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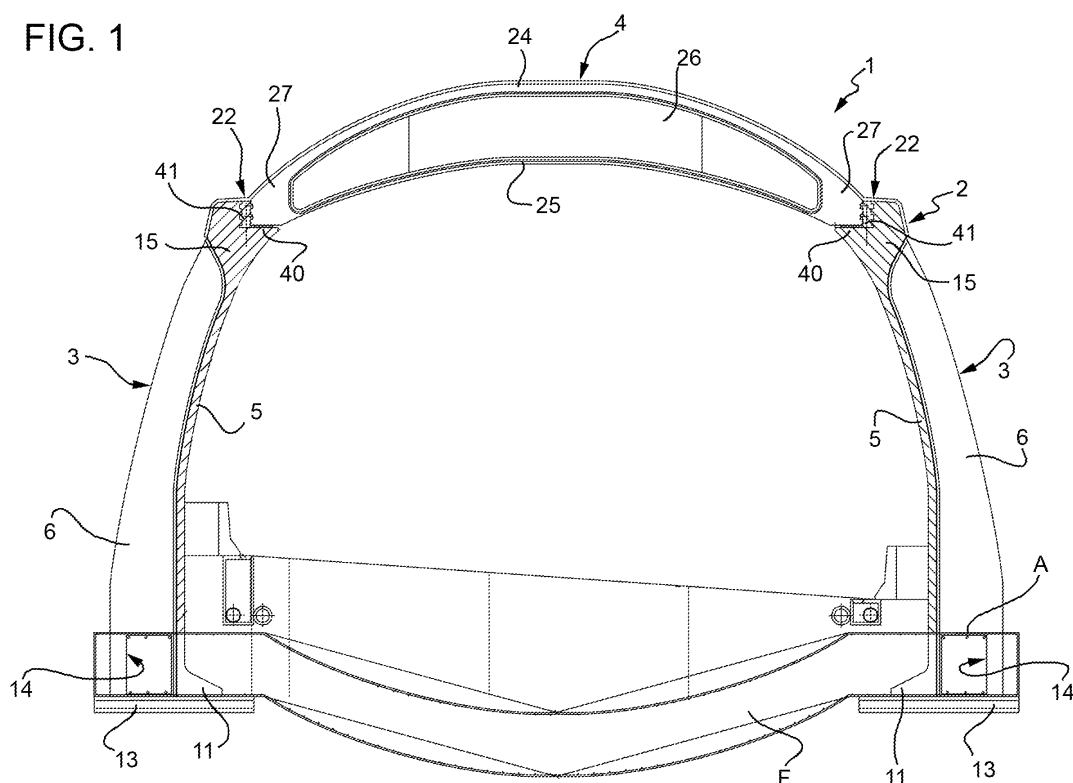
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(54) **Structural module for building prefabricated arch tunnels**

(57) A structural module for building prefabricated arch tunnels, the module having two shoulders (3), and an arched calotte (4) resting on the shoulders (3) and having an I-shaped cross section; the calotte (4) has a

curved top wall (24) and a curved bottom wall (25) connected integrally by a vertical central web (26), so as to define, in combination with a number of identical calottes (4) assembled to one another, a lightweight vault with smooth underside and topside surfaces.

FIG. 1



Description

[0001] The present invention relates to a structural module for building artificial prefabricated arch tunnels.

[0002] Artificial tunnels are often built using prefabricated modular structures defined by a succession of structural modules fitted axially to one another and each defining a cross section of the tunnel.

[0003] Artificial tunnels may be box-shaped, i.e. with a substantially rectangular cross section, or arch-shaped.

[0004] Box tunnel modules are normally in three segments: two uprights and a flat horizontal slab. Box solutions have the drawback of being limited in terms of load resistance of the slab, which is subjected to bending stress.

[0005] As for arch tunnels, two-segment modular solutions are known, but pose problems in terms of the enormous size of the segments, which substantially correspond to half the tunnel section, and are therefore difficult to transport and assemble. This is further compounded by the non-self-standing shape of the segments.

[0006] Three-segment modules normally comprise two curved shoulders; and a convex calotte that rests on the shoulders to form an arch structure.

[0007] A three-segment arch structure partly solves the problems posed by the size of the segments, but not the limitations in terms of the loads withstandable by the calotte.

[0008] High resistance to vertical loads, in fact, calls for an extremely thick calotte, with all the cost and weight drawbacks this entails.

[0009] Alternatively, the calotte may be ribbed, but this results in a non-smooth underside or topside surface of the tunnel, which poses problems as regards ventilation, lighting, protective lining and/or external waterproofing.

[0010] It is an object of the present invention to provide a structural module for building prefabricated arch tunnels, designed to eliminate the drawbacks of known solutions.

[0011] According to the present invention, there is provided a structural module as claimed in Claim 1.

[0012] Two preferred embodiments of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a cross section of a prefabricated tunnel built using a structural module in accordance with the present invention;

Figures 2, 3 and 4 show front, outer side and inner side views respectively of a shoulder of the Figure 1 structural module;

Figure 5 shows a view in perspective of a number of assembled shoulders and respective foundation reinforcing rods;

Figure 6 shows a front view of a calotte of the structural module according to the invention;

Figure 7 shows a plan view of the Figure 6 calotte;

Figures 8, 9 and 10 show cross sections along lines VIII-VIII, IX-IX and X-X in Figure 7;

Figure 11 shows a cross section of a prefabricated double-arch tunnel built using a structural module in accordance with the present invention;

Figures 12 and 13 show front and side views respectively of a central upright of the Figure 11 tunnel.

[0013] Number 1 in Figure 1 indicates a prefabricated artificial tunnel built from a number of identical arch-shaped structural modules 2, each defining a section of the tunnel.

[0014] Each module 2 substantially comprises two identical, curved lateral shoulders 3 spaced apart with their concavities facing; and an arched calotte 4 resting on shoulders 3.

[0015] Figures 2 to 4 show a shoulder 3 with a substantially T-shaped cross section. More specifically, shoulder 3 comprises a wall 5 which, in use, forms a portion of a lateral wall of the tunnel; and a vertical rib 6 extending along the longitudinal centreline of wall 5.

[0016] Wall 5 comprises a flat vertical bottom portion 7, and a curved top portion 8.

[0017] At its base, bottom portion 7 of wall 5 has two trapezoidal openings 10 spaced apart, and between which a foot 11 projects from portion 7 so that shoulder 3 is self-standing. That is, by virtue of foot 11 and rib 6, shoulder 3 has a cross-shaped base portion 12 enabling shoulder 3 to rest stably on a temporary flat base 13.

[0018] Close to its base, rib 6 also has an opening 14; and openings 10 and 14 serve to feed through the reinforcing rods A (Figure 5) and concrete of the foundation F (Figure 1) built once shoulders 3 are positioned.

[0019] Top portion 8 of wall 5 forms a top end 15, which is widened crosswise to form a substantially L-shaped seat 16 for supporting calotte 4. More specifically, seat 16 is bounded at the bottom by a flat horizontal surface 17, and laterally by a substantially vertical surface 18 with horizontal grooves 19.

[0020] Two or more vertical corrugated tubes 20 (Figure 2) are embedded, flush with surface 17, in top end 15 of shoulder 3, and define respective inner seats (not shown) for loosely housing pins 21.

[0021] Grooves 19 and pins 21 serve to form a node 22 for connection to calotte 4, as described in detail below.

[0022] Figures 6 to 10 show calotte 4, which is downwardly concave, and has a varying I-shaped cross section. More specifically, calotte 4 comprises a top wall 24; a bottom wall 25; and a vertical intermediate web 26 extending along the centrelines of, and connected integrally to, top and bottom walls 24 and 25.

[0023] Top wall 24 and bottom wall 25 are the maximum distance apart, which corresponds to the maximum height of web 26, at the transverse centreline of calotte 4, and converge at the lateral ends of calotte 4 to form respective bearing portions 27.

[0024] Each bearing portion 27 is bounded by a flat

bottom surface 28, and by a substantially vertical end surface 29 with horizontal grooves 30 similar to those in surface 18 of seat 16 of the corresponding shoulder 3.

[0025] Calotte 4 is made of reinforced concrete. The reinforcing rods (not shown inside the concrete) project from end surfaces 29 of calotte 4 to form, at each end, two closed U-shaped brackets 31 arranged side by side in the same horizontal plane.

[0026] Each bracket 31 defines an opening 32 large enough to loosely house a respective pin 21 projecting upwards from shoulder 3.

[0027] Top wall 24 has asymmetrically shaped opposite edges 33, 34, one of which has a longitudinal projection 35 flush with the outer surface, and the other of which has a recess 36 complementary in shape, so that edge 33 of one calotte 4 mates with edge 34 of an adjacent calotte to form a joint designed to permit and compensate for slight rotation between the calottes of curved tunnels.

[0028] Tunnel 1 is assembled as follows.

[0029] Shoulders 3 are first placed on temporary bases on either side of the dig. On each side, shoulders 3 are placed successively next to one another, so that walls 5 form a seamless lateral wall of tunnel 1 (Figure 5).

[0030] Next, the foundation reinforcing rods are inserted through openings 10 and 14 in the shoulders; and, once the reinforcement is completed, foundation F is poured to embed, as explained above, and make base portions 12 of shoulders 3 integral with one another (Figure 1).

[0031] Finally, a calotte 4 is assembled to each pair of shoulders 3, by placing bearing portions 27 on surfaces 17 of respective shoulders 3. A layer 40 of elastic material is conveniently inserted between each surface 17 and the respective surface 28 of the calotte.

[0032] The calotte is positioned so that pins 21 engage openings 32 in respective brackets 31. The slack between pins 21 and corrugated tubes 20, and between pins 21 and brackets 31 allows a certain amount of misalignment of the pins and, therefore, a certain amount of assembly tolerance. More specifically, thanks also to the connection between edges 33 and 34 of calottes 4, the calottes can be rotated (about a vertical axis) with respect to one another to form a curved tunnel.

[0033] When calotte 4 is assembled to a pair of shoulders 3, with pins 21 inserted inside brackets 31, the end surfaces 29 of calotte 4 face vertical surfaces 18 of seats 16; and node 22 connecting calotte 4 to each shoulder 3 is completed with a fill pour 41, which embeds pins 21 and brackets 31, and fills grooves 19 and 30 to form a monolithic structure and enhance the shear strength of node 22.

[0034] Once assembled, calottes 4 also form a seamless succession defining the vault of the tunnel, with smooth underside and topside surfaces, and a lightweight but highly strong structure thanks to the I-shaped cross section.

[0035] The smooth underside surface enables lining

materials to be applied easily, and provides for an optimum cross section of the tunnel in terms of ventilation and interior lighting.

[0036] The smooth topside surface enables waterproofing to be applied directly.

[0037] The Figure 11 embodiment shows a tunnel 45 with two arches 46, 47 in accordance with the present invention.

[0038] In this case, the basic structural module 48 has five segments : two shoulders 3, as described above, defining the opposite lateral walls of the two arches 46, 47 of the tunnel; a central upright 49 defining a centre wall separating the two arches; and two calottes 4, each resting on a respective shoulder 3 and on upright 49.

[0039] Upright 49 is shown in detail in Figures 12 and 13, and has a substantially I-shaped cross section defined by two parallel vertical walls 50, 51 connected by a web 52. At its base, upright 49 has two feet 53 projecting outwards from the centrelines of walls 50, 51, so that it is self-standing.

[0040] Upright 49 has a top end 54 forming, on opposite sides, two seats 55 identical to seats 16 of shoulders 3.

[0041] Tunnel 45 is assembled, and in particular the nodes are formed, in exactly the same way as tunnel 1, except for the use of central upright 49 and two calottes 4 instead of one.

[0042] Clearly, changes may be made to tunnels 1, 45 as described herein without, however, departing from the protective scope defined in the accompanying Claims.

Claims

1. A structural module (2; 48) for building artificial pre-fabricated arch tunnels (1; 45), the module comprising at least two shoulders (3), and at least one arched calotte (4) resting on said shoulders (3); and being **characterized in that** said calotte (4) has an I-shaped cross section, and comprises a curved top wall (24) and a curved bottom wall (25) connected integrally by a vertical central web (26), so as to define, in combination with a number of identical calottes assembled to one another, a lightweight vault with smooth underside and topside surfaces.
2. A module as claimed in Claim 1, **characterized in that** said top wall (24) and said bottom wall (25) converge at the ends of the calotte (4) to form bearing portions (27).
3. A module as claimed in Claim 2, **characterized in that** said bearing portions (27) are each bounded by a flat horizontal bottom wall (28) and a substantially vertical end surface (29).
4. A module as claimed in Claim 3, **characterized in that** said calotte (4) comprises reinforcing rods form-

ing respective brackets (31) projecting from the end surfaces (29) of said bearing portions (27).

5. A module as claimed in any one of the foregoing Claims, **characterized in that** each of said shoulders (3) has a base portion (12) designed to make it self-standing. 5
6. A module as claimed in Claim 5, **characterized in that** said base portion (12) of each of said shoulders (3) has at least one laterally projecting foot (11). 10
7. A module as claimed in Claim 5 or 6, **characterized in that** said base portion (12) of each of said shoulders (3) has at least one opening (10, 14) through which to insert foundation reinforcing rods (A). 15
8. A module as claimed in any one of the foregoing Claims, **characterized in that** said shoulders (3) each define, at a top end (15), a seat (16) for a respective bearing portion (27) of said calotte (4). 20
9. A module as claimed in Claim 8, **characterized in that** said seat (16) is bounded by a flat horizontal bottom surface (17), on which said bottom surface (28) of a respective bearing portion (27) of said calotte (4) rests, and by a substantially vertical lateral surface (18) facing said end surface (29) of said calotte (4). 25
10. A module as claimed in Claim 9, **characterized in that** said lateral surface (18) of said seat (16) and said end surface (29) of said calotte (4) have respective numbers of horizontal grooves (19; 30). 30
11. A module as claimed in Claim 9 or 10, **characterized by** comprising pins (21) extending vertically from the bottom surface (17) of said seat (16) and engaging respective said brackets (31) of said calotte (4). 35
12. A module as claimed in Claim 11, **characterized in that** said pins (21) are housed loosely inside tubes (20) incorporated in said shoulders (3). 40
13. A module as claimed in one of Claims 9 to 12, **characterized by** comprising a fill pour (41) between said end surface (29) of said bearing portion (27) and said lateral surface (18) of said seat (16). 45
14. A module as claimed in Claims 10 to 13, **characterized in that** said fill pour (41) embeds said pins (21) and said brackets (31), and fills said grooves (19; 30). 50
15. A module as claimed in any one of the foregoing Claims, **characterized in that** said top wall (24) of said calotte (4) has respective edges (33, 34) which are complementary in shape, so that one edge (33; 34) of one calotte (4) mates with a complementary 55

edge (34; 33) of the adjacent calotte (4).

16. A module as claimed in any one of the foregoing Claims, for building a prefabricated two-arch tunnel (45), and **characterized by** comprising two lateral shoulders (3); a centre upright (49); and two calottes (4), each resting on a respective said shoulder (3) and on said upright (49).

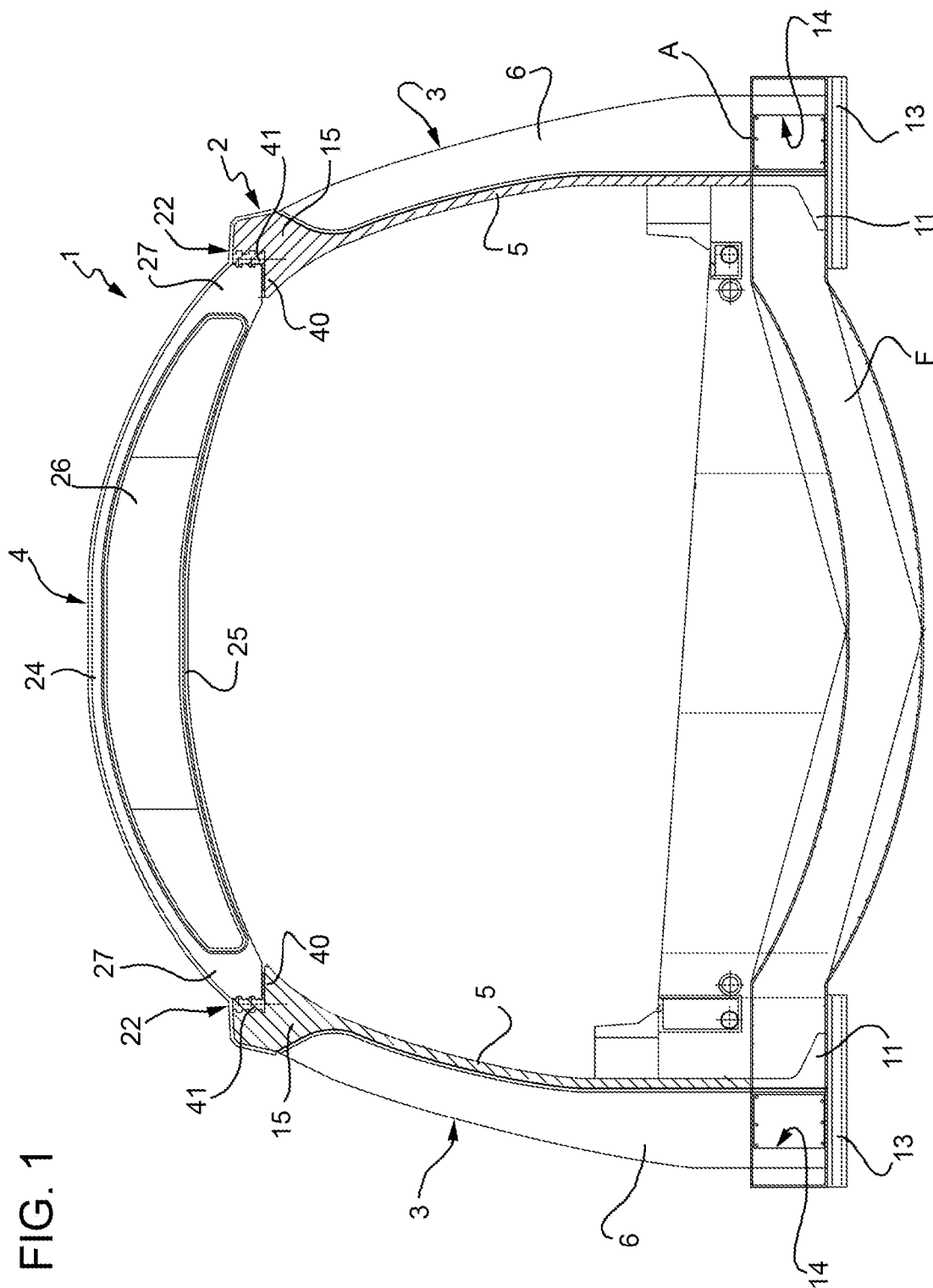
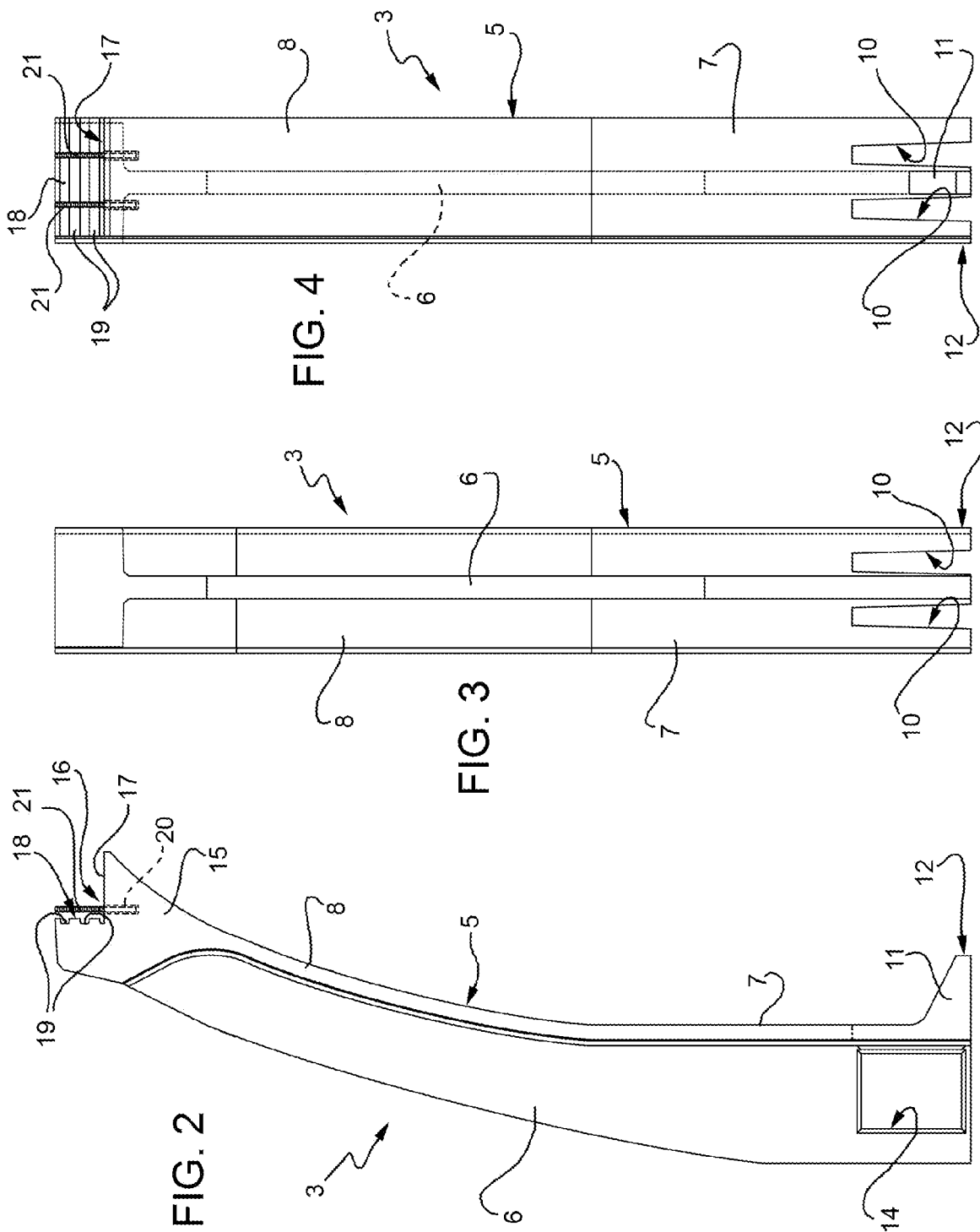


FIG. 1



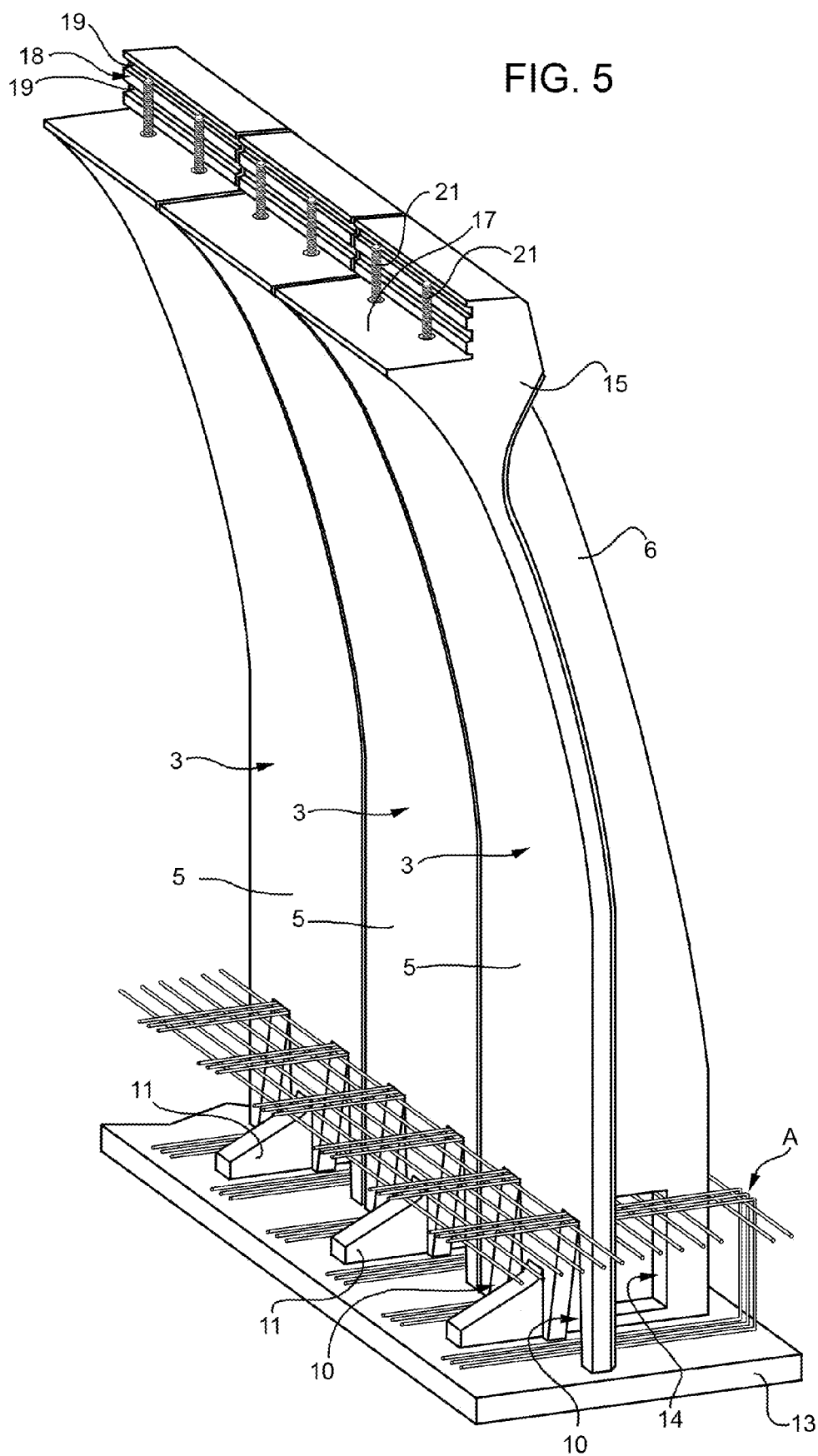


FIG. 6

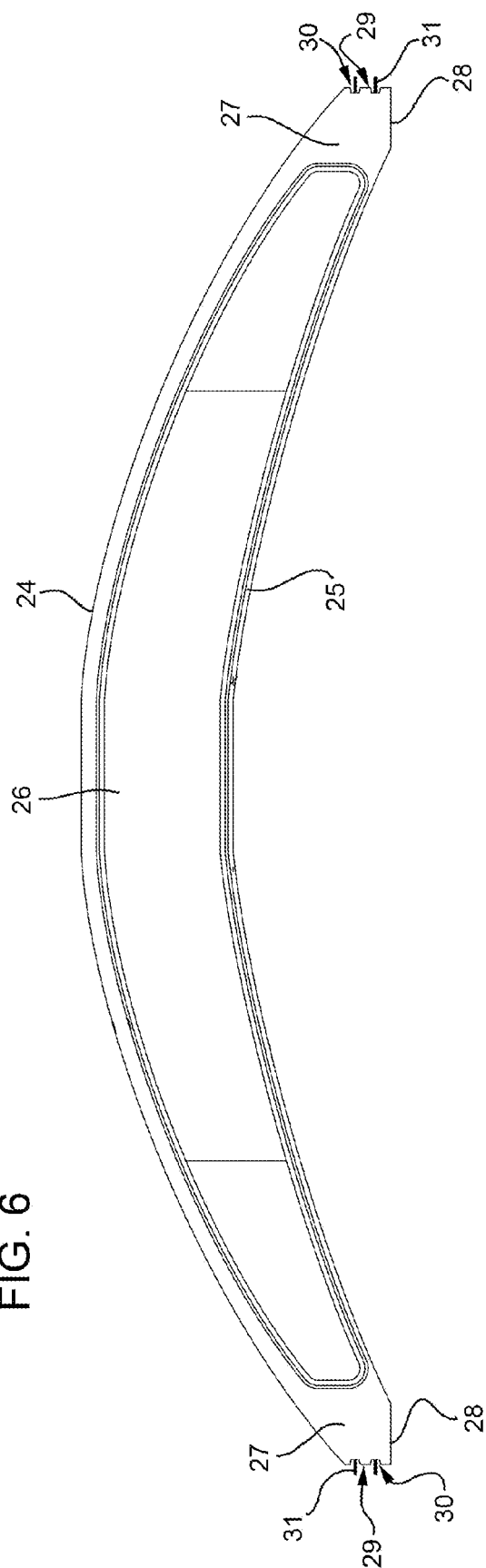


FIG. 7

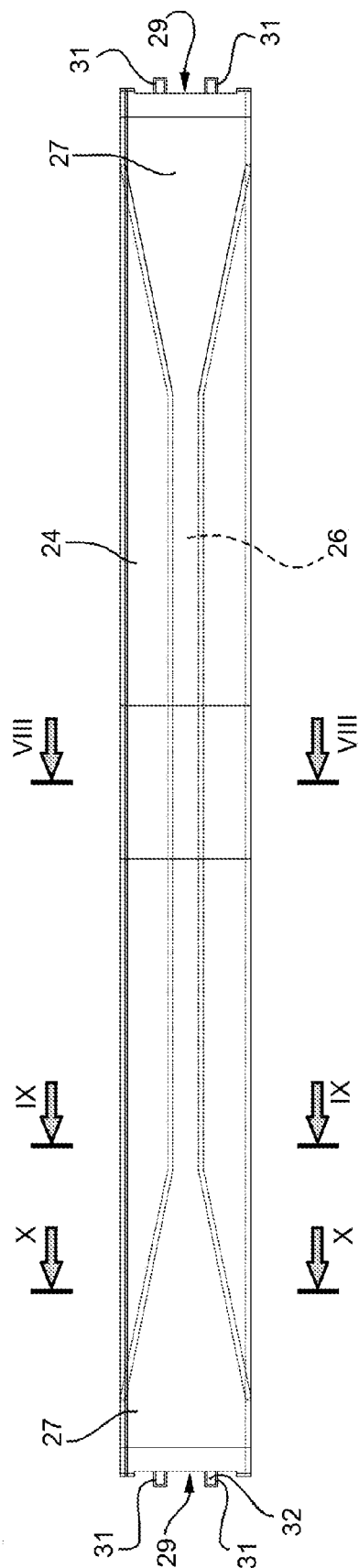


FIG. 8

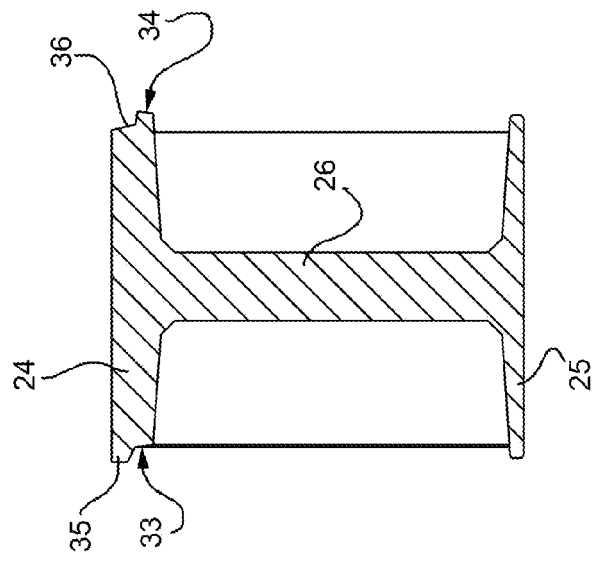


FIG. 9

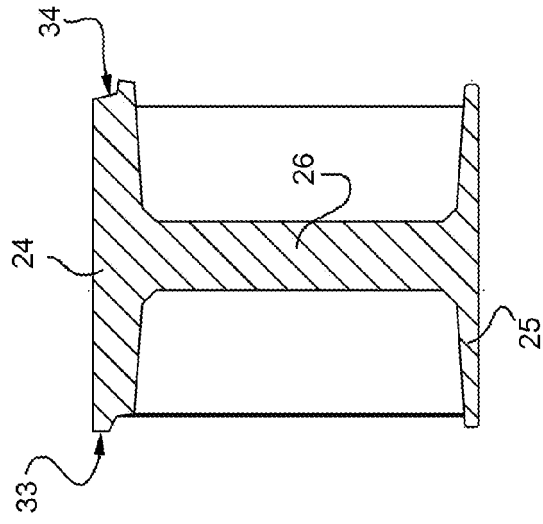


FIG. 10

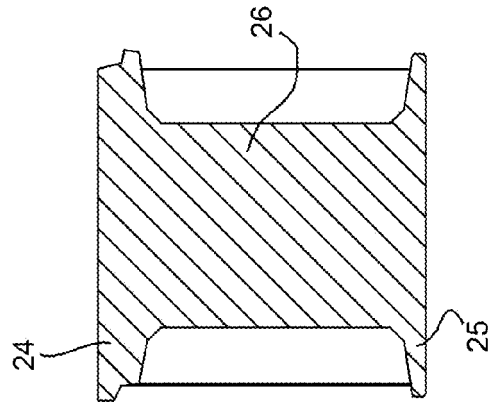
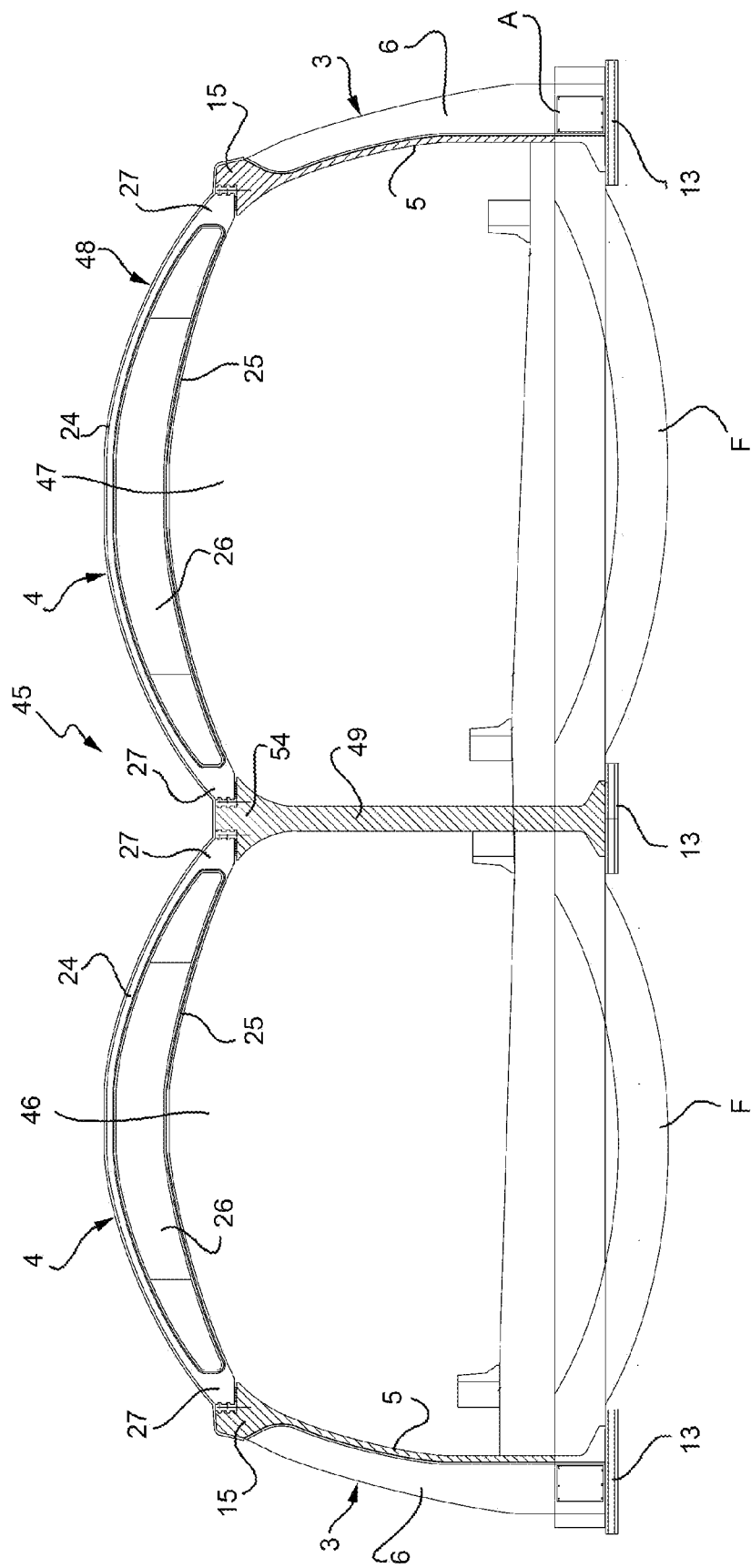


FIG. 11



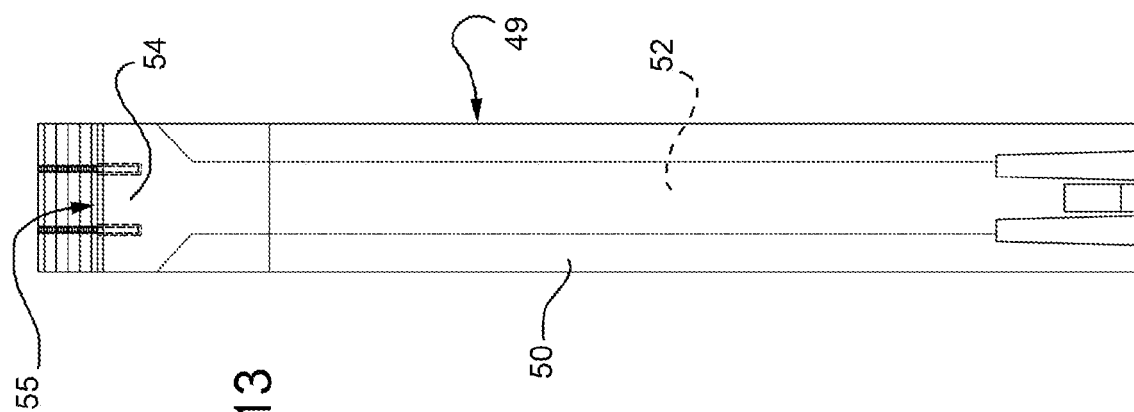


FIG. 13

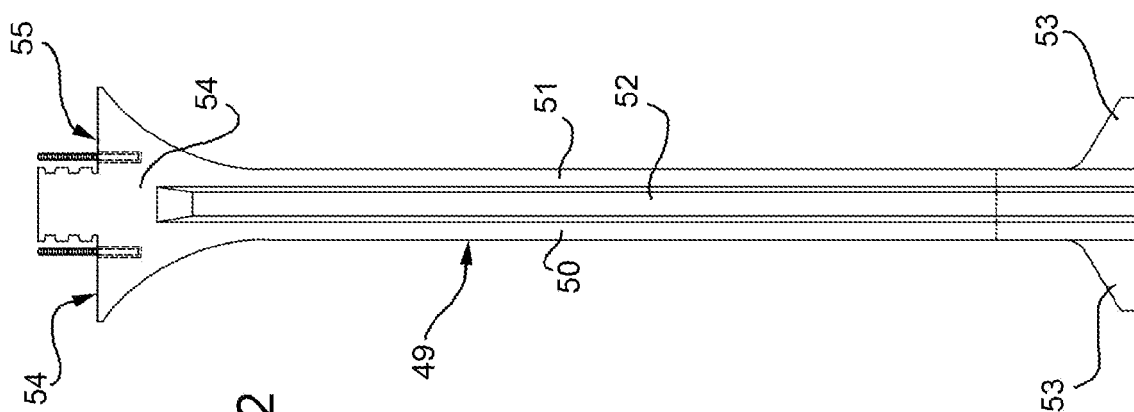


FIG. 12



EUROPEAN SEARCH REPORT

Application Number
EP 10 15 4408

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			TECHNICAL FIELDS SEARCHED (IPC)
			E21D E02D E04B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 May 2010	Examiner Ott, Stéphane
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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