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(54) **Form and method for constructing a lined tunnel**

(57) Form (4) for constructing a lined tunnel. The form (4) is suitable for placing behind an excavating device (3), viewed in a direction of excavation (3a). The form comprises at least one top sheet (4a), which in the radial direction is at such a distance from the surrounding earth (2) that an annular gap (5) is situated between the at least one top sheet (4a) of the form (4) and the surrounding earth (2). The gap (5) serves to accommodate fluid lining material (6) and to allow it to harden. The form (4) is designed to absorb a propulsion force that is required for the propulsion of the excavating device (3). The form (4) is provided with spring means for transmitting the propulsion force of the excavating device (3) in a distributed manner to the hardening and hardened lining material (6).

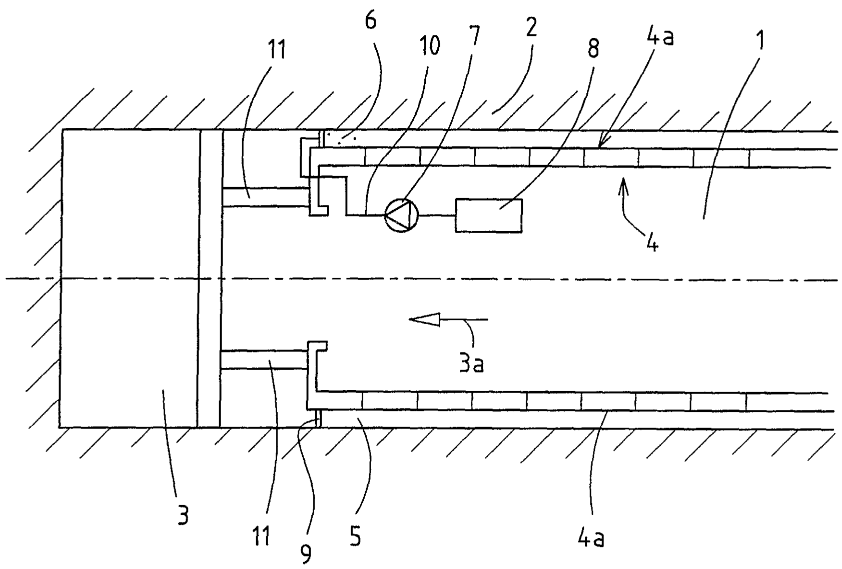

Fig. 1

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Description

[0001] The invention relates to a form for constructing a lined tunnel, which form is suitable for placing behind an excavating device, viewed in a direction of excavation, the form comprising at least one top sheet, which in the radial direction is at such a distance from the surrounding earth that an annular gap is situated between the at least one top sheet of the form and the surrounding earth, which gap serves to accommodate fluid lining material and to allow it to harden, and the form being designed to absorb a propulsion force that is required for the propulsion of the excavating device.

[0002] Such a form is known from WO 79/00159. For the propulsion of the excavating device, it is necessary to have a force, which has to be transmitted to the lining material. Said force transmission is executed by way of the form, which is placed behind the excavating device, viewed in the direction of excavation. The form is much more rigid than the hardening lining material. The lining material situated closest to the excavating device is still largely fluid, and consequently can absorb few or no forces, while lining material situated further away from the excavating device has hardened further and can therefore absorb more forces. A problem that arises as a result of this is that virtually all forces are transmitted by way of the rigid form to the part of the tunnel lining that has hardened sufficiently. That part is therefore subjected to a heavy load, and high material stress consequently occurs in the lining material, which can lead to cracks forming in the latter.

[0003] The object of the invention is to provide a form in the case of which this problem is overcome.

[0004] To this end, the invention proposes a form of the type described above, which form is characterized in that it is provided with spring means for transmitting the propulsion force of the excavating device in a distributed manner to the hardening and hardened lining material, with the result that it is possible to convey the propulsion force as uniformly as possibly into the lining material over the entire length of the form.

[0005] In a preferred embodiment of a form according to the invention, the spring means comprise a layer of resilient plastic material or rubber material, which is provided on the side of the at least one top sheet of the form that faces the gap. A layer of rubber material is preferably vulcanized on the at least one top sheet.

[0006] This embodiment is advantageous because with a slight adaptation to an existing design of a form a resilient effect can be provided between the hardening tunnel lining and the form. By means of the resilient effect, the propulsion force of the excavating device is transmitted uniformly from the form to the tunnel lining.

[0007] In a further embodiment of a form according to the invention, said form comprises a supporting structure that is rigid substantially in the axial direction, and the spring means are in the form of resilient lamellae, which extend substantially in a radial direction between the supporting structure and the at least one top sheet of the form, and are connected to the latter at their ends.

[0008] An advantage of this embodiment is that a great deformation of the spring means is possible.

[0009] In another preferred embodiment of a form according to the invention, the form comprises a supporting structure that is rigid in the axial direction, and the spring means are springs acting substantially in the axial direction, which are connected to the supporting structure and the at least one top sheet of the form. Axially acting springs that can be used are, for example, coil springs, leaf springs or fluid springs.

[0010] In the case of this embodiment it is advantageous that the spring stiffness can be adapted in a simple manner by, for example, varying the spring length or by varying the number of springs. This embodiment therefore has great flexibility for adapting it to the prevailing circumstances.

[0011] Apart from the avoidance of the stress peaks in the lining layer as a result of the force transmission by way of the form, stresses can also occur in the lining material owing to temperature differences that occur in time during the hardening process. In order to ensure that these stresses do not lead to cracks forming at arbitrary points in the lining material, thereby giving rise to leakage in the tunnel, it is possible to weaken the lining layer at predetermined points, so that cracks form only at those predetermined points.

[0012] In order to make the weak points in the lining material, the form is removed before the lining layer is fully hardened, but when it has hardened to such an extent that the lining layer remains intact when the form is removed. In the circumferential direction of the tunnel radial grooves are then made in the lining layer at a distance from each other in the longitudinal direction of the tunnel, which grooves are formed in such a way that the open side of each groove has a smaller width than the bottom of the groove. An elastically deformable jacket section is then placed in each groove, corresponding in length to the groove. A core section is subsequently introduced into the jacket section.

[0013] The grooves can be made by sawing. In this case a groove is formed by means of one or more saw cuts. A possible method in this case is that a first saw cut is made substantially perpendicularly to the tunnel wall, and an oblique second saw cut is subsequently made at an angle to the first saw cut, and an oblique third saw cut is subsequently made at an angle to the first saw cut, which angle is substantially equal to and in the opposite direction to that of the second saw cut. The first saw cut can in this case be deeper than the second saw cut and the third saw cut.

[0014] The seal of the jacket section with the core section can be tested as follows. By introducing test fluid under pressure underneath the jacket section, it can be examined whether the seal is fluid-tight. For this purpose, a channel can be made from the tunnel wall to the deepest part of the groove, for example the deepest part of the first saw cut. The test fluid is then fed through the channel.

[0015] A sealing system comprising a jacket section and a core section is used for sealing the groove. The jacket section is elastically deformable and is substantially U-shaped. The legs of the U-shape are designed to rest against the walls of the groove. When the core section is in the mounted state in the jacket section, the legs of the jacket section are pressed against the grooves under pretension.

[0016] Another aspect of the invention relates to a form according to claim 33 and a method according to claim 38.

[0017] The invention will be explained in greater detail by means of the following description and with reference to the appended drawing, in which:

Fig. 1 shows diagrammatically a front part of a lined tunnel during its construction;
Fig. 2 shows diagrammatically a part of a first embodiment of a form according to the invention;
Fig. 3 shows diagrammatically a part of a second embodiment of a form according to the invention;
Fig. 4 shows diagrammatically a part of a third embodiment of a form according to the invention;
Fig. 5a shows the placing of a jacket section of a seal in a groove;
Fig. 5b shows the placing of a core section of a seal in the jacket section according to Fig. 5a;
Fig. 5c shows the seal in the mounted state;
Fig. 5d shows a groove with oblique walls;
Fig. 6 shows a front view of a device for making and sealing the groove according to Figs. 5a - 5c;
Fig. 7 shows a side view of the device of Fig. 6;
Fig. 8 shows a front view of the device of Fig. 6 during the making of the groove in the lining layer;
Fig. 9 shows a front view of the device of Fig. 6 during the provision of the seal in the groove;
Fig. 10a shows a form ring of a preferred embodiment of the form according to the invention;
Fig. 10b shows a form constructed of form rings from Fig. 10a;
Figs. 11a to 11d show various views in perspective of a form segment of the form ring of Fig. 10a;
Fig. 12 shows a diagrammatic cross section of a form segment of Figs. 11a to 11d;
Fig. 13a shows a diagrammatic view in cross section of two form rings on the front side of the form, in a disconnected state;
Fig. 13b shows a diagrammatic view in cross section of two form rings on the front side of the form, in a connected state;
Fig. 14a shows a diagrammatic view in cross section of two form rings on the rear side of the form, in a connected state;
Fig. 14b shows a diagrammatic view in cross section of two form rings on the rear side of the form, in a disconnected state;
Fig. 15 shows a dismantling device for dismantling a form ring; and
Fig. 16 shows a detail of a dismantling device.

[0018] Fig. 1 shows diagrammatically a front part of a tunnel 1, which is surrounded by earth 2. An excavating device 3 for excavating the tunnel is situated in the tunnel 1. Such an excavating device 3 may be of any type known from the prior art, and will therefore not be discussed in any further detail here.

[0019] A form 4 has also been placed behind the excavating device 3, viewed in an excavating direction 3a. The form 4 comprises a top sheet 4a, which during the construction is at a distance from the surrounding earth 2, so that there is an annular gap 5 between the form 4 and the surrounding earth 2. An annular sealing element 9 is provided, in order to seal the annular gap 5 in the direction of the excavating device 3. Fluid lining material 6 is supplied by means of a pump 7 into the gap 5 from a tank 8 by way of a pipe 10, which extends through the seal 9. Concrete, for example, is used as the lining material. The fluid lining material 6 has the opportunity to harden in the gap 5. Until that time it remains supported by the form 4.

[0020] The force required for the propulsion of the excavating device 3 is transmitted to the form 4 by way of elements 11, such as jacks of the hydraulic type. In Fig. 2 the force exerted by the excavating device upon the form 4 is shown by an arrow indicated by F. A layer 13 of plastic or rubber is placed on the top sheet 4a of the form 4, on the side 12 facing the layer of lining material 6. This layer 13 of plastic or rubber has a resilient effect. A layer of rubber material is preferably vulcanized on the top sheet. As a reaction to the force F, a reaction force is exerted upon the lining layer 6 by way of the form 4 and the layer 13 of plastic or rubber. This reaction force is uniformly distributed over the length of the form 4 through the deformation of the layer 13 of plastic or rubber, this being shown by arrows indicated by r. In this way a situation is prevented in which the lining layer 6 absorbs virtually no force in a region, roughly indicated by 14, close to the excavating device 3, where the lining material has not fully hardened, while a region, roughly indicated by 15, where the lining layer 6 has hardened sufficiently, then has to realize the entire reaction force and is consequently subjected to a heavy load. Owing to this load, material stresses arise in the lining layer 6 in the region 15, and on further hardening can lead to cracks in the lining 6.

[0021] Another embodiment of a form according to the invention is shown in Fig. 3. The form in this embodiment comprises a structure 18 which is rigid in the axial direction. The spring means in this embodiment are in the form of resilient lamellae 16. Said resilient lamellae 16 are fixedly connected at one end to the top sheet 4a of the form 4. At an opposite end 17 they are fixedly connected to the structure 18 which is rigid in the axial direction.

[0022] The propulsion force of the excavating device 3 is shown as in Fig. 2 by an arrow indicated by F. By means of this force F, the lamellae 16, which act as a sort of leaf spring, are deformed in the axial direction. Through this deformation of the resilient lamellae 16, the force F is uniformly transmitted from the axially rigid structure by way of the side 12 of the top sheet 4a of the form 4 that faces the lining layer 6 to said layer 6. The result is therefore that distributed reaction forces are produced along the length of the form 4 in the lining layer 6, which as in Fig. 2 is shown by arrows indicated by r.

[0023] It is advantageous in the case of this embodiment compared with the preferred embodiment illustrated earlier that with the lamellar structure a greater choice in spring stiffness applied in the axial direction is possible than is the case with a layer of plastic or rubber placed on the form, so that a greater deformation in the axial direction can be permitted, with the result that a greater force F can be absorbed and transmitted to the lining layer. As in Fig. 2, the top sheet 4a can be clad with a resilient layer of rubber or plastic.

[0024] Fig. 4 shows yet another preferred embodiment of a form according to the invention, which comprises a structure 18 that is rigid in the axial direction. Axially acting springs 23 are provided between the top sheet 4a of the form 4 and the rigid structure 18. First supporting elements 19 are provided on the rigid structure 18 on the radially outward side 20. The top sheet 4a of the form 4 has second supporting elements 22 on the radially inward side 21. The first supporting elements 19 and the second supporting elements 22 can be in the form of ribs extending in the circumferential direction. Springs 23 extend in the axial direction between each of the first supporting elements 19 and second supporting elements 22. These springs 23 are each fixedly connected at one end to a first supporting element 19, and thus to the axially rigid structure 18. At the opposite end the springs 23 are each fixedly connected to a second supporting element 22, and consequently to the top sheet 4a. The springs 23 can be in the form of, for example, coil springs, fluid springs or leaf springs. As in Fig. 2, the top sheet 4a can be clad with a resilient rubber or plastic layer.

[0025] The propulsion force F of the excavating device 3 is supported on the axially rigid structure 18. Said force is transmitted by the springs 23 to the top sheet 4a and by way of the top sheet 4a to the hardening lining layer 6. The reaction forces are again shown by arrows indicated by r. In Fig. 4 only two springs are shown by way of example, but it is clear that in the case of this embodiment springs with a suitable stiffness can be placed depending on the required stiffness, and that a variable number of springs can also be selected.

[0026] As already described with reference to Fig. 1, the force required for the propulsion of the excavating device 3 is transmitted to the form 4 by way of elements 11, such as jacks of the hydraulic type.

[0027] According to a preferred embodiment of the invention, the form 4 is constructed of form rings. Such a form ring 40 is shown in Fig. 10a. The form ring 40 illustrated is constructed of a number of form segments 41 (in this example eight). Fig. 10b shows how the form 4 is constructed according to a "half-brick bond" from form rings 40, the form rings 40 being connected to each other in a manner that will be described below.

[0028] A form segment 41 is shown in various views in perspective in Figs. 11a to 11d. Each form segment 41 has connecting means, which serve to connect the form segments 41, which are connecting axially to each other, and to absorb in the form 4 the pressure force that the excavating device 3 exerts by way of the elements 11. The form segment 41 is provided on the outside with a rubber layer 13, in order to transmit force absorbed in the form to the lining layer 6, as already described above.

[0029] The connecting means comprise a channel 44, which extends in the axial direction through the form segment 41, and a club-shaped connecting member 43 with a club head 43a, as shown diagrammatically in cross section in Fig. 12.

[0030] When a new form segment 41 is being added on the front side (viewed in the direction of excavation) of the form 4, two elements 11 (see Fig. 1) are pulled back in the direction of the excavating device 3. The form segment 41 is placed between the front form ring 40 and the elements 11 (see Fig. 13a), after which the elements 11 are inserted at the end 42 of the channel 44, as can be seen in Fig. 13b. The element 11 presses against the connecting member 43, so that the connecting member 43 is moved over a distance x and the club head 43a on the other side is partially forced out of the channel 44 and into the channel 44 of the form segment 41 behind it. Owing to the pressure of the element 11, the form segments 41 and 41a are pressed against each other, so that ring stiffness is provided on the form rings 40 by the axial normal force between the form segments 41, 41a. The connecting member 43 further provides a connection between the two form segments 41 and 41a.

[0031] On the side of the segment 41 on which the club head 43a is situated, lugs 45 are fitted around the opening of the channel (see Figs. 11b and 11d). On the other side of the segment 41 at the end 42 recesses 46 are provided around the opening of the channel 44, which recesses are complementary with the lugs 45. During use, the lugs 45 of a segment 41 are accommodated in the recesses 46 of the segment 41a behind. In this way it is ensured that the form segments 41, 41a cannot rotate relative to each other, and additional ring stiffness is therefore given to the form rings 40.

[0032] It is shown in Figs. 14a and 14b how the form segments 41 on the rear side of the form 4 can be removed when the lining layer 6 has hardened sufficiently. The connecting member 43 of the second last segment 41 is pressed back in order to be able to break the connection between the last segment 41a and second last segment 41 and to be able to take the last segment 41a with a radial movement inwards out of the form 4. The connecting member 43 of the last segment 41a is pushed back by means of a pressure member 49 over a distance ½x. Owing to the fact that the connecting member 43 of the second last segment 41 is pressed against the connecting member 43 of the last segment 41a, the connecting member 43 of the second last segment 41 is moved over a distance ½x and pressed out of the channel 44 of the last segment 41a. The connection between the two segments 41 and 41a is consequently broken, as shown in Fig. 14b. The last segment 41a can now be removed from the form 4. When the last form ring 40a has been entirely dismantled, the second last form ring 40 is dismantled. In the process, the connecting members 43 of the last form ring 40a are again moved over a distance ½x. In the case of the example shown, it is therefore the case that during the construction the connecting members 43 are pushed backwards in one go over a distance x (see Figs. 13a and 13b), and during the dismantling are pushed backwards in two goes over a distance ½x (see Figs. 14a and 14b). The lugs 45 are otherwise designed in such a way that purely radial removal of the segments 41 from the form 4 is possible.

[0033] For the dismantling of the form 4 at the rear side, a dismantling device 500 of the type shown in Fig. 15 is preferably used. The dismantling device 500 comprises a number of pressure members 49 corresponding to the number of connecting members 43 in a form ring 40, which pressure members are connected to cylinders 501. In the above example of eight segments 41 per form ring 40, each with two connecting members 43, sixteen pressure members 49 and the same number of cylinders 501 are therefore present on the dismantling device 500.

[0034] The cylinders 501 are mounted on a bedplate ring 502, which is connected by means of hydraulic cylinders 503 to the central shaft 504 of the dismantling device 500. The cylinders 503 are blocked during the pushing back of the clubs 43, so that the axial reaction forces occurring as a result are guided by way of foundation ring 502 and the cylinders 503 to the central shaft 504, so that these reaction forces can be dissipated into the remainder of the structure.

[0035] The pressure member 49 is dimensioned in such a way that said pressure member can still push back the connecting member 43 in the event of the connecting member 43 and the pressure member 49 not lying exactly in line with each other.

[0036] The cylinders 501 are each individually controllable, so that the connecting members 43 can be pushed back individually and the form 4 can be dismantled segment 41 by segment 41.

[0037] Before the connecting members 43 are pushed back, the segments 41 are clamped by clamping means with a certain force against the lining layer 6. The clamping means in this exemplary embodiment comprise a hydraulically controllable lever construction 505, which is fitted on the foundation ring 502. Said lever construction 505 is shown in greater detail in Fig. 16 and comprises a lever 508 that can be extended by means of a hydraulic cylinder 506. The lever-cylinder combination 508, 506 is hingedly connected to the foundation ring 502 at point 509. At one end the lever-cylinder combination 508, 506 is connected to a substantially radially directed hydraulic cylinder 507. By retracting of the cylinder 507, the lever 508 acts with the other, free end upon the form segment 41 and holds the latter with force against the lining layer 6. Thereafter the connecting members 43 of the form segment 41 are pushed back from the form segment 41, so that the latter is disconnected from the form segment 41 in front of it. The force with which the lever 508 is pressed against the segment 41 can then be reduced in a controlled manner by adjusting the control setting of the cylinder 507, and the segment can be removed radially. The lever construction 505 can be designed in such a way that it can also pull away the segment 41 if the latter remains stuck to the lining layer 6.

[0038] After dismantling of the form ring 40, the dismantling device 500 is moved in each case over a distance corresponding to the axial length of a form ring 40, in order to be able to dismantle the next form ring 40. To this end, the dismantling device 500 is provided with movement means, in this example comprising a step mechanism having a movable auxiliary foundation 510, which is connected by means of cylinders 511 to the foundation ring 502. When a form ring 40 has been dismantled the foundation ring 502 is not fixed relative to the form 4 by way of the levers 508. By adjusting the control setting of the cylinders 511, the foundation ring 502 is moved forward relative to the auxiliary foundation 510 over a distance corresponding to the width of a form ring 40. When the foundation ring 502 is subsequently fixed again relative to the form 4 by means of the levers 508, the auxiliary foundation 510 can be pulled up again by retracting the cylinders 511.

[0039] In order to ensure that stresses occurring during the hardening of the lining do not lead to cracks forming at arbitrary points in the lining material, it is possible to weaken the lining layer at predetermined points, so that cracks form only at those predetermined points. A method that is known per se for making cracks form in this controlled way is to make grooves in the lining layer.

[0040] When the lining layer 6 is not yet fully hardened, but is hardened sufficiently, the form can be removed from the tunnel wall in the manner described above. Radial grooves can then be made in the lining layer at a distance from each other, viewed in the longitudinal direction of the tunnel. The grooves can be made by sawing.

[0041] It can be seen in Fig. 5a that a groove 101 is formed in such a way that the open end 102 of the groove 101 is of a smaller width than a bottom 103c of the groove 101. The groove 101 has walls 103a, 103b, which taper from the bottom 103c towards the open end

102. By means of the groove 101, the lining layer 6 is deliberately weakened locally, and a crack may form. However, in order to keep the tunnel wall liquid-tight, it is necessary to make a seal in the groove. The seal can be produced in a manner known per se by placing a sealing section in the groove.

[0042] An advantageous embodiment of the sealing section is shown in Figs. 5a - 5c. In this case an elastically deformable jacket section 105 with a length corresponding to that of the radial groove is placed in the radial groove 101, as shown in Fig. 5a. The bottom of the jacket section 105 is foldable in the centre region 105a (see Fig. 5a), in order to permit the jacket section to be placed in the groove. The jacket section 105 has a substantially U-shaped cross section in the fitted state, the legs 107 of the U-shape being designed to rest under pretension against the groove walls 103a, 103b. A core section 106 is subsequently placed in the elastically deformable jacket section 105 between the legs 107 of the U-shape, as shown in Fig. 5b. Through the insertion of the core section 106, the legs 107 of the jacket section 105 are pressed against the groove walls 103a, 103b (see Fig. 5c). The legs 107 of the jacket section 105 are provided with hooked edges 109 on the inside. In the mounted state the hooked edges 109 are situated behind edges 108 of recesses in the core section 106, so that the core section 106 is wedged in the jacket section 105. On the side facing the groove walls 103a, 103b, the legs 107 are provided with ribs 110, which are designed to interact with the groove walls 103a, 103b, so that in the fitted state the jacket section is immovable. The ribs 110 also have a sealing function.

[0043] The radial grooves are preferably made in the lining layer of the tunnel wall by sawing. In order to obtain a groove with oblique groove walls 103a, 103b, a saw cut is first made substantially perpendicularly to the tunnel wall. An oblique saw cut is then made at an angle α (see Fig. 5d) relative to the first saw cut. A further oblique saw cut is subsequently made in the opposite direction, rotated through an angle α relative to the first saw cut. The first saw cut is deeper than the oblique saw cuts, so that in the bottom region 103c of the groove 101 a deepened groove section 103d is produced.

[0044] After the seal, comprising the jacket section 105 and the core section 106, has been provided in the groove 101, the seal is preferably tested. For this purpose, a test fluid under pressure is introduced underneath the jacket section 105. In order to introduce the test fluid, a supply channel 112 (indicated by a broken line) is provided from the tunnel wall to the deepened groove part 103d. By monitoring the pressure in the course of a predetermined period of time, it can be established whether the seal is working adequately. The tunnel wall can be inspected with the eye, and it can be seen whether test fluid is leaking out from underneath the seal.

[0045] For making the grooves in the lining layer and subsequently sealing said grooves with a seal of the type described above, it is preferable to use a device which can perform all these operations in one go. This device can be situated behind the dismantling device described above during the construction of a tunnel.

[0046] Figs. 6 and 7 show such a device, indicated by 201. The device 201 comprises a first sawing device 202 for sawing a radial groove in the lining layer 6 of the tunnel wall perpendicularly to the inside surface of said tunnel wall. In addition, the device comprises a levelling device 203 for levelling the lining layer 6 of the tunnel wall, which is necessary to provide a reference plane relative to which the subsequent saw cuts can be measured.

[0047] The device also comprises a second sawing device 204 for sawing a first oblique saw cut, in order to form a first groove wall 107, and a third sawing device 205 for sawing a second oblique saw cut, in order to form a second groove wall 107.

[0048] The device also comprises a reel off system 206, comprising two reels, the jacket section being reeled onto a first reel, and the core section being reeled onto a second reel, and a pressure system comprising a first pressure member 207 for pressing the jacket section into the groove and a second pressure member 208 for pressing the core section into the jacket section. The first sawing device 202, the levelling device 203, the second sawing device 204, the third sawing device 205, the reel off system 206 and the pressure system 207, 208 are placed on the periphery of a substantially cylindrical carrier 209, which cylindrical carrier 209 is substantially concentric with the lining layer 6 of the tunnel wall and is rotatable about its axis. In order to rotate the carrier 209, said carrier is provided on the inside with a tooth system 210. A gearwheel 211, which is driven by driving means (not shown in any further detail), meshes with the tooth system 210. By driving the gearwheel 211, the carrier 209 can be rotated about its axis, and in this way the first sawing device 202, the levelling device 203, the second sawing device 204, the third sawing device 205, the reel off system 206 and the pressure system 207, 208 are simultaneously moved along the surface of the lining layer 6 of the tunnel. In a rotational movement a straight saw cut is made with the first sawing device 202, after which a reference plane is produced, by means of the levelling device 203, for making the oblique saw cuts with the second and third sawing device 204 and 205 respectively. In a subsequent rotational movement after the groove has been fully sawn, the sections are put in place by means of the reel off system 206 and the pressure system with the pressure members 207 and 208.

[0049] The device can then be moved forward in the longitudinal direction of the tunnel to the next place at which a groove is to be made. For this purpose, the device 201 is provided with wheels 214, which are fixed to the jacket 209 by means of feet 213.

Claims

1. Form (4) for constructing a lined tunnel, which form (4) is suitable for placing behind an excavating device (3), viewed in a direction of excavation, the form (4) comprising at least one top sheet (4a), which in the radial direction is at such a distance from the surrounding earth (2) that an annular gap (5) is situated between the at least one top sheet (4a) of the form (4) and the surrounding earth (2), which gap (5) serves to accommodate fluid lining material and to allow it to harden, and the form (4) being designed to absorb a propulsion force that is required for the propulsion of the excavating device (3), **characterized in that** the form (4) is provided with spring means (13, 16, 23) for transmitting the propulsion force of the excavating device (3) in a distributed manner to the hardening and hardened lining material (6).

2. Form according to claim 1, **characterized in that** the spring means comprise a layer (13) of elastic plastic material or rubber material, which is provided on the side of the at least one top sheet (4a) of the form (4) that faces the gap (5).

3. Form according to claim 2, **characterized in that** the layer (13) is made of rubber material that is vulcanized on the at least one top sheet (4a).

4. Form according to claim 1, **characterized in that** the form (4) comprises a supporting structure (18) that is rigid in the axial direction, and **in that** the spring means are in the form of resilient lamellae (16), which extend substantially in a radial direction between the supporting structure (18) and the at least one top sheet (4a) of the form (4) and are connected to the latter.

5. Form according to claim 1, **characterized in that** the form (4) comprises a supporting structure (18) that is rigid in the axial direction, and **in that** the spring means are springs (23) acting substantially in the axial direction, which are connected to the supporting structure (18) and the at least one top sheet (4a) of the form (4).

6. Form according to claim 5, **characterized in that** the springs (23) are coil springs.

7. Form according to claim 5, **characterized in that** the springs (23) are leaf springs.

8. Form according to claim 5, **characterized in that** the springs (23) are fluid springs.

9. Form according to claim 5, **characterized in that** the supporting structure (18) is provided with first supporting elements (19) extending in the radial direction towards the at least one top sheet (4a), **in that** the at least one top sheet (4a) is provided with second supporting elements (22) extending in the radial direction towards the supporting structure (18), and **in that** the springs (23) are fitted between the first and the second supporting elements (19, 22).

10. Form according to claim 9, **characterized in that** the first and/or second supporting elements (19, 22) are ribs extending in the circumferential direction.

11. Form according to one of the preceding claims, **characterized in that** the form (4) is constructed of form rings (40) that connect to each other in the axial direction, each form ring (40) comprising interconnecting form segments (41).

12. Form according to claim 11, **characterized in that** the form segments (41) of each form ring (40) are staggered in the circumferential direction relative to the form segments (41) of the connecting form ring (40).

13. Form according to claim 12, **characterized in that** the form segments (41) are placed staggered in the circumferential direction substantially half a length relative to each other, so that the form (4) is constructed according to a "half-brick bond".

14. Form according to one of claims 11 - 13, **characterized in that** each form segment (41) is provided with connecting means (43, 44), for connecting the form segment (41) to a form segment (41) connecting axially to it.

15. Form according to claim 14, **characterized in that** the connecting means comprise a channel (44) containing a connecting member (43), in the connected state of the form segment (41) the connecting member (43) projecting partially out of the channel (44) and being accommodated in the channel (44) of the connecting form segment (41).

16. Method for constructing a lined tunnel, comprising:

- excavating a tunnel or a part of a tunnel by means of an excavating device (3),
- placing a form (4) behind the excavating device (3), which form (4) comprises at least one top sheet (4a), which in the radial direction is at such a distance from the surrounding earth (2) that an annular gap (5) is situated between the at least one top sheet (4a) of the form (4) and the surrounding earth (2),
- filling the annular gap (5) with a fluid lining material such as fluid concrete,

- allowing the tunnel lining material to harden, so that a tunnel lining (6) is formed,

characterized in that the form (4)is provided with spring means (13, 16, 23), and **in that** the propulsion force necessary to move the excavating device (3) in the excavating direction is transmitted in a distributed manner to the hardening and hardened lining material (6) by way of the spring means (13,16, 23) of the form (4).

17. Method according to claim 16, further comprising:

- removing the form (4) when the lining layer (6) has not yet fully hardened, but has hardened to such an extent that the lining layer (6) remains intact when the form (4) is removed,
- making radial grooves (101) in the lining layer (6) viewed in the longitudinal direction of the tunnel (1), at a distance from each other in the circumferential direction of the tunnel, which grooves (101) are formed in such a way that the open side of each groove (101) has a smaller width than the bottom (103c) of the groove (101),
- placing an elastically deformable jacket section (105) in each groove (101), corresponding in length to the groove,
- placing a core section (106) in the jacket section (105).

18. Method according to claim 17, **characterized in that** the radial grooves (101) in the lining layer (6) are made by sawing.

19. Method according to claim 18, **characterized in that** each radial groove (101) is formed by means of several saw cuts.

20. Method according to claim 19, **characterized in that** a first saw cut is made substantially perpendicularly to the tunnel wall, and an oblique second saw cut is subsequently made at an angle (α) to the first saw cut, and an oblique third saw cut is subsequently made at an angle (α) to the first saw cut, which angle (α) is substantially equal to and in the opposite direction to that of the second saw cut.

21. Method according to claim 20, **characterized in that** the first saw cut is deeper than the second saw cut and third saw cut.

22. Method according to claim 17, **characterized in that** a channel (112) is made from the tunnel wall to the deepest part of the groove (101), after which a test fluid is fed through the channel (112), in order to test the sealing effect of the jacket section (105) with the core section (106) placed in it.

23. Sealing system for sealing a groove (101) made by the method according to one of claims 18 - 22, the sealing system comprising a jacket section (105) that is elastically deformable and has a substantially U-shaped cross section, in the fitted state the legs (107) of the U-shape being designed to rest against the groove walls (103a, 103b) under pretension, and which sealing system further comprises a core section (106), which is formed to be inserted between the legs (107) of the U-shape, in order to press the legs (107) of the jacket section (105) against the groove walls (103a, 103b).

24. Sealing system according to claim 23, **characterized in that** on the side of the legs (107) of the jacket section (105) that is to face the groove walls (103a, 103b) the legs are provided with a number of ribs (110), which are designed to interact in a sealing manner with the groove walls (103a, 103b).

25. Sealing system according to claim 23 or 24, **characterized in that** on the open side of the section the legs (107) of the jacket section (105) are provided on the inside with hooked edges (109), which are designed to interact with the core section (106), in order to retain the core section (106) in the jacket section (105).

26. Sealing system according to one of claims 23 - 25, **characterized in that** the bottom of the section is foldable in a centre region (105a) of said section.

27. Device (500) for removing the form (4) according to claim 15, comprising pressure members (49) for pressing back the connecting members (43) in the channel (44) of the form segment (41) during the disconnection of said form segment.

28. Device according to claim 27, **characterized in that** the pressure members (49) are operable separately.

29. Device according to claim 27 or 28, **characterized in that** the device (500) is further provided with clamping means (505 - 509) for clamping the form segment (41) against the tunnel lining (6) during the disconnection of the form segment (41).

30. Device according to claim 29, **characterized in that** the clamping means (505 - 509) comprise a hydraulically controllable lever construction (505), in which the free end of the lever (508) can act upon the form segment (41).

31. Device according to one of claims 27 - 30, **characterized in that** the device (500) is provided with movement means (510, 511), for moving the device (500) in each case over a distance corresponding to the width of a form ring (40).

32. Device (201) for carrying out the method according to one of claims 17 - 21, comprising:

- a first sawing device (202) for sawing a radial groove in the tunnel wall perpendicularly to the inside surface of said tunnel wall,
- a levelling device (203) for levelling the tunnel wall,
- a second sawing device (204) for sawing a first oblique saw cut,
- a third sawing device (205) for sawing a second oblique saw cut,
- an reel off system (206) comprising two reels, the jacket section being reeled onto a first reel, and the core section being reeled onto a second reel,
- a pressure system comprising a first pressure member (207) for pressing the jacket section (105) into the groove and a second pressure member (208) for pressing the core section (106) into the jacket section (105),

the first sawing device (202), the levelling device (203), the second sawing device (204), the third sawing device (205), the uncoiling system (206) and the pressure system being placed on the periphery of a carrier (209), which carrier (209) is substantially concentric with the tunnel wall and is rotatable about its axis.

33. Form for constructing a lined tunnel, **characterized in that** the form (4) is constructed of form rings (40) connecting to each other in the axial direction, each form ring (40) comprising form segments (41) that connect to each other in the circumferential direction.

34. Form according to claim 33, **characterized in that** the form segments (41) of each form ring (40) are staggered in the circumferential direction relative to the form segments (41) of the connecting form ring (40).

35. Form according to claim 34, **characterized in that** the form segments (41) are placed staggered in the circumferential direction substantially half a length relative to each other, so that the form (4) is constructed according to a "half-brick bond".

36. Form according to one of claims 33 - 35, **characterized in that** each form segment (41) is provided with connecting means (43, 44), for connecting the form segment (41) to a form segment (41) connecting axially to it.

37. Form according to claim 36, **characterized in that** the connecting means comprise a channel (44) containing a connecting member (43), in the connected state of the form segment (41) the connecting member (43) projecting partially out of the channel (44) and being accommodated in the channel (44) of the connecting form segment (41).

38. Method for constructing a lined tunnel, **characterized in that** a form according to one of claims 33 - 37 is used.

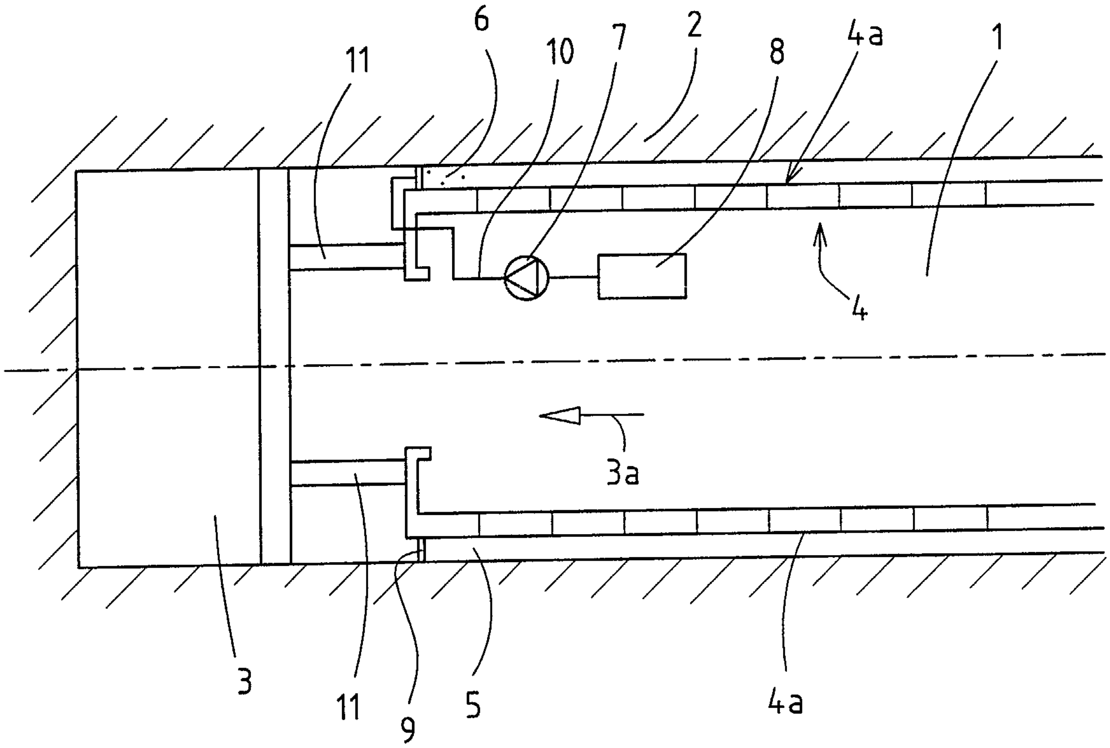


Fig. 1

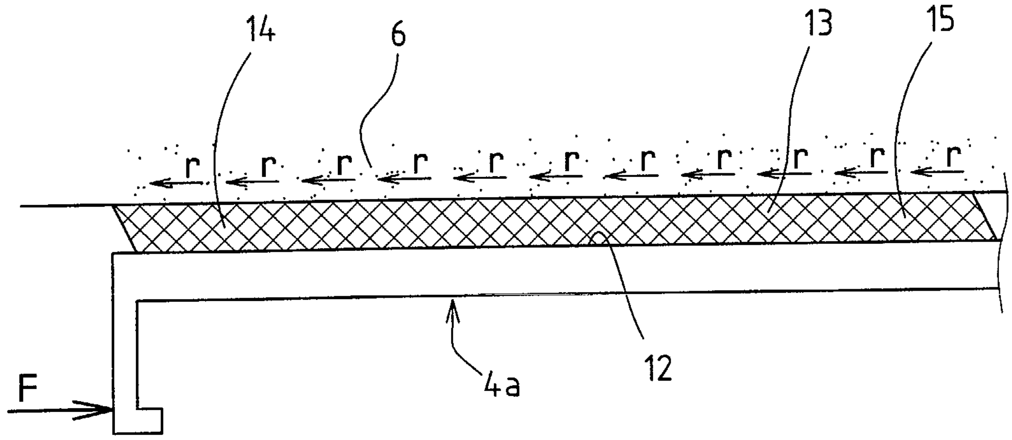


Fig. 2

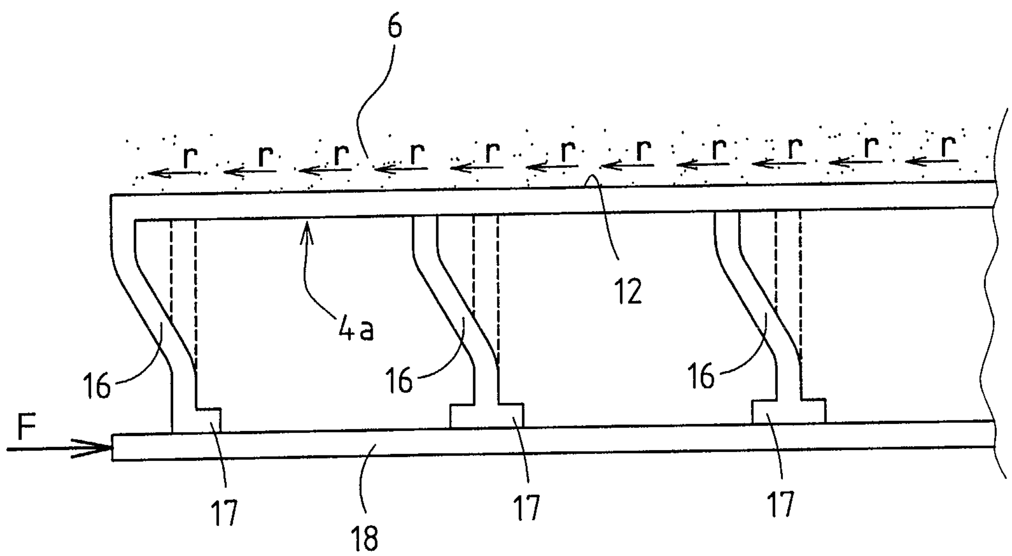


Fig. 3

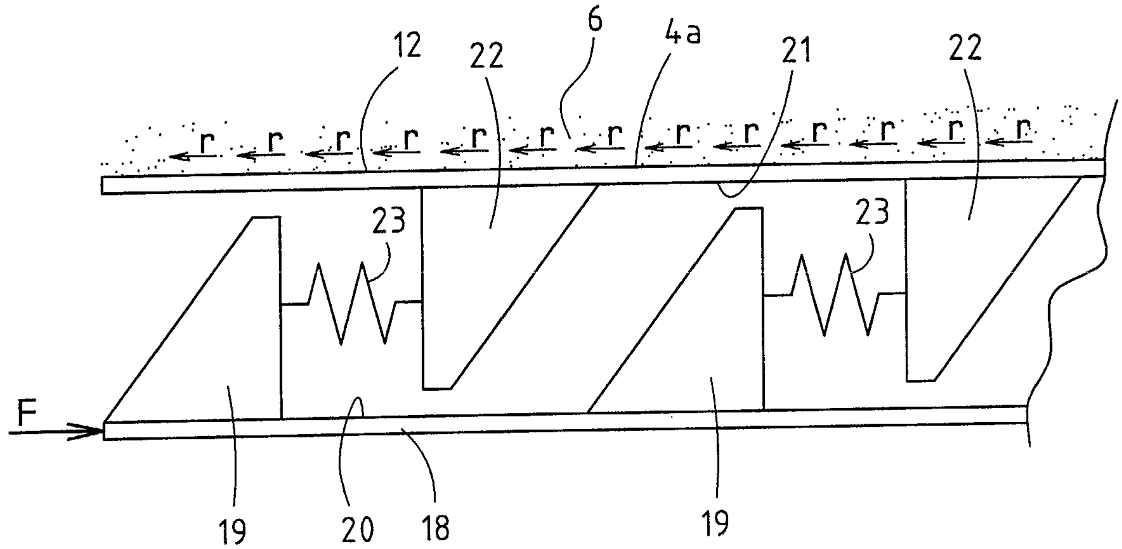


Fig. 4

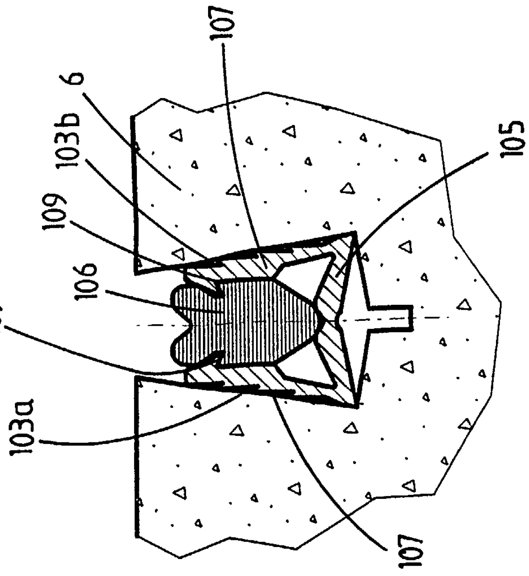


Fig. 5c

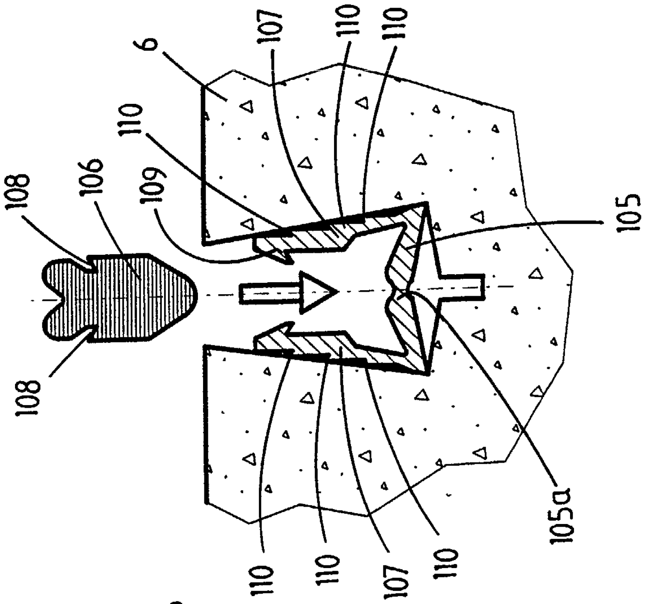


Fig. 5b

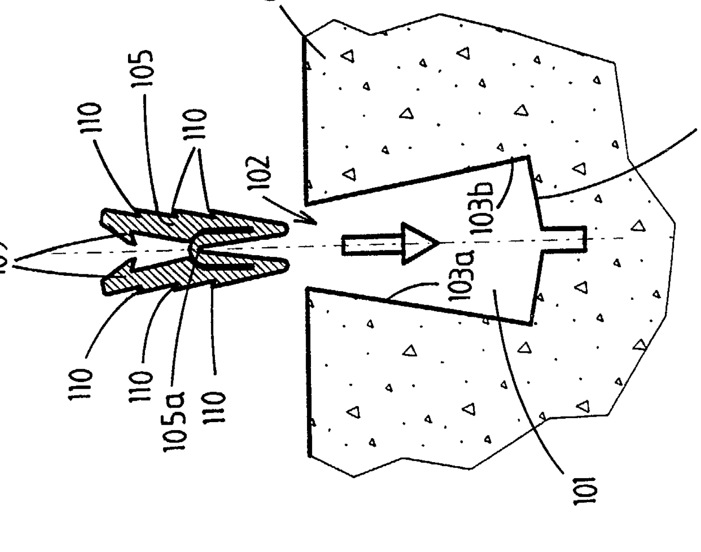


Fig. 5a

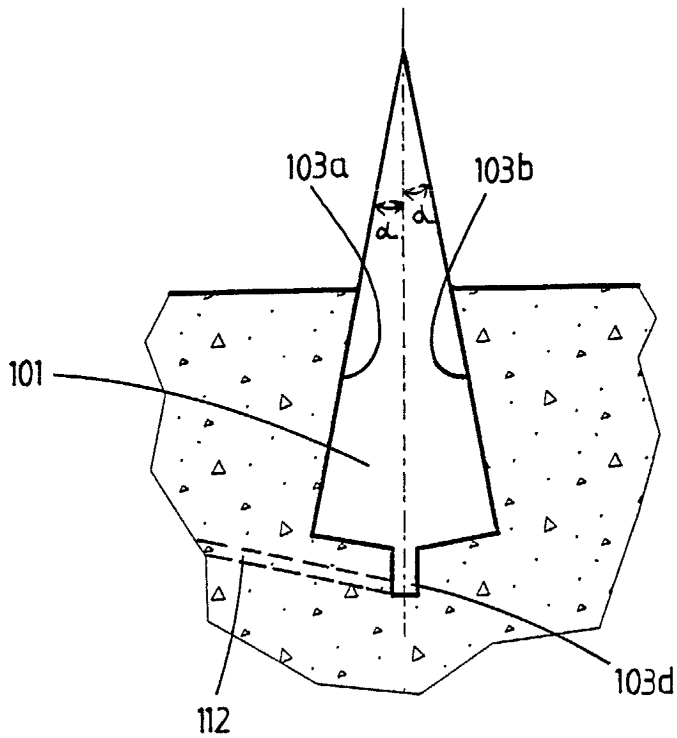


Fig. 5d

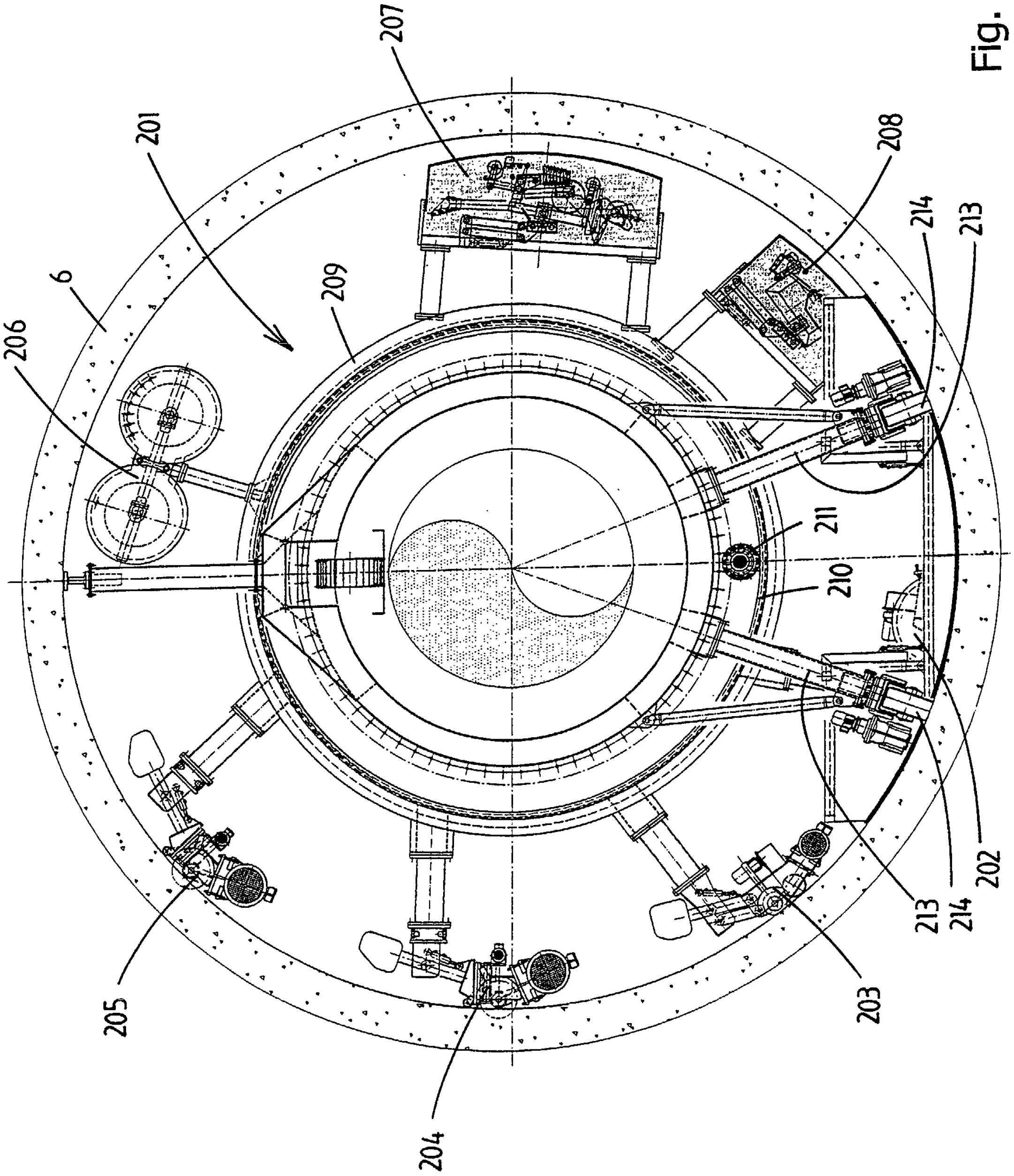


Fig. 6

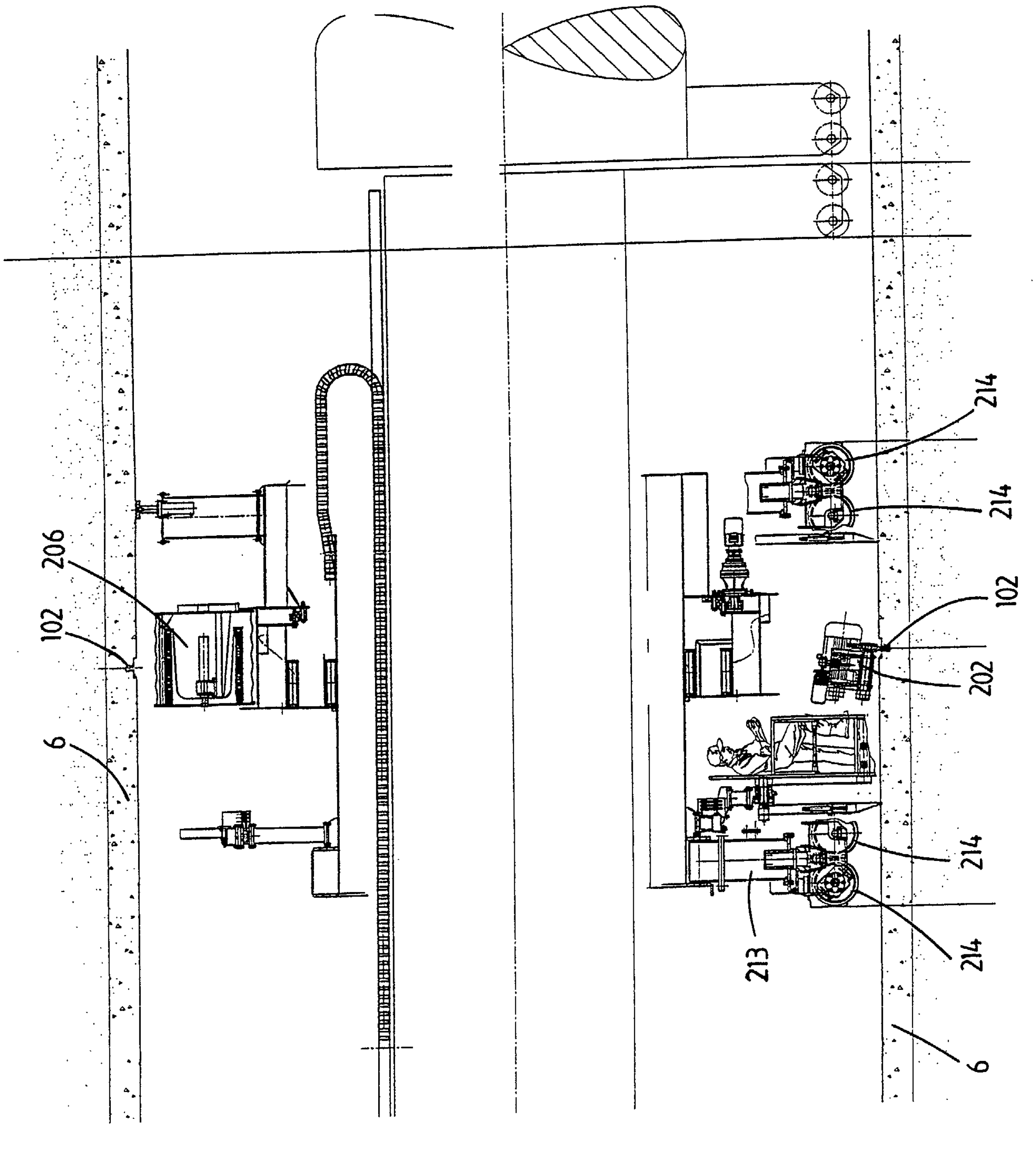


Fig. 7

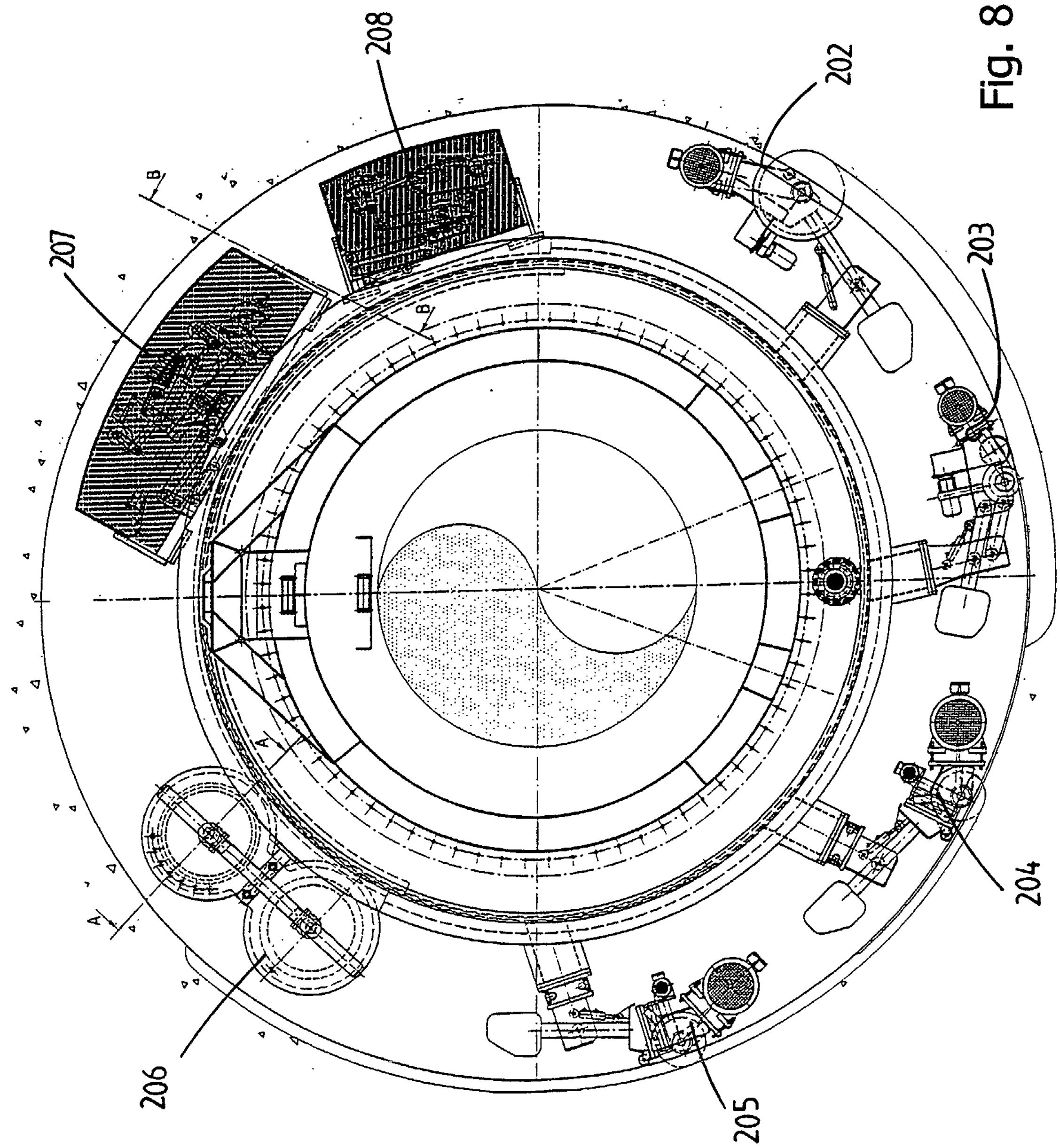


Fig. 8

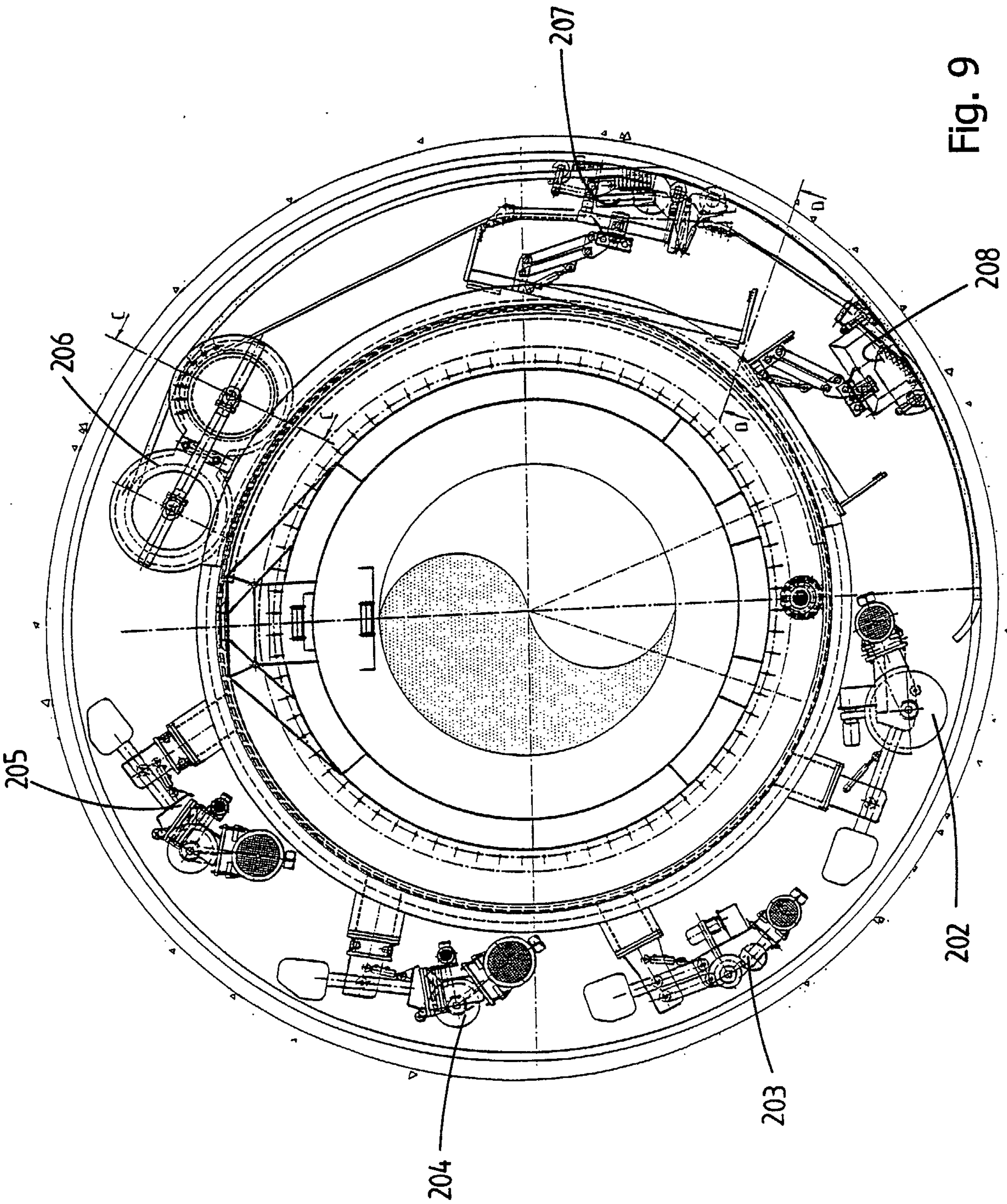


Fig. 9

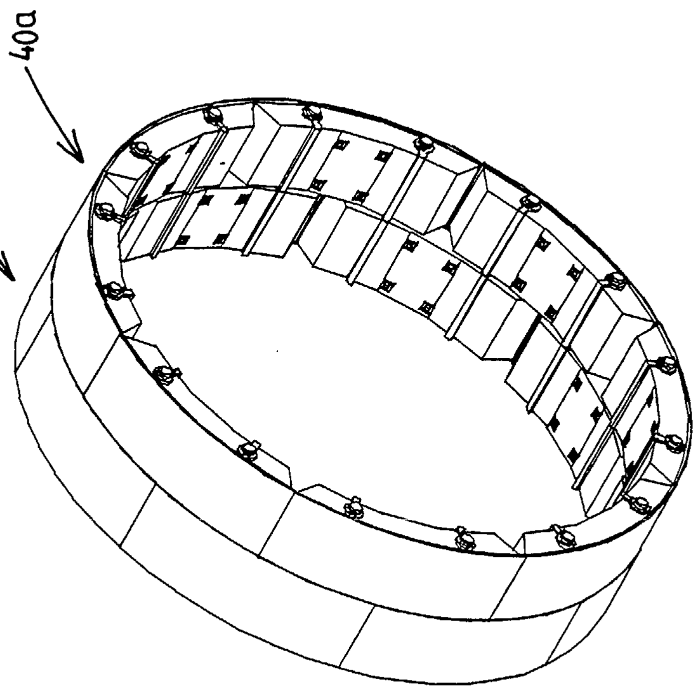


Fig. 10b

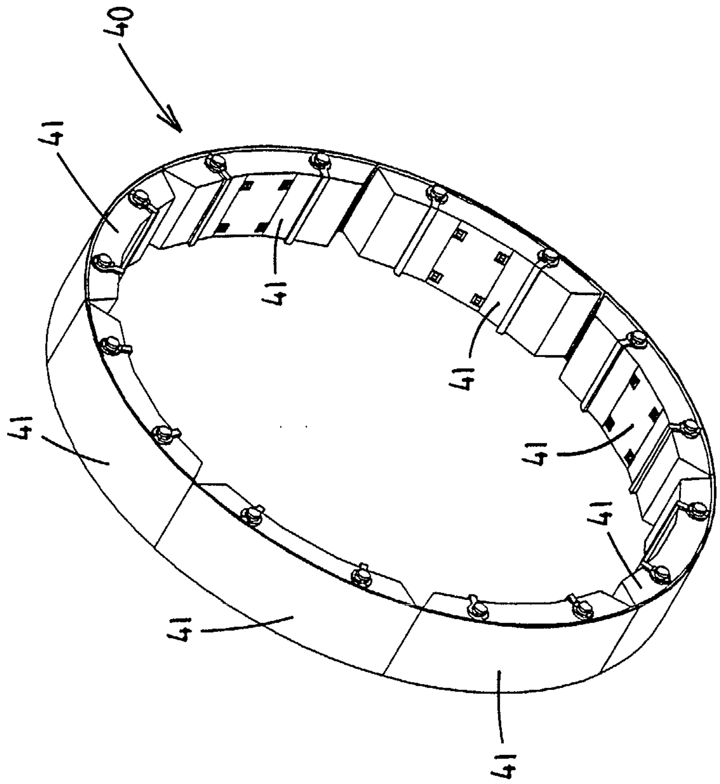


Fig. 10a

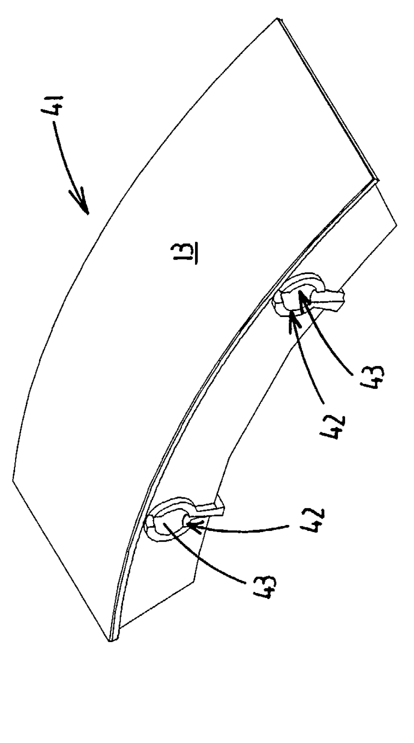


Fig. 11a

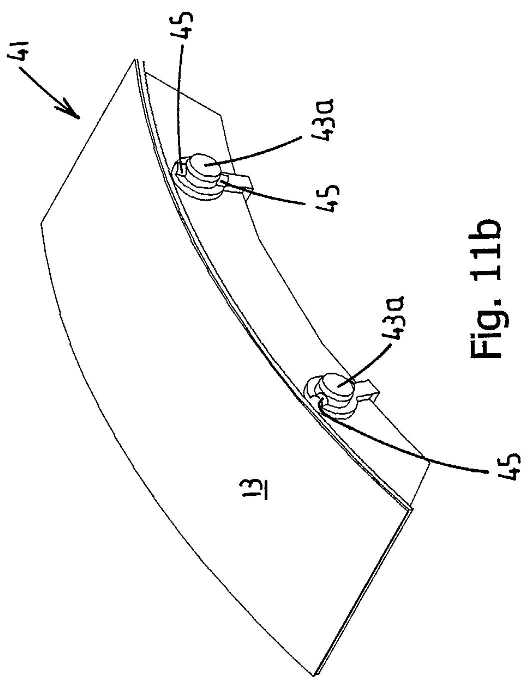


Fig. 11b

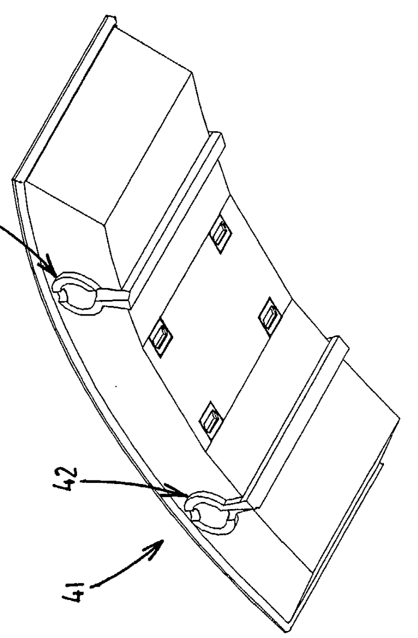


Fig. 11c

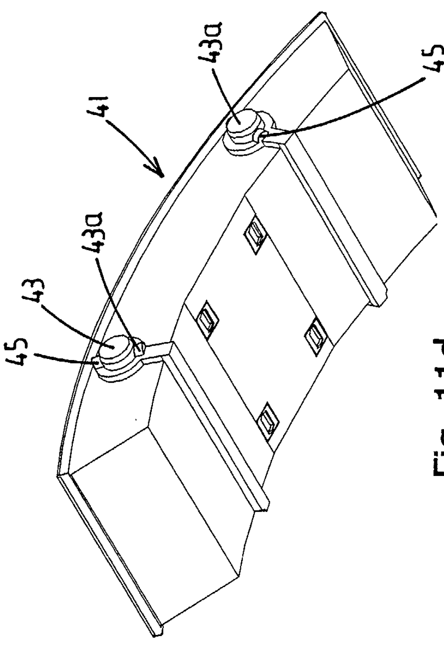


Fig. 11d

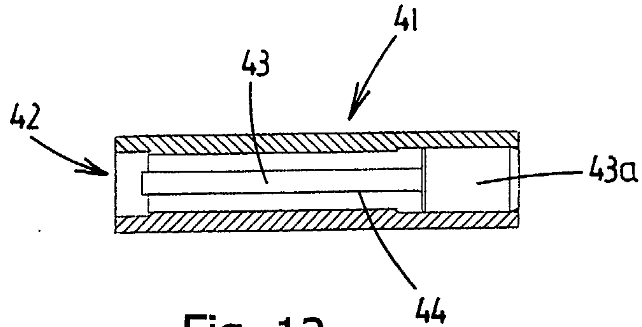


Fig. 12

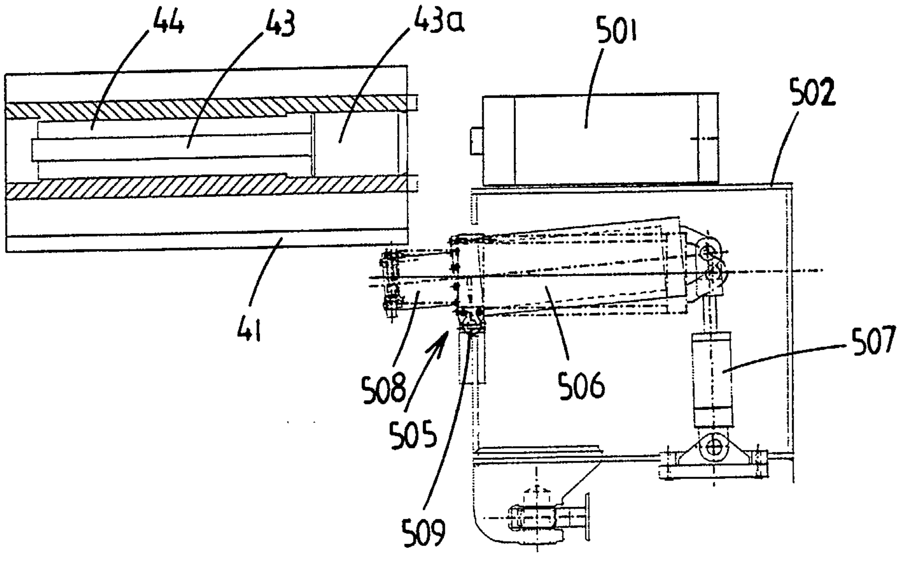


Fig. 16

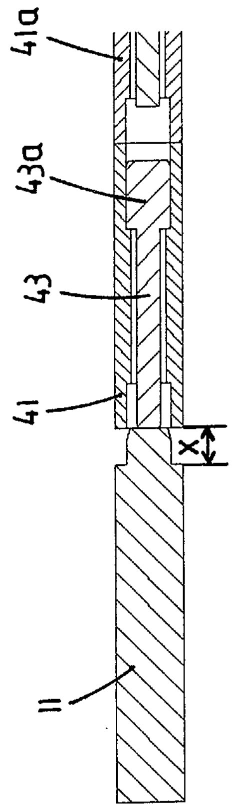


Fig. 13a

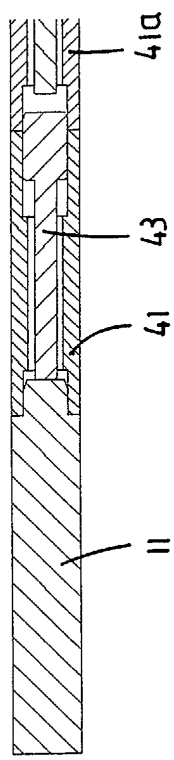


Fig. 13b

Fig. 14a

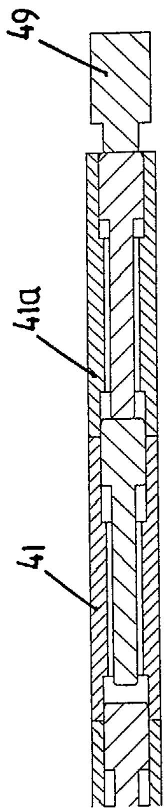
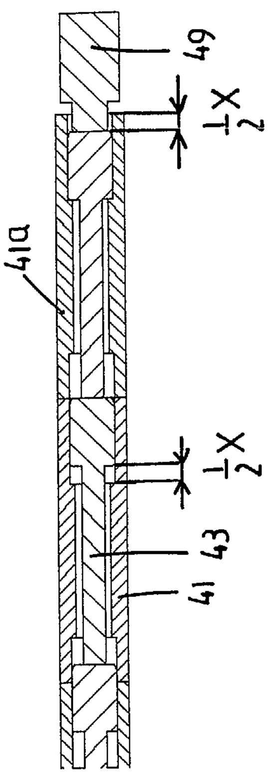


Fig. 14b



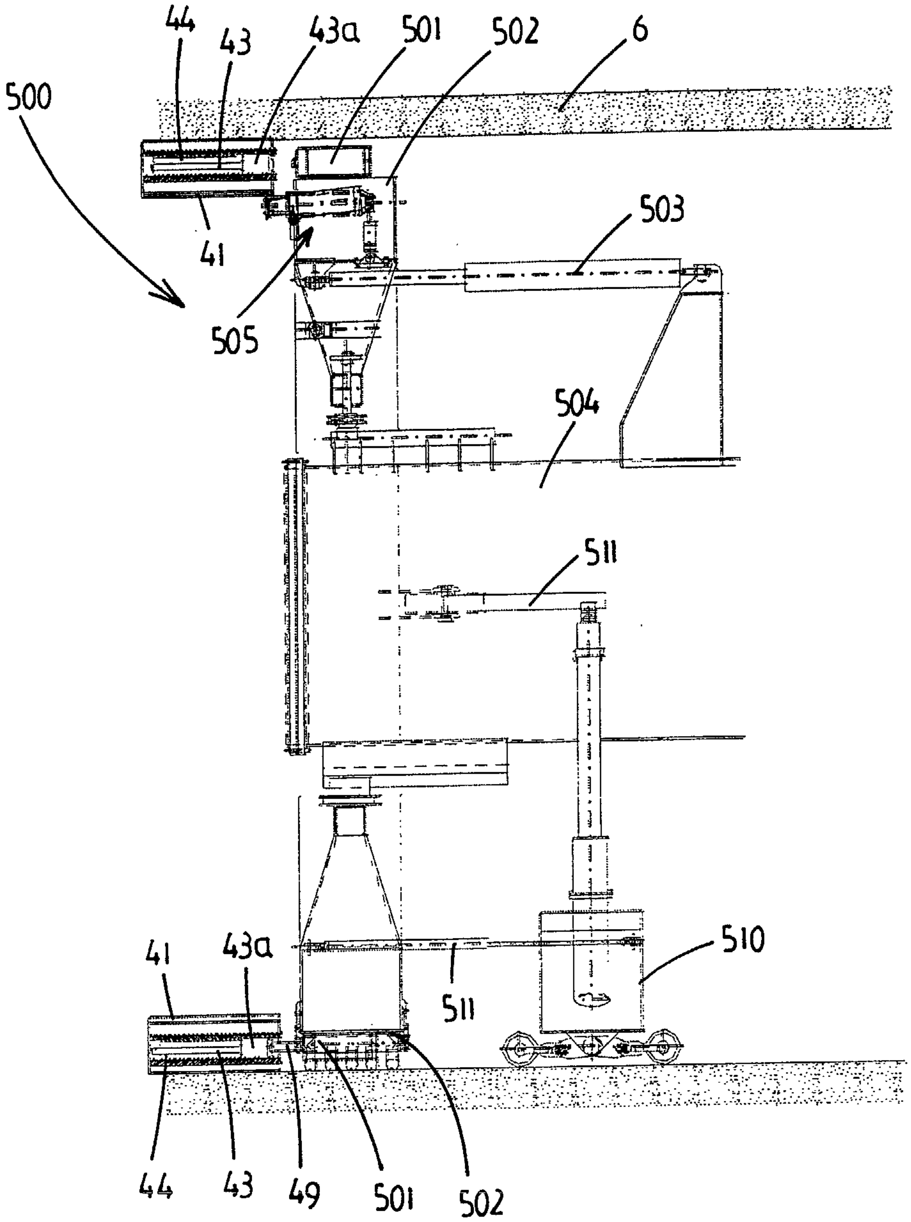

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Fig. 15