with a frame 100, is pulled onto the frame of the tunnel wall section 118 in the tunnel. The way in which this takes place will be explained in more detail below with reference to Figs. 10a, 10b and 12.

[0036] Figs. 9a-9c show a drive device 128 for displacing an earth removing device 130, which is illustrated highly diagrammatically, along a base rod 132 which is fixed with respect to the ground. The drive device 128 contains two double-acting partial drive devices 128a and 128b, which each in turn comprise two units 134 of the type which will be explained in more detail below with reference to Figs. 11a-11f. The partial drive device 128a comprises double-acting piston-cylinder units 136 with connecting rods 138 which are connected to the earth removing device 130. The partial drive device 128b comprises double-acting piston-cylinder units 140 with connecting rods 142 which extend through the partial drive device 128a and are connected to the earth removing device 130. The partial drive devices 128a and 128b are each provided with wedges 144 which can be engaged with or disengaged from the base rod 132 in a controllable manner in order to fix the partial drive device 128a or 128b, respectively, with respect to the base rod 132.

[0037] In the situation shown in Fig. 9a, the base rod 132 is fixed with respect to the ground, in a manner which is not shown in more detail. The partial drive device 128b is fixed with respect to the base rod 132 by means of its wedges 144. The connecting rods 142 of the piston-cylinder units 140 of the partial drive device 128b are moved outwards, which will cause the earth removing device to move in the direction of arrow 146 with respect to the ground. The partial drive device 128a can move freely with respect to the base rod 132. The connecting rods 138 of the piston-cylinder units 136 of the partial drive device 128a are moved inwards, with the result that the partial drive device 128a moves

towards the earth removing device 130.

[0038] In the situation shown in Fig. 9b, the connecting rods 142 of the piston-cylinder units 140 of the drive device 128b have been moved all the way out and are at the end of their stroke, and the connecting rods 138 of the piston-cylinder units 136 of the partial drive device 128a have been moved all the way in to the beginning of their stroke.

[0039] As illustrated in Fig. 9c, the partial drive device 128a is then fixed with respect to the base rod 132 with the aid of the wedges 144, after which the connecting rods 138 of the piston-cylinder units 136 of the partial drive device 128a are moved outwards in order for the earth removing device 130 to be advanced further. The fixing of the partial drive device 128b on the base rod 132 has been released, and the connecting rods 142 of the piston-cylinder units 140 of the partial drive device 128b are moved inwards until the partial drive device 128b is located immediately behind the partial drive device 128a. As a result of the fixing of the partial drive device 128a on the base rod 132 being released and the partial drive device 128b being fixed to the base rod 132, the situation shown in Fig. 9a is restored, and the earth removing device 130 can be moved further in the direction of the arrow 146.

[0040] Fig. 10a diagrammatically shows the earth removing device 130 and the partial drive devices 128a and 128b.

[0041] One end of a tunnel-wall drive device 150 is connected to the partial drive device 128b and the opposite end of this tunnel-wall drive device 150 is coupled, in a manner not shown in more detail, to the pipe 102 of the tunnel wall section 108 which is provided with the frame 100. The tunnel wall drive device 150 comprises three substantially annular sleeves 152a, 152b and 152c, which are each provided with a number of radially projecting lugs 154. Double-acting piston-cylinder units 156 with connecting rods 158 are arranged between the lugs 154 of the sleeves 152a and 152b and between the lugs 154 of the sleeves 152b and 152c.

[0042] During the displacement of the earth removing device 130 with respect to the ground and the base rod 132 with the aid of the partial drive devices 128a and 128b, as described above with reference to Figs. 9a-9c, the cylinders of the piston-cylinder units 156 which are connected to the lugs 154 of the sleeve 152a move with the partial drive device 128b. The cylinders of the piston-cylinder units 156 which are connected to the lugs 154 of the sleeve 152c remain at a standstill with respect to the ground and the base rod 132. The piston rods 158 of the piston-cylinder units 156 are therefore moved out until they have reached the end of their stroke. Then, both the partial drive device 128a and the partial drive device 128b are fixed with respect to the base rod 132. The situation which is reached in this way is shown in Fig. 10a.

[0043] From the position shown in Fig. 10a, the piston rods 158 of the piston-cylinder units 156 are moved

inwards until the situation shown in Fig. 10b is reached. In the process, the tunnel wall section 108 which is connected to the pipe 102 of the frame 100 (and any other tunnel wall sections which are coupled thereto via the frame 100) is displaced in the direction of arrow 160.

[0044] Then, the earth removing device 130 can again be displaced further along the base rod 132, as discussed above with reference to Figs. 9a-9c, after which the tunnel wall section(s) can again be displaced along the base rod 132, as discussed above with reference to Figs. 10a and 10b. Consequently, movements of the earth removing device 130 and the tunnel wall section(s) take place alternately. It will, incidentally, be clear that the movements may also take place simultaneously.

[0045] It should be noted here that the earth removing device 130 - as seen in the direction of the tunnel path - may also be fixedly connected to the base rod 132, the movement of the earth removing device 130 with respect to the ground being brought about as a result of the base rod 132 being displaced in the direction of the arrow 160 with respect to the ground. If, in such a case, the tunnel-wall drive device 150 - as seen in the direction of the tunnel path - is fixedly connected to the earth removing device 130 (and consequently to the base rod 132) or directly to the base rod 132 by means of the sleeve 152a, the tunnel-wall drive device 150 can be used, in the same way as that explained above in conjunction with Figs. 10a and 10b, to advance the tunnel wall section(s) with respect to the ground, the base rod 132 then being temporarily fixed with respect to the ground. Under these conditions, the base rod behind the earth removing device 130 may, incidentally, be dispensed with altogether.

[0046] Figs. 11a-11f show a unit 134 with a substantially cylindrical housing 170 which is provided with flanges 170a and 170b. As shown by Figs. 11a-11c in particular, the unit 134 contains four piston-cylinder units 172 which at one end are coupled, via a projection 174, to the housing 170 and at the other end are coupled to lugs 176 of a ring 178. As a result of the connecting rods of the piston-cylinder units 172 being moved in and out, the ring is displaced in the housing 170 between the positions shown in Figs. 11b and 11c. As shown in particular by Figs. 11a, 11d and 11e, the unit 134 also contains 12 wedges 144, which, with the aid of the ring 178, can be displaced along ribs 180 provided with sloping edges, between the positions shown in Figs. 11d and 11e. In this case, the distance between two diametrically opposite wedges 144 in the situation shown in Fig. 11e is greater than that in the situation shown in Fig. 11d, so that the wedges 144 can be used to clamp the unit 134 securely on a base rod 132 which is indicated by a dashed line in Fig. 11a. As shown by Figs. 11a and 11f in particular, the unit 134 contains eight guides 182 which, on the sides facing towards one another, are provided with a friction-reducing coating 184. The distance between two diametrically opposite

coatings 184 is greater than the external diameter of the base rod 132.

[0047] Fig. 12 illustrates that the tunnel-wall section drive device 150, with a slight modification, is also suitable for use between adjoining tunnel wall sections 190 and 192: in Fig. 12, the sleeve 152a is designed in such a manner that it can be fixedly connected to one end of the pipe 102 of the tunnel wall section 190. To enable the tunnel wall section 190 to move with respect to the tunnel wall section 192 while keeping the space inside the tunnel wall sections 190, 192 sealed with respect to the surrounding ground, the tunnel wall section 190 is provided with a collar 194, the inner surface of which bears against a seal 196 of the tunnel wall section 192. With the tunnel-wall section drive device 150 shown, it is possible:

- for the tunnel wall section 190 not to move with respect to the ground and the tunnel wall section 192 to move away from it;
- for the tunnel wall section 192 not to move with respect to the ground and the tunnel wall section 190 to move away from it;
- for the tunnel wall section 190 not to move with respect to the ground and the tunnel wall section 192 to move towards it; and
- for the tunnel wall section 192 not to move with respect to the ground and for the tunnel wall section 190 to move towards it.

[0048] Fig. 13 shows an earth removing device 200 which, with the aid of a drive device 204, can be advanced with respect to a base rod 202, which is fixed with respect to the ground, in a similar manner to that explained above with reference to Figs. 9a-9c. With the aid of clamping devices 214, elongate tubular tunnel wall sections 206, 208 are fixed with respect to pipes 210 and 212, respectively, which can be moved freely along the base rod 202. The pipes 210, 212 are connected to drive devices 216, a section 216a of which is designed as the unit shown in Figs. 11a-11f, enabling the drive device to be fixed with respect to the base rod 202. Another section 216b of the drive device 216 comprises a number of piston-cylinder units which couple the section 216a to the associated pipe 210, 212, the length of which coupling, as seen in the direction of the tunnel path, can be lengthened and shortened in a controllable manner. It will be clear that the drive devices can either pull a pipe 210, 212 at one end or can push it at the opposite end, through the ground, during which process the drive devices 216 are supported on the base rod 202 which is fixed with respect to the ground. The forwards movement of the earth removing device 200 and the wall sections 206, 208 in the ground may in principle take place independently of one another, provided that they are not moved so far apart that the seal between them is lost. With the aid of a plurality of drive devices 216 arranged along the base rod 202, tunnel

wall sections arranged between them can be displaced in the ground by means of a "caterpillar motion".

[0049] Fig. 14 shows an earth removing device 220 which is advanced through the ground as a result of the rotation in the direction of arrow 222 and as a result of a tensile force being exerted on a pull rod 224 in the direction of arrow 226. The earth removing device 220 is connected to a centring device 230 by means of a decoupling device 228. The decoupling device 228 transmits the tensile force exerted by the pull rod 224 to the centring device 230, but does not transmit its rotation. The centring device 230 is in turn coupled to the pipe 210 via a drive device 232. A similar drive device 232 is used to couple pipe 210 to pipe 212. A sealing cap 234 which is coupled to the centring device 230 bears in a sealed manner against the outer surface of the tunnel wall section 206 and can slide in the direction of the tunnel path with respect thereto. The drive devices 232 are of the type shown in Fig. 12.

[0050] In operation, the earth removing device 220 is displaced over a predetermined distance in the ground as a result of the displacement of the pull rod 224 in the direction of the arrow 226, after which the pull rod 224 is fixed with respect to the ground and the tunnel wall sections 206, 208 are displaced in the direction of the arrow 226 with the aid of the drive devices 232. During the displacement of the earth removing device 220, the decoupling device 228, the centring device 230, the sealing cap 234 and part of the drive device 232 located behind will be displaced with it.

[0051] Fig. 15 shows, in a similar way to Figs. 7 and 8, tunnel wall sections 240 in which a frame 242 is arranged in the form of a lattice structure. The frames 242 can be coupled to one another in order to transmit pushing or pulling forces to the tunnel wall sections 240 which are connected thereto. Fig. 16 shows one end of a frame 242a, which is provided with projections 244. Another end of a similar frame 242b is provided with openings 246 for receiving the projections 244, so that compressive forces can be transmitted between the frames 242a, 242b in a controlled manner.

Claims

1. Method for constructing a tunnel in the ground along a predetermined path, which method comprises the steps:

- (a1) positioning at least a first base rod in the ground along the path;
- (b1) fixing the at least one base rod with respect to the ground at at least one location; and
- (c1) displacing an earth removing device along the at least one base rod for the purpose of constructing the tunnel, at least a first drive device, which acts on the at least one base rod and the earth removing device, being provided

for the purpose of supplying at least part of the force for displacing the earth removing device.

2. Method for constructing a tunnel in the ground along a predetermined path, which method comprises the steps:

(a2) displacing an earth removing device in the ground for the purpose of constructing the tunnel;
 (b2) positioning at least a second base rod in the ground;
 (c2) fixing the at least one base rod with respect to the ground at at least one location; and
 (d2) displacing at least one tunnel wall section along the at least one base rod, at least one second drive device, which acts on the at least one base rod and the at least one tunnel wall section, being provided for the purpose of supplying at least part of the force for displacing the at least one tunnel wall section.

3. Method according to claim 2, in which the earth removing device is displaced (with the aid of the base rod).

4. Method according to claim 3, comprising the steps:

(a4) fixing the at least one base rod with respect to the ground at at least one location; and
 (b4) displacing an earth removing device along the at least one base rod for the purpose of constructing the tunnel, at least a first drive device, which acts on the at least one base rod and the earth removing device, being provided for the purpose of supplying at least part of the force for displacing the earth removing device.

5. Method according to claim 1 or 4, comprising the steps:

(a5) after the earth removing device has been displaced over a predetermined distance, releasing the fixing of the base rod with respect to the ground, and releasing the engagement of the first or the third drive device, respectively, on the base rod; and
 (b5) displacing the base rod with respect to the ground.

6. Method according to claim 3, further comprising the steps:

(a6) coupling an earth removing device to the at least one base rod;
 (b6) positioning at least one tunnel wall section

behind the earth removing device;

(c6) displacing the at least one base rod, so that the earth removing device is displaced a predetermined distance in the ground;

(d6) fixing the at least one base rod with respect to the ground at at least one location; and

(e6) displacing the at least one tunnel wall section.

7. Method according to claim 6, in which the second drive device acts on the at the least one base rod via the earth removing device.

8. Method according to any of claims 1-7, in which the at least one base rod is introduced into the ground by means of the steps:

(a8) using at least one controlled drilling along the path to position a pull rod in the ground;

(b8) coupling one end of the pull rod to one end of the at least one base rod, at which end of the at least one base rod a reamer is arranged; and
 (c8) using the pull rod to pull the at least one base rod along the path in the ground, the reamer increasing the transverse dimensions of the passage in the pull rod to at least substantially the transverse dimensions of the at least one base rod.

9. Method according to any of claims 1-7, in which the at least one base rod is introduced into the ground by means of the steps;

(a9) coupling one end of the at least one base rod to a base earth removing device;

(b9) pressing the said end of the at least one base rod along the path in the ground, the base earth removing device forming a passage in the ground which has transverse dimensions which substantially correspond to the transverse dimensions of the at least one base rod.

10. Method according to any of claims 2-9, furthermore comprising the step:

(a10) coupling tunnel wall sections together with the aid of at least a fourth drive device which acts on adjoining tunnel wall sections and, as seen in the direction of the path, can be lengthened and shortened in a controllable manner in order to increase or reduce, respectively, the distance between the adjoining tunnel wall sections.

11. Method according to claim 2, 6 or 10, in which each tunnel wall section is coupled to a frame, and the second, third or fourth drive device, respectively,

acts on the tunnel wall section via the frame.

- 12.** Device for constructing a tunnel in the ground along a predetermined path, comprising:

(a12) means for positioning at least a first base rod along the path in the ground;

(b12) means for fixing the at least one base rod with respect to the ground at at least one location;

(c12) an earth removing device for constructing the tunnel; and

(d12) at least a first drive device, which acts on the at least one base rod and the earth removing device, for the purpose of supplying at least part of the force for displacing the earth removing device along the at least one base rod.

- 13.** Device for constructing a tunnel in the ground along a predetermined path, comprising:

(a13) an earth removing device for constructing the tunnel;

(b13) means for positioning at least a second base rod in the ground;

(c13) means for fixing the at least one base rod with respect to the ground at at least one location;

(d13) at least one tunnel wall section for constructing the tunnel; and

(e13) at least a second drive device, which acts on the at least one base rod and the at least one tunnel wall section, for the purpose of supplying at least part of the force for displacing the tunnel wall section along the at least one base rod in the fixed state.

- 14.** Device according to claim 13, further comprising;

(a14) means for displacing the earth removing device with the aid of the at least one base rod.

- 15.** Device according to claim 14, further comprising;

(a15) means for fixing the at least one base rod with respect to the ground at at least one location; and

(b15) at least a third drive device, which acts on the at least one base rod and the earth removing device, for the purpose of supplying at least part of the force for displacing the earth removing device along the at least one base rod.

- 16.** Device according to claim 14, in which the earth removing device is coupled to the at least one base rod.

- 17.** Device according to any of claims 13-16, further

comprising:

(a17) a fourth drive device, which acts on adjoining tunnel wall sections and, as seen in the direction of the path, can be lengthened and shortened in a controllable manner for the purpose of increasing or reducing, respectively, the distance between the adjoining tunnel wall sections.

- 18.** Device according to any of claims 13-17, in which each tunnel wall section is coupled to a frame, and the second, third or fourth drive device, respectively, is designed to act on the tunnel wall section via the frame.

- 19.** Device according to claim 18, in which the frame comprises:

(a19) at least one central body;

(b19) a number of arms which extend from the at least one body and are intended to be coupled to a tunnel wall section.

- 20.** Device according to claim 19, in which the central body is provided with an opening, the transverse dimensions of which are larger than those of the base rod.

- 21.** Device according to claim 18, in which the frame comprises:

(a21) a lattice structure.

- 22.** Device according to any of claims 13-21, in which each tunnel wall section is composed of at least two tunnel walls subsections.

- 23.** Device according to any of claims 13-22, in which each tunnel wall section is tubular and has two open ends, and in which one of the ends is provided with a sealing collar made from a flexible, resilient sealing material, and the other end is provided with a mating collar which is intended to bear against the sealing collar of an adjoining tunnel wall section.

- 24.** Device according to claim 12 or 13, in which the first or second drive device comprises:

(a24) at least one fixing device for controllably fixing at least part of the first or second drive device with respect to the base rod;

(b24) at least one actuator, which is coupled to the at least one fixing device and to the earth removing device or to the at least one tunnel wall section, for displacing the earth removing device or the at least one tunnel wall section with respect to the at least one fixing device, in

the direction of the path.

25. Device according to claim 24, in which the fixing device is a clamping device for securely clamping at least part of the drive device to the base rod. 5
26. Device according to claim 17, in which the fourth drive device comprises:
- (a26) at least one actuator, which can be coupled to a first tunnel wall section and to a second, adjoining tunnel wall section, for the purpose of displacing the first and second tunnel wall sections with respect to one another. 10 15
27. Device according to any of claims 24-26, in which the actuator is a double-acting piston-cylinder unit.

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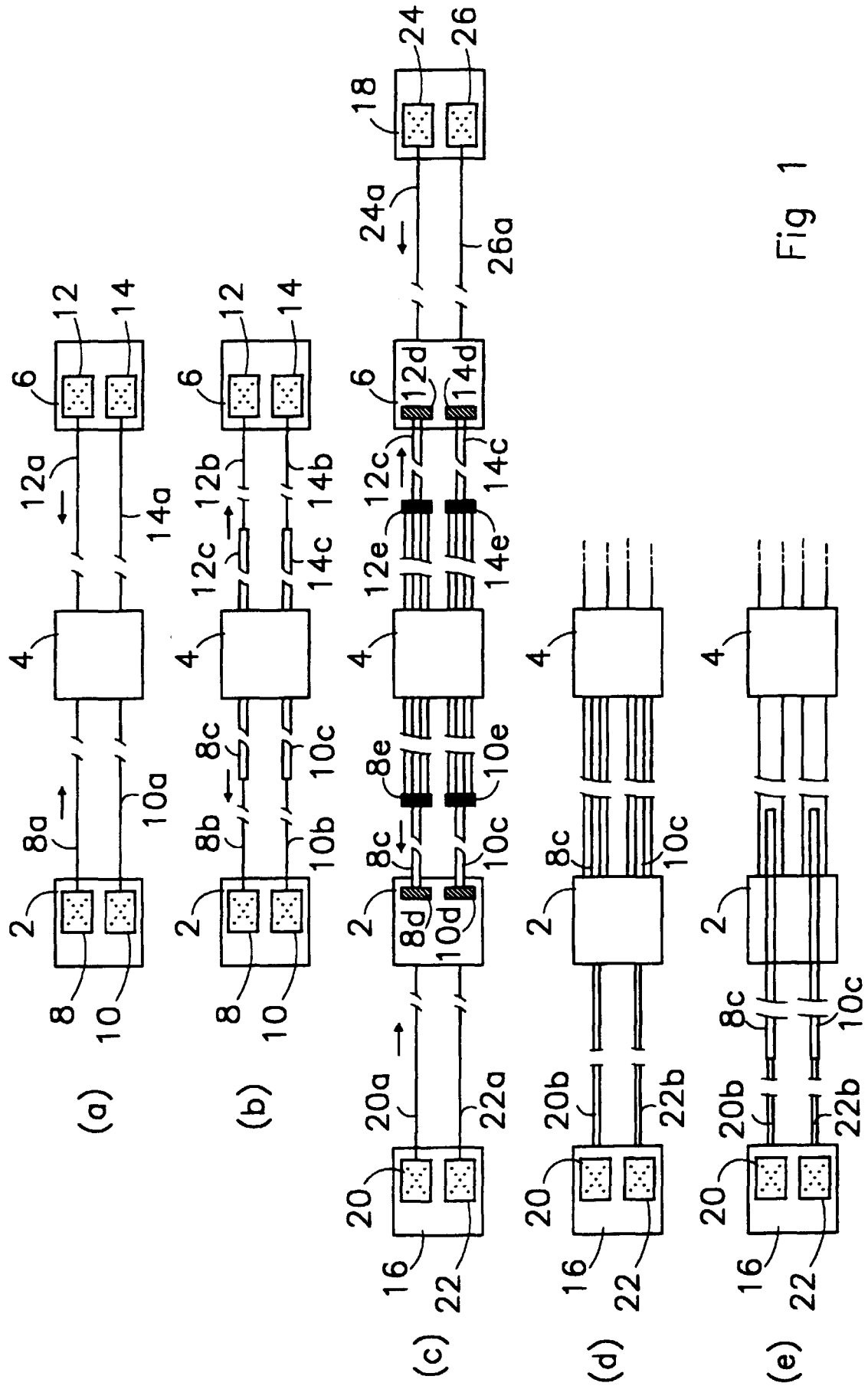


Fig 1

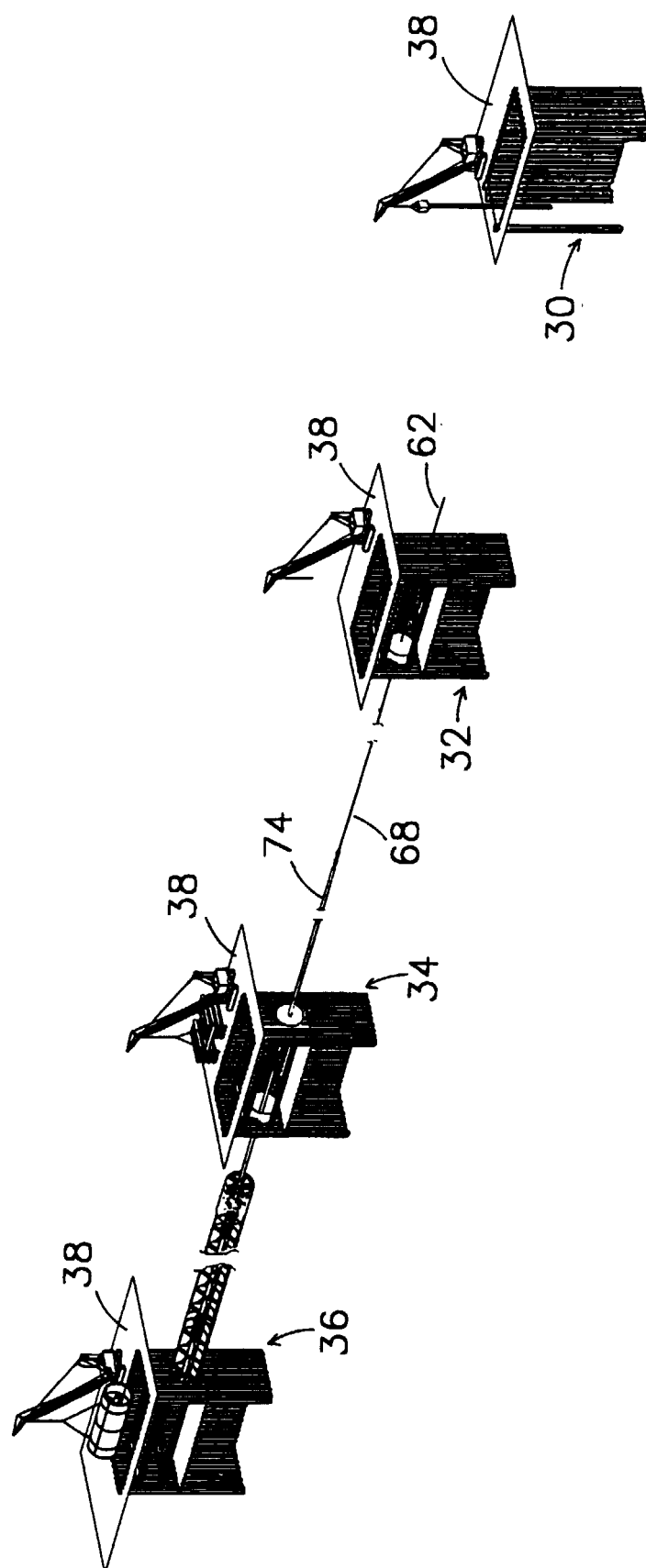


Fig 2

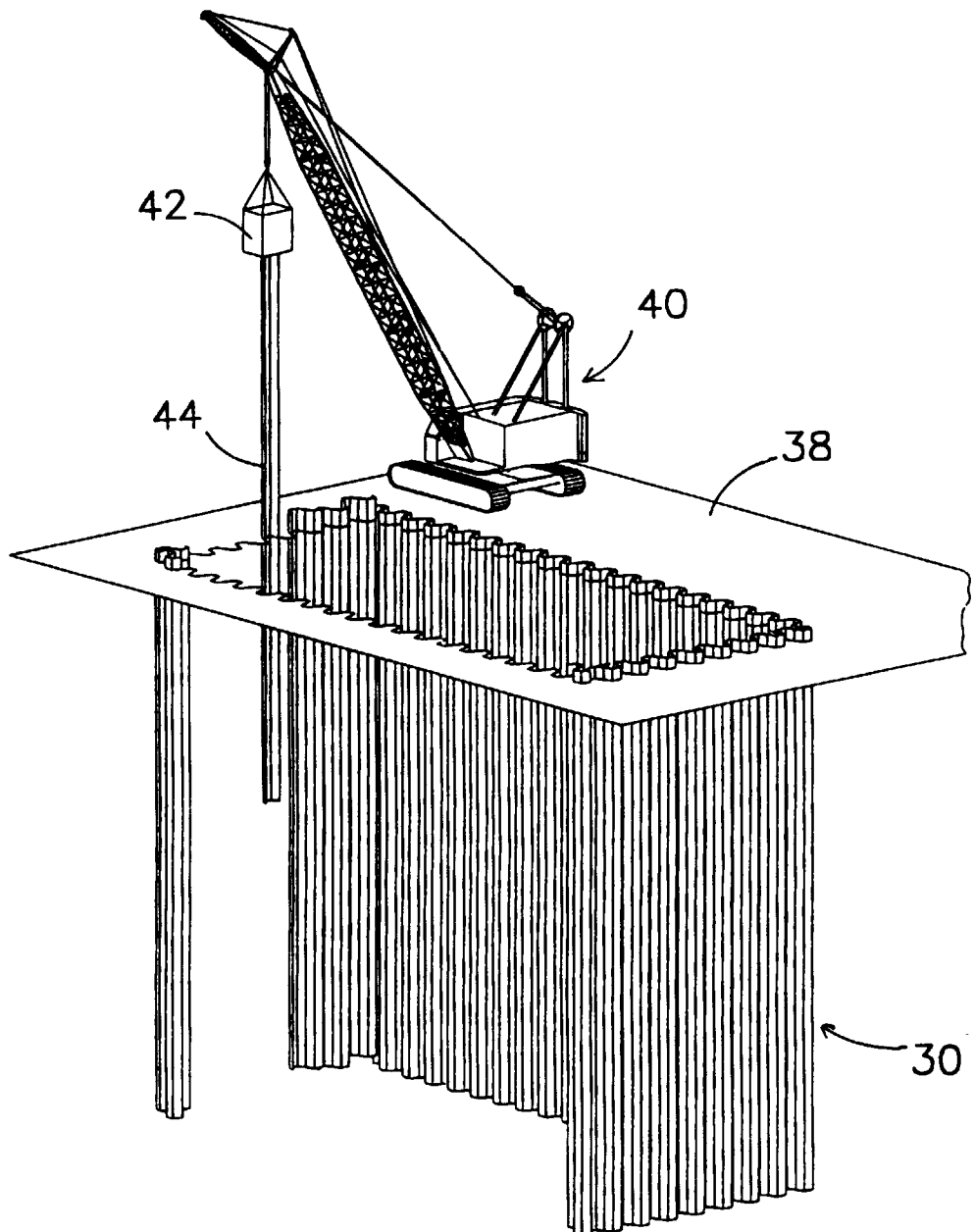


Fig 3

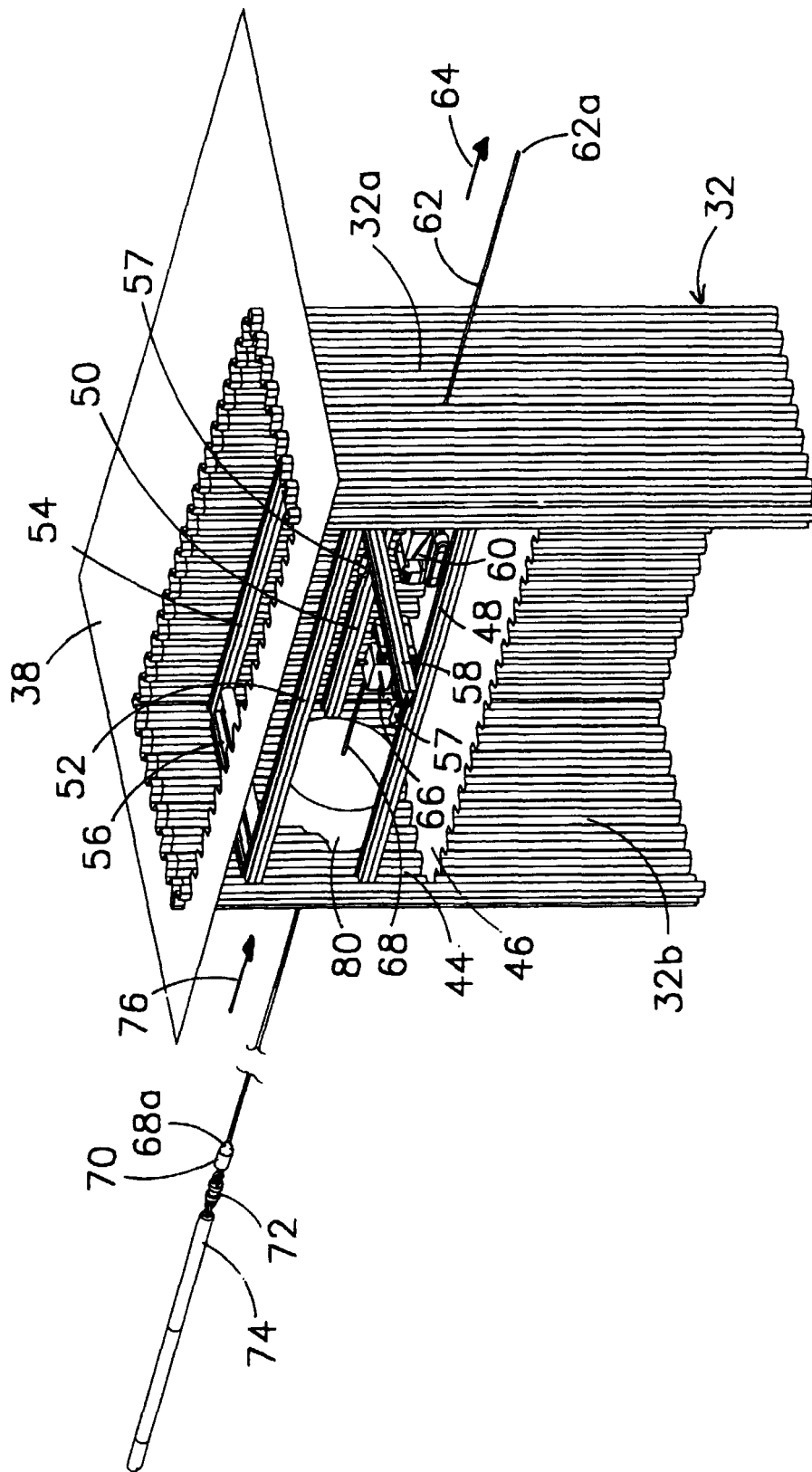


Fig 4

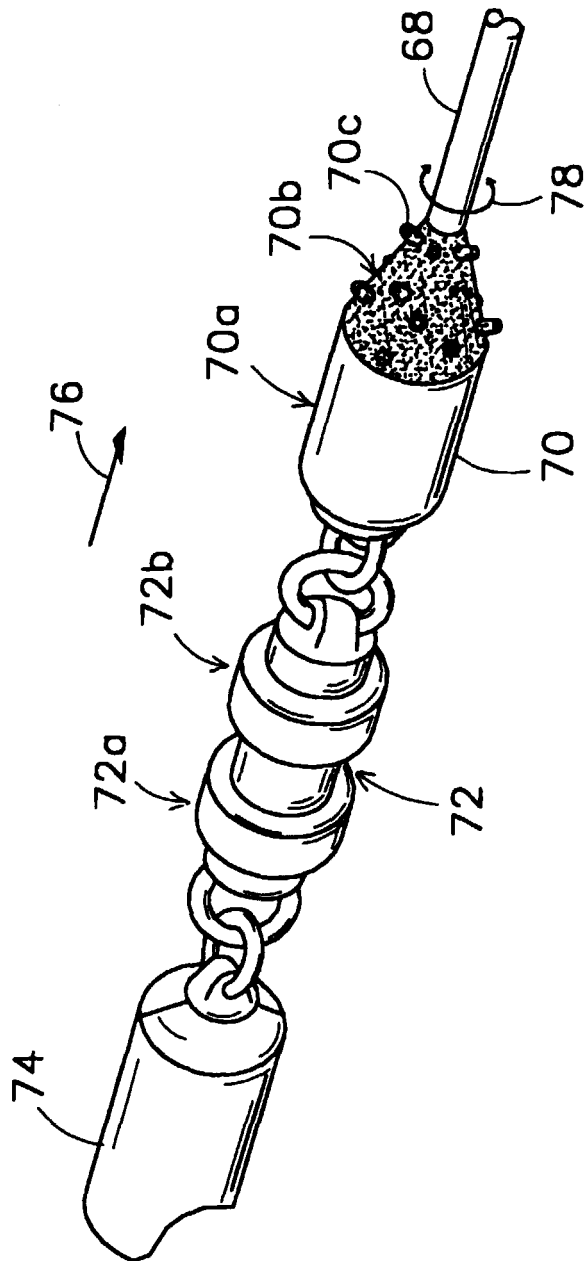


Fig 5

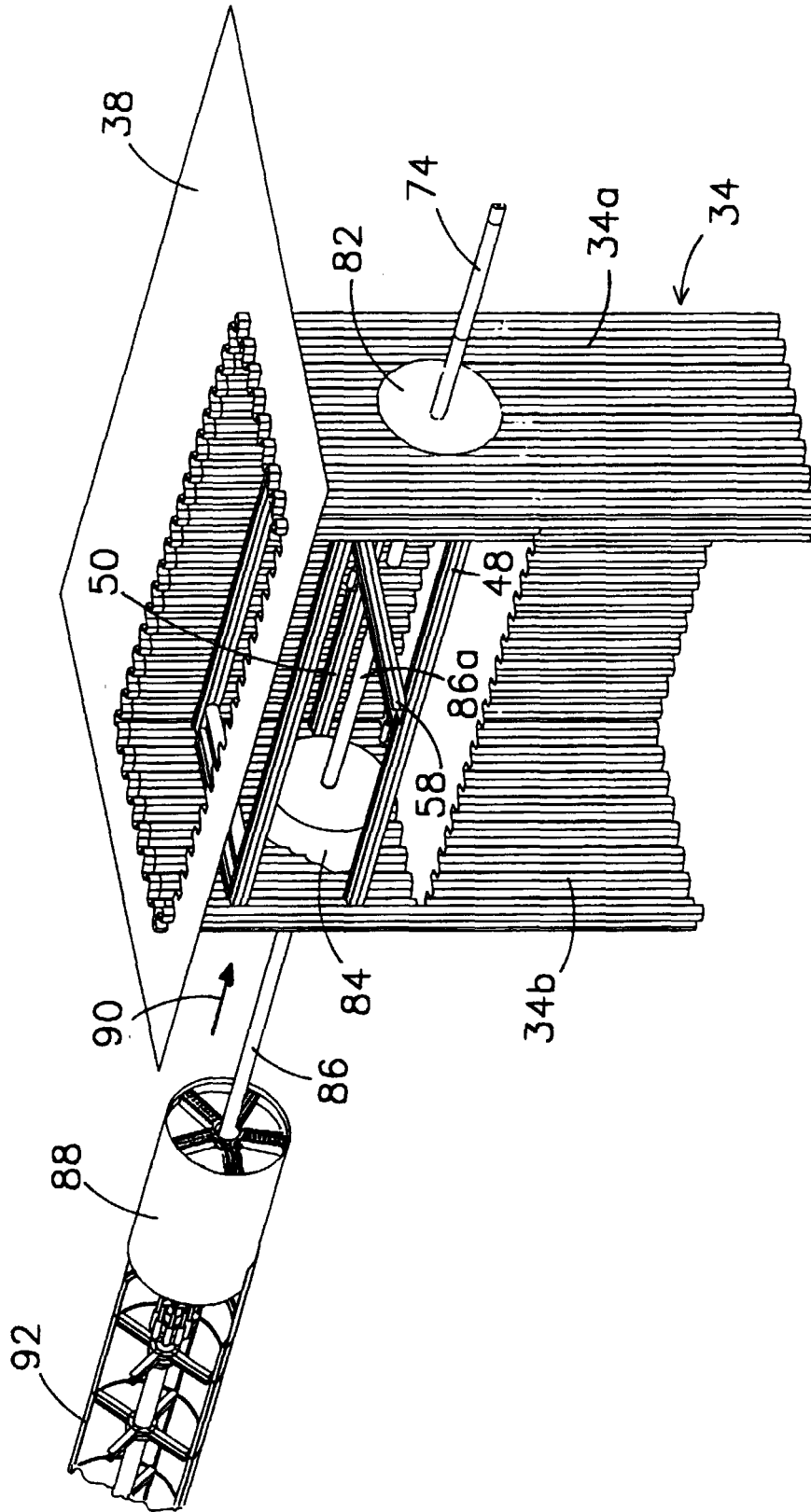
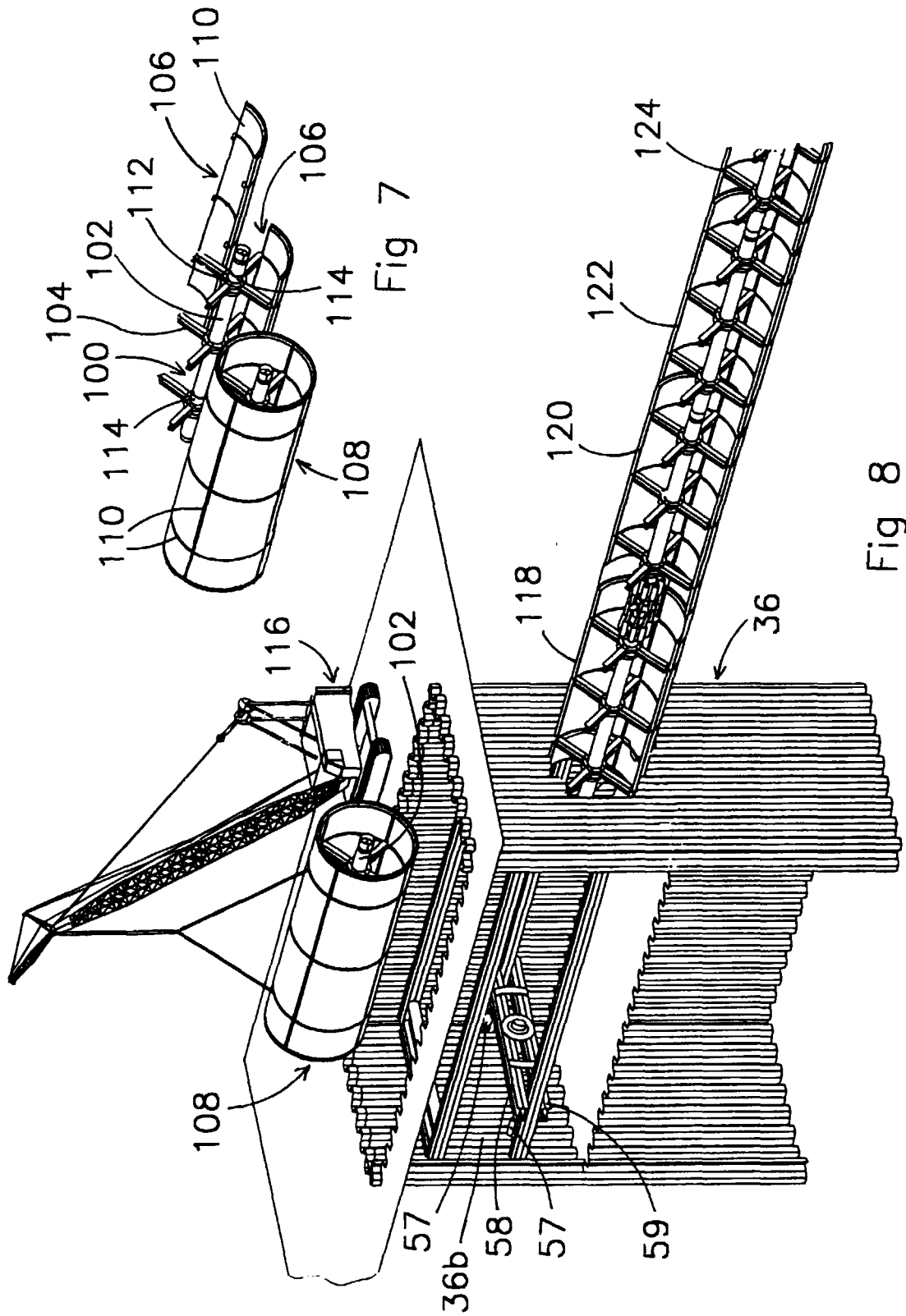
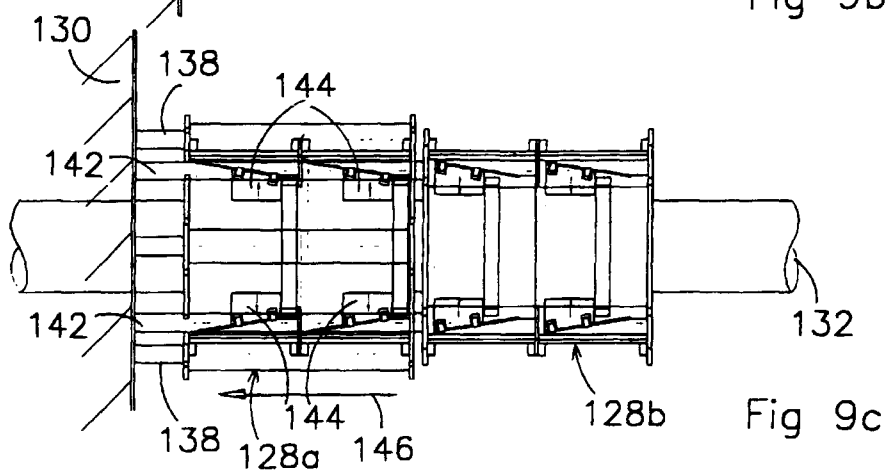
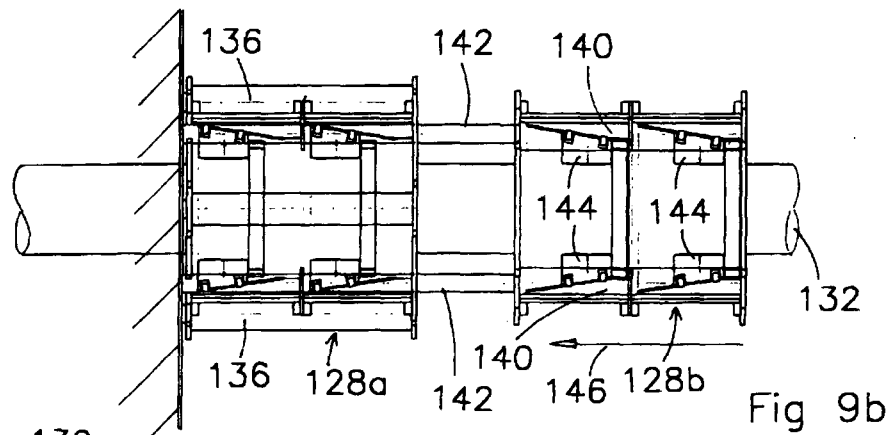
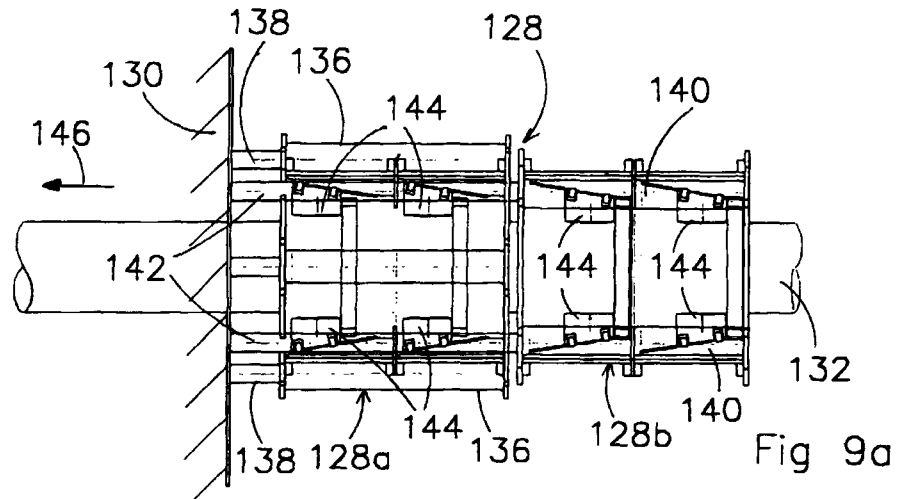


Fig 6





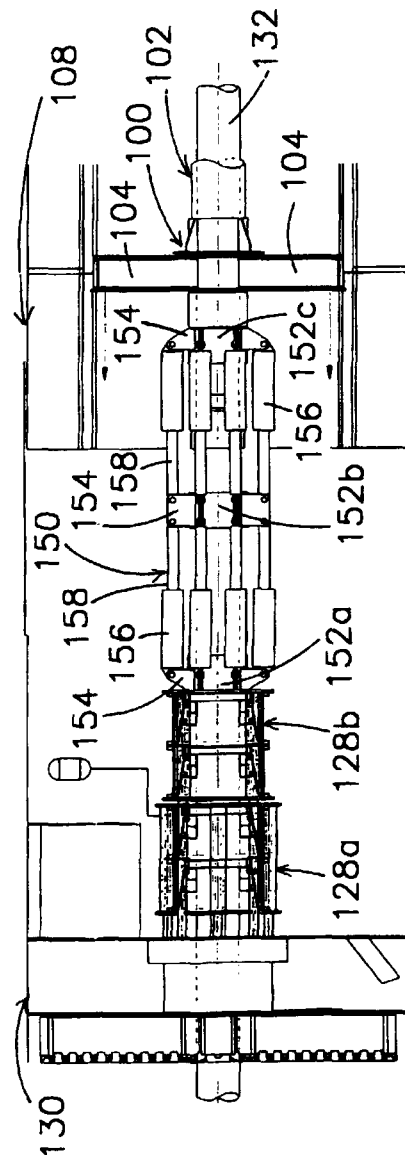


Fig 10a

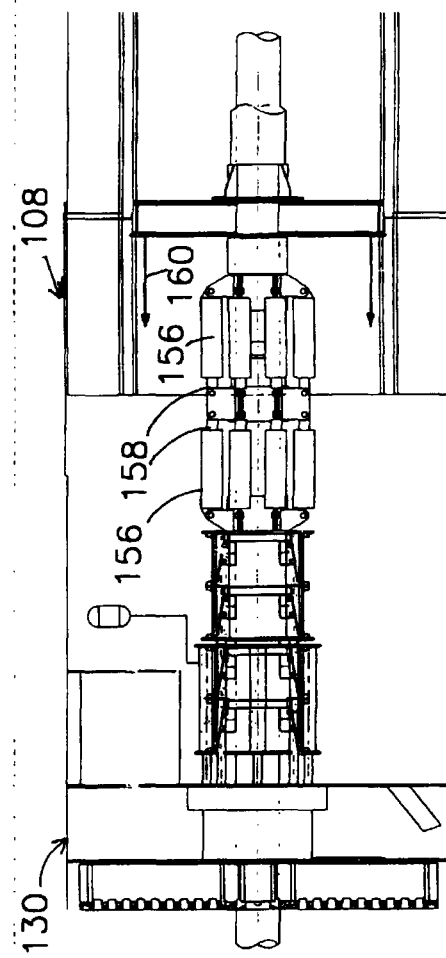


Fig 10b

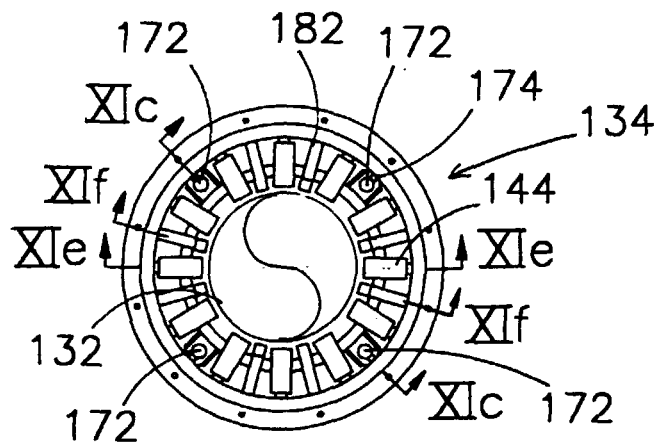


Fig 11a

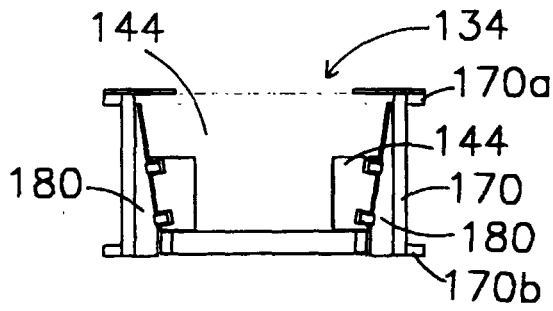


Fig 11d

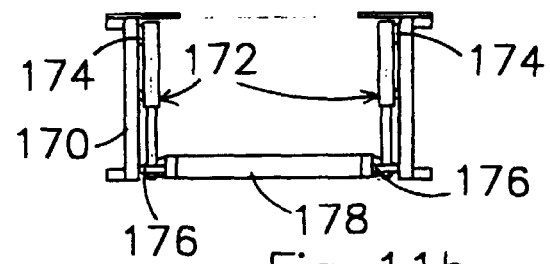


Fig 11b

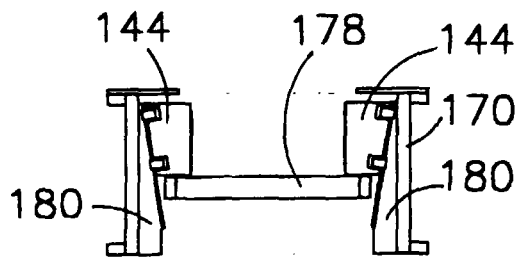


Fig 11e

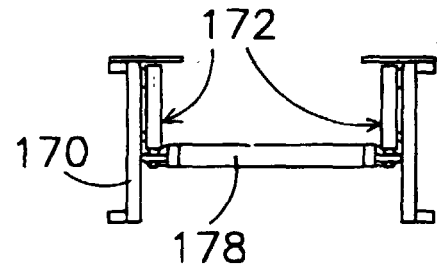


Fig 11c

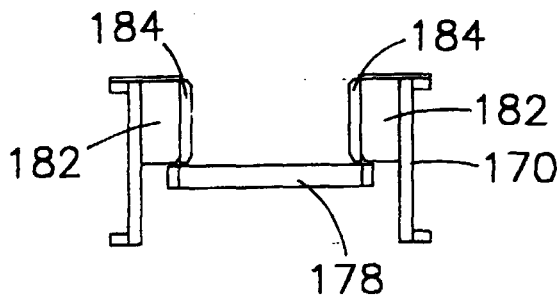


Fig 11f

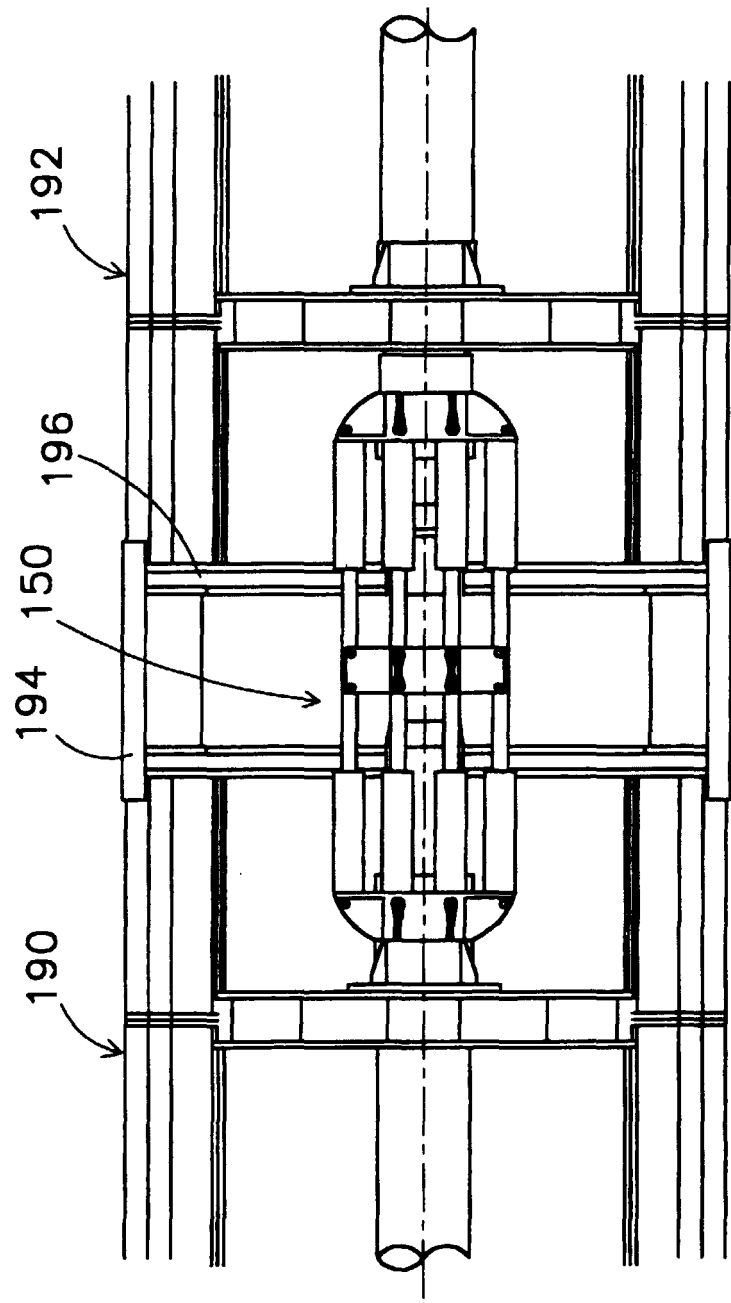


Fig 12

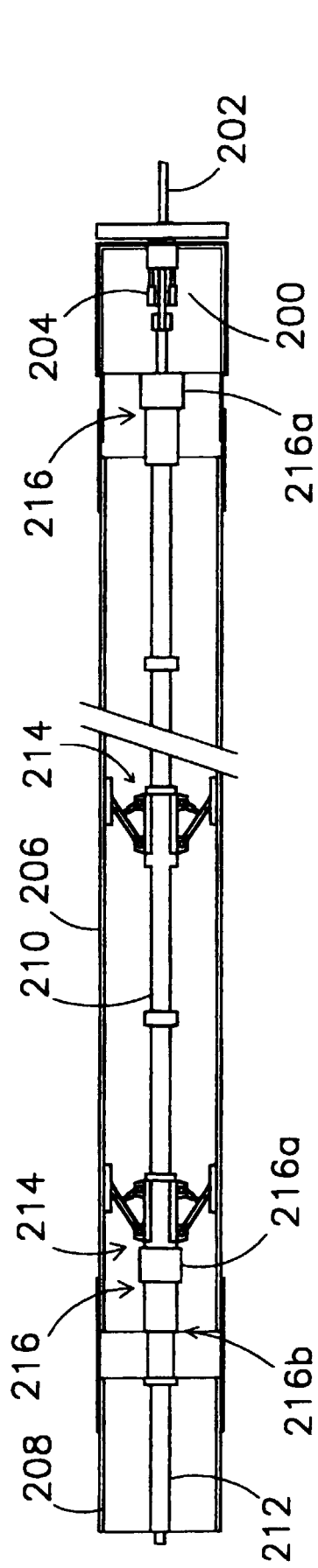


Fig 13

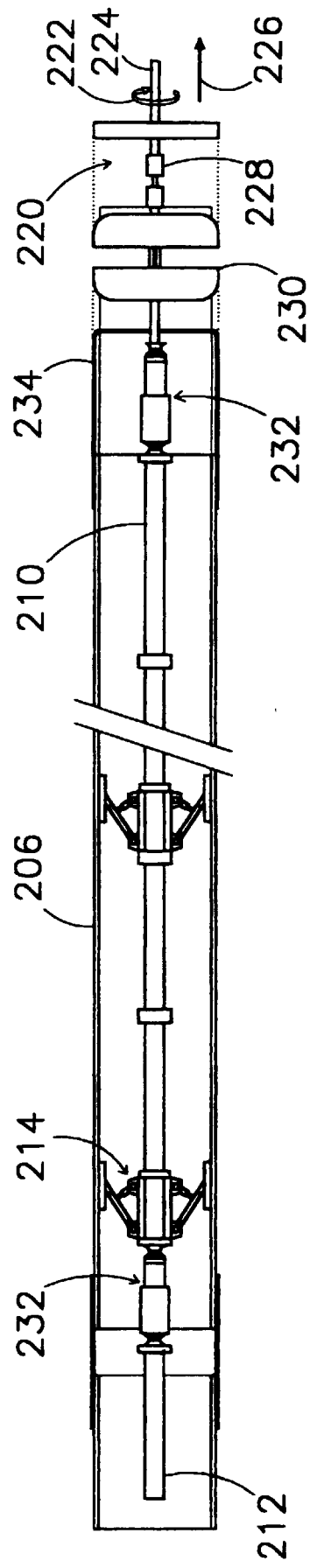


Fig 14

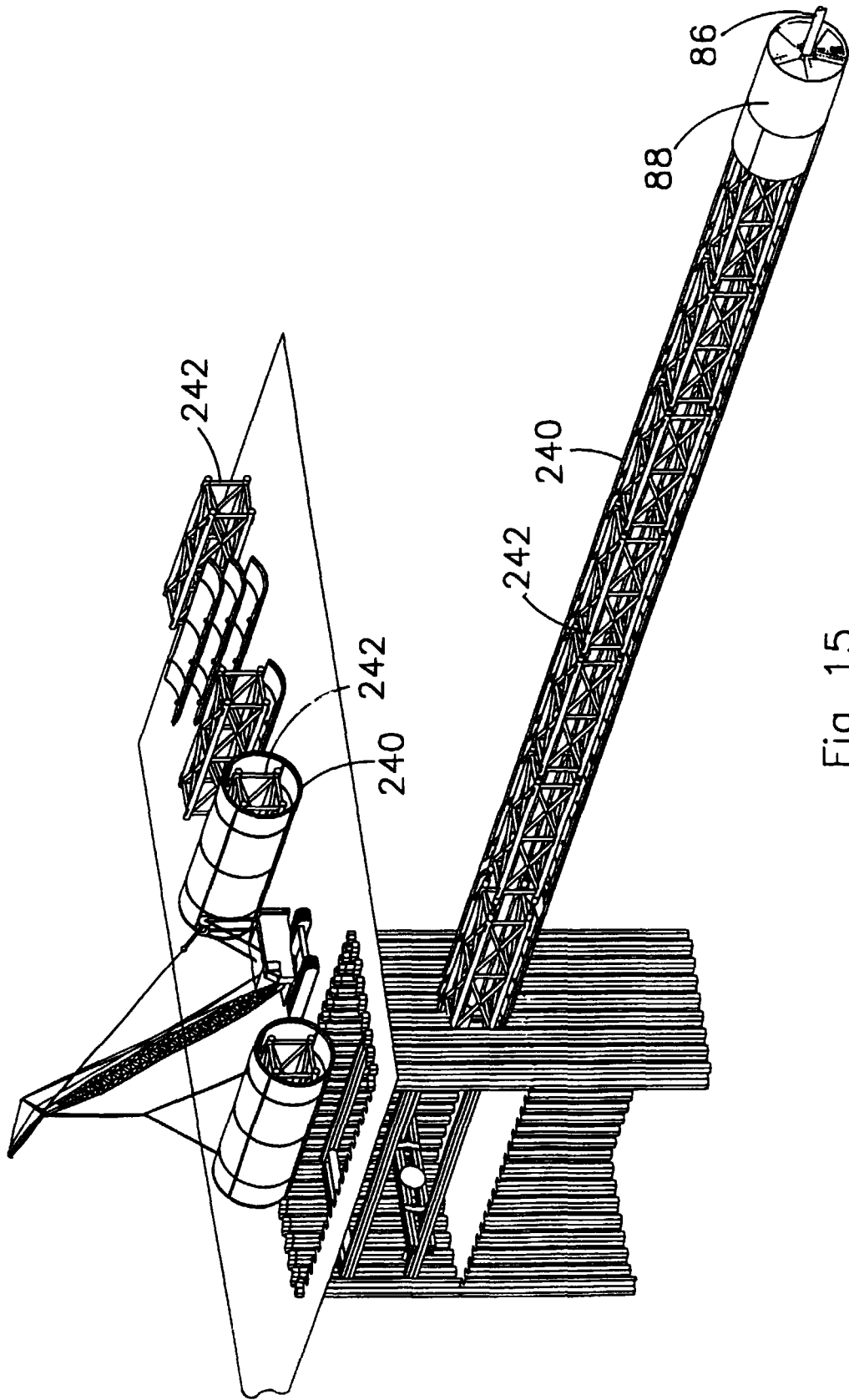


Fig 15

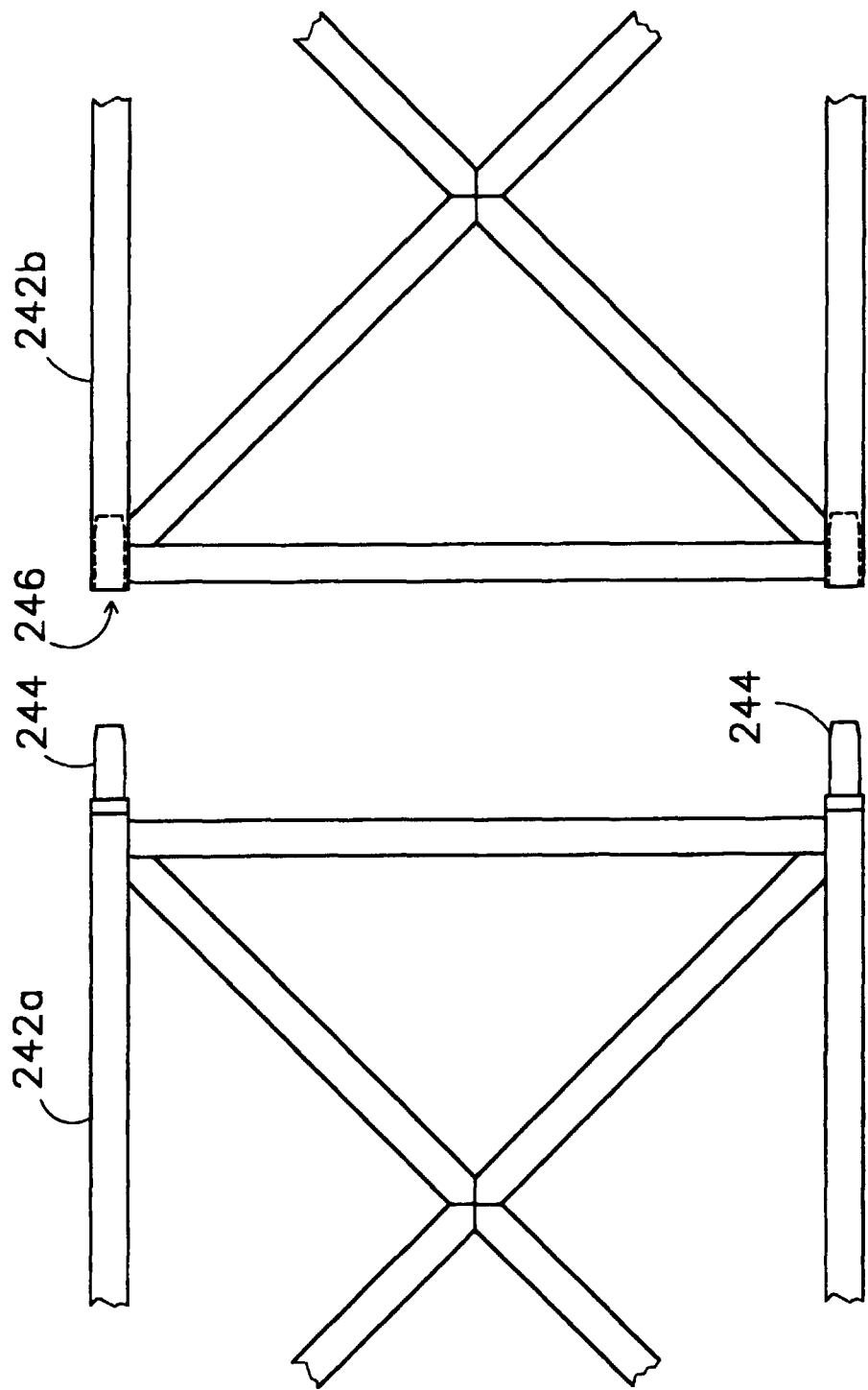


Fig 16