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(71) Applicant *(for all designated States except US)*: **TURBOWINDS S.A.** [BE/BE]; Rue de Praetere, 14, B-1050 Brussels (BE).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **CROES, Valère** [BE/BE]; Mouveldstraat, 8, B-3850 Nieuwerkerkene (BE).

(74) Agents: **VANDEBERG, Marie-Paule** et al.; Avenue Wolfers, 32, B-1310 La Hulpe (BE).

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(54) **Title:** SEGMENT FOR A TOWER, TOWER CONSTRUCTED FROM TOWER SEGMENTS, ELEMENT FOR A SEGMENT FOR A TOWER, METHOD FOR THE PRE-ASSEMBLY OF SEGMENTS FOR A TOWER, METHOD FOR THE ASSEMBLY OF A TOWER CONTAINING SEGMENTS

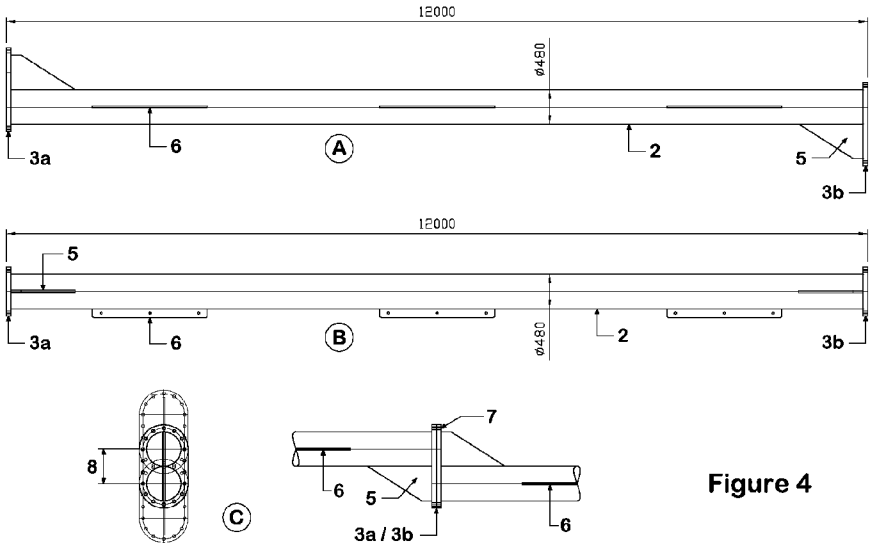


Figure 4

(57) **Abstract:** A segment for a tower containing a number of longitudinal corner elements (2), with protruding flanges (3a, 3b) at the bottom and top end, by which the flanges protrude in opposite directions, and the corner elements being interconnected by cross bars (4), the bottom flanges being located in a bottom plane (BOT), and the top flanges in a top plane (TOP), the flanges (3b) at the bottom side being directed outward, and the flanges at the top (3a) being directed inward.

WO 2008/152101 A1

Segment for a tower, tower constructed from tower segments, element for a segment for a tower, method for the pre-assembly of segments for a tower, method for the assembly of a tower containing segments.

The invention relates to a segment for a tower.
Additionally, the invention relates to an element for a segment for a tower.
Furthermore, the invention relates to a building package for a segment for a tower.
Additionally, the invention relates to a working method for the assembly of multiple segments for a tower.
The invention further relates to a method for the construction of a tower, containing segments.
The invention further relates to a tower constructed from tower segments.

Towers containing segments are, amongst other applications, used for wind turbine constructions.
Known and so called tubular towers are constructed from a number, usually made from steel or concrete, tower elements in tubular form.
Each element is a tubular segment, of which the section reduces towards the tower top.
Each of these tubular segments is manufactured separately.
At the building site, the separate tubular tower sections are mounted on top of each other.
The major disadvantage of this construction method is that these tower elements are very large and heavy, requiring also very heavy handling equipment to manufacture, transport and mount the tower segments.

For many locations, it is very difficult or even impossible because, for instance, the roads towards the construction site are not adapted for this heavy equipment, or the terrain cannot support the heavy equipment, or due to lack of sufficient space for the equipment that is required to mount the tower parts.

Additionally, in many countries the required heavy handling equipment is not available, or rare and expensive.

Even if the equipment is readily available, the transportation of the tubular tower sections requires oversized transportation convoys, with related consequences such as temporary road and highway blocks.

Therefore, for many applications, this conventional tubular tower is not or less desirable.

It is a major aim of the current invention to provide an economically attractive tower segment, to at least reduce or avoid the described disadvantages of the conventional technology.

For that purpose, a segment of the tower is characterized by a number of longitudinal corner elements, with flanges at both ends extending in planes transverse to the longitudinal direction and protruding sideways in opposite directions, the corner elements being mutually connected by cross bars, the flanges at the bottom being situated in a bottom plane transverse to the longitudinal direction, and the top flanges being situated in a top plane transverse to the longitudinal direction, the bottom flanges being orientated outward, and the top flanges inward.

The corner elements constitute the ribs of each tower segment, the flanges at the top providing a connection point for the next tower segment that is mounted on top.

This construction method allows a stepwise reduction of the segment section, while in principle the same basic elements (corner elements and cross connection plates) can be reused. The concept allows a tower construction that requires much less and lighter production and handling equipment.

On locations where conventional tubular towers would be difficult, or impossible to install, the tower concept, according to the current invention, could be installed.

It has to be recognized that towers, made from a collection of different bars and beams, are a known technology. Known examples are tower for electric high voltage overhead lines (so called classic lattice towers).

Such lattice towers however, are constructed out of a very large number of members. Both the manufacturing and assembly of such lattice towers is very labor intensive, and requires technically skilled personnel. Furthermore, the amount of bolted connections, to be made on site, is extensive and also depending on the tower size (base section size and tower height).

The assembly of such towers requires skilled and experienced technicians, and is therefore costly, especially in countries where the expertise is not available, and the required specialists have to be provided from abroad.

Prior art elements have been provided with flanges at opposite ends of longitudinal members to connect elements to each other, as for instance known from US patent nr. 4187034 and US patent nr. 5687537. Said document disclose elements with flanges at both ends. The shape and form of the flanges is such that when connected to each the longitudinal axes of the elements coincide, i.e. the two elements extend along a single line. The sideways protrusion to opposite sides of the

flange in the present invention allows a sideways shift between two elements.

The tower segments, according to the invention, allow much easier working methods and a higher degree of automation, in a sense of reducing the required number of basic operations.

The segments for a tower, according to the current invention, require much less different elements, and therefore easier assembly methods, on site, or partially pre-assembled in the factory.
Additionally, the concept allows the composition of building packages, suitable for tower segments of different base section, while the length of each segment can and preferably should be the same (for instance 12 m standard length for commercial steel tubing).
A large amount of simplification in the assembly process of the tower segments, as well as automation of the handling is made possible this way. The required knowledge, as well as the required training, of the personnel doing the assembly of such tower segments, is greatly reduced.
Preferably the corner elements are symmetric in profile. Even more preferable, these profiles are cylindrical tubes, equipped with flanges at both sites, the flanges sideways protruding by a distance larger than the diameter of the corner profile.
The next tower segment can then be mounted on top and connected to the flanges of the tower segment below, which simplifies the stacking of the subsequent tower segments.
The essence of the eccentrically placed flanges, is situated in the fact that, this way, a gradual decrease in base

section is obtained, while the number and section of the corner elements remains the same, and only the dimension of the cross connection plates has to be adapted.

This provides an elegant and simple way to adapt the resistance of the tower structure to the decreasing loading in function of height.

This way it is possible to maintain the same stress level, regardless of the tower segment in which the tube is incorporated.

Preferably, the end flanges are equipped with reinforcement stiffeners. These stiffeners reinforce the support capacity of the flanges.

Preferably, the flanges are perpendicular to the longitudinal axis of the corner elements.

Although, in the most general sense of the invention, this flange can have an angle other than 90°, the angle is preferably perpendicular.

When the angle is not perpendicular, the tower segments become tapered, and therefore less attractive with regard to simplicity.

The highest level of simplicity, with regard to construction and assembly is obtained when the flanges are attached to the corner elements, at a straight angle.

In the proposed design, each tower segment has 4 corner elements. This number is preferable from a structural point of view, however, the concept remains equally valid for a different quantity (3, 5, 6, …).

The element for a segment, according to the invention, is characterized by having flanges at both ends that are protruding sideways in opposite directions and in planes

transverse to the longitudinal direction. Preferably, the elements are equipped with reinforcement stiffeners at the flanges.

The construction package, for a segment for a tower, contains a number of longitudinal corner elements, having protruding flanges at the top and bottom end, the flanges being orientated in opposite directions, and cross connection plates for the mutual connection of the corner elements.

The cross bars are present for the lateral connection between the corner elements.

The method for the assembly of tower segments, according to the invention, is characterized by separate tower segments being pre-assembled in vertical position and segments of different base section that are assembled into each other.

The possibility to pre-assemble segments into each other offers considerable advantages with regard to space savings on site and manipulation cost.

A considerable advantage of the invention is the large amount of automation that can be achieved in the fabrication and assembly processes, as a consequence of the concept.

A tower segment can be assembled, and the next larger segment (with larger base section) around the first one, and again the next larger segment around the second one, and so on.

In order to fit into each other, and to be easily retrievable afterwards, odd and even numbered tower segments can be pre-assembled in two separate stacks.

Odd en even numbered tower segments, with different base sections, fit into each other.

Next, the largest tower segment is mounted on the foundation, followed by subsequent smaller tower segments.

The invention makes it possible to mount towers at locations with limited available space.

These and other aspects of the invention are described and demonstrated in the following drawings.

In the drawings is illustrated:

Figure 1: A known tower concept for wind turbines, containing conventional cylindrical tube elements.

Figure 2: A known classic lattice tower concept for wind turbines.

Figure 2A and 2B: known elements for towers.

Figure 3: A tower concept, with segments, according to the invention.

Figure 4: A corner element, for a segment, for a tower, according to the invention.

Figure 5: A construction kit, for a segment, for a tower.

Figure 6: The assembly of a tower segment.

Figure 7: The assembly of different tower segments.

Figures 8, 9 and 10: The stacking of subsequent tower segments.

Figure 11: A segment, in top view, according to the invention.

Figures 12 and 13: Assembly of a tower, according to the invention.

The figures are not always drawn to scale, and similar elements are in principle referred to with similar identification numbers.

Dimensions, indicated on the figures, are given by means of example, and should not be considered as constraints, unless explicitly specified otherwise.

Figure 1 shows, in front, side and top view, a wind turbine with, in this example, a tower made of three conventional tubular segments. Some dimensions are specified in this figure, as not limitative example.

Such segmented tower concepts for wind turbines are manufactured as follows:

The tubular tower segments are fabricated in the factory.

Each of these tubular tower segments is transported to the building site, by means of special over size transportation convoy, because of the large size of these elements.

On site, the segments are mounted on top of each other. Next, the nacelle of the wind turbine is mounted on the tower top, and finally the blades are mounted on the rotor hub.

A major disadvantage of this construction method is that the elements of the tower are considerably large and heavy, requiring very heavy equipment to fabricate, transport and assemble these elements.

For many locations, this is not possible because, for instance, the roads leading to the building site are not adapted to the requirements to transport these elements, or the soil bearing capacity being insufficient to carry the equipment and the load, or due to lack of free space at the building location.

In many countries, the required handling and transportation equipment is not present, or not readily available and expensive.

Figure 2 illustrates a tower, for a wind turbine, made of a large number of interconnected elements (classic lattice construction). This construction has the disadvantage that the assembly is very complex, due the large amount of elements, and requires specialized personnel.
Hundreds of bolted connections have to be made on site.

Figure 2A illustrates a known construction of elements, disclosed in United States Patent nr. 4187034.
The elements are provided with flanges at both ends, the flanges do not protrude sideways, but along the longitudinal direction of the elements. When the flanges are interconnected the two elements extend along the same line.
Figure 2B illustrates another known construction of longitudinal elements.
In this construction flanges are provides at both ends. Although the flanges extend in planes transverse to the longitudinal direction, they do not protrude sideways in opposite directions. Both flanges form a circle with the centre point coinciding with the longitudinal axis of the elements. When the flanges are interconnected, the longitudinal axes of the two elements coincide. The two elements also have different ends.
Figure 3 illustrates a tower according to the invention. The tower is constructed from segments (1).
The segments contain a number of corner elements (2), in this example four corner elements (2).
The corner elements (2) are foreseen of flanges (3a) and (3b) at, respectively, the top and bottom end.
The cross bars (4) provide interconnections between the corner elements.

Figure 4 shows a corner element (2). View (A) is a side view, view (B) a front view, and view (C) a top view and side view, in which is shown how two flanges are connected together, in this example by means of bolts (7).

Dimensions, indicated on the figures, are given by means of example, and should not be considered as constraints, unless explicitly specified otherwise.

However, the specified dimensions can be considered to be realistic approximations, corresponding with the order of magnitude of the construction.

In this example, the length of the corner elements is 12 meter, which is a practical, commercially available size, and an ideal size for transportation in 40 feet sea containers.

Preferably, the length of the corner elements is situated between 6 and 16 meter.

Longer corner elements are, due to their length and weight, difficult to handle and transport, while for shorter elements, the required number of tower segments, for a tower with conventional height, becomes so large that the assembly becomes more labor intensive, such that the advantage of the invention becomes less obvious.

The corner element (2) contains flanges (3a) and (3b), protruding sideways in opposite directions.

Additionally, the corner element is equipped with stiffeners (5). The stiffeners (5) support and reinforce the flanges.

View (C) demonstrates how the flanges of subsequent corner elements are interconnected and how two corner elements are stacked on top of each other, with an axial offset, which is schematically shown in the figure, by means of the arrow (8).

As can be seen by comparison with figures 2A and 2B, wherein

the elements are axially aligned, such an axial offset is not possible with the known constructions.

In this example, the corner element is a cylindrical tube, between the flanges (3a) and (3b).

This is a preferred construction form. However, the section between the flanges can possibly have an alternative section, like a square, T, H or other beam section.

Preferably, the selected beam should have symmetric strength properties, relative to the major reference axes (X and Y).

A round tube is most preferable, because for such a tube, the symmetry is omni-directional, resulting in an ideal strength/weight ratio.

Figure 5 illustrates how the tower elements can be stacked in a conventional 40 feet sea container.

A number of corner tube elements (2) fit exactly inside the container. The cross connection plates (4) fit in the remaining free space.

A standard 40 feet container is the preferred transportation method; however, the advantages of the concept remain equally valid for other transportation methods, such as flat bed trucks or transport frames.

The tower construction kit can be assembled easily and loaded onto conventional trucks or inside standard 40 feet sea containers and transported to the building site.

The size and shape of the tower elements allow optimal exploitation of standard container space.

Figure 6 illustrates the typical assembly method of a tower segment MOD, in this case the bottom tower segment.

The construction kit, inside a container (CT) is delivered, on site, by means of a conventional truck.
The corner elements (2) are mounted in vertical position and mutually connected by means of the cross connection plates (4).
The distance between the corner elements is determined by the size of the cross connection plates.
The flanges (3b) are situated in the bottom plane (BOT) and directed outward, while the flanges (3a) are situated in the top plane (TOP) and directed inward.

Figure 7 illustrates the assembly of different subsequent segments, MOD 1, MOD 2, MOD 3 and MOD 4.
The assembly of the different segments is easy and straightforward, and in principle, the same for all segments and the number of elements and required handling operations is relatively limited.
Figure 8 demonstrates the stacking method of different tower segments. Tower segment MOD 2 is lifted by means of a crane. The flanges (3b) of the segment MOD 2 are connected to the flanges (3a) of the segment MOD 1.
Next, the tower segment MOD 3 is mounted onto the previous segment MOD 2, in a similar way.

This is illustrated in **figure 9**. Next, segment MOD 4 is mounted onto segment MOD 3, which is illustrated in **figure 10**.

Figure 11 shows a tower segment, according to the invention, in top view. In this example, the segment is equipped with grid floors (9). These grid floors enable technicians access,

to perform maintenance, connect flanges or carry out safety inspections.

Figure 11 also illustrates the natural reduction of the base section for the subsequent tower segments, due to the stepwise lateral offset, caused by the inward protrusion of the flanges (3a, 3b).

As a consequence of this stepwise reduction, the structural resistance of the subsequent tower sections runs parallel with the reducing tower load in function of the height.

Consequently, this results in quasi constant loading of the corner elements, independent of the tower segment in which they are incorporated. Due to the quasi constant stress level, the position of the corner elements in the tower is less relevant, and consequently the same type of tube (same diameter and wall thickness) can be applied, resulting in a fabrication process that can be extensively automated (i.e. application of manipulation and welding robots).

This aspect is a major advantage of the invention, compared to the described conventional tower concepts.

Due to the natural reduction in tower section, a quasi constant loading on the cross connection plates can also be achieved, independent of the tower segment in which they are incorporated.

The cross plate section, and the bolt connections (6) with the corner elements, can consequently be unified.

Only the planar section of the cross connection plates needs to be adapted to the corresponding tower segment in which they will be incorporated.

For the corner elements, a number of predefined and preferred connection points (6) can eventually be provided. In preferable execution forms, and to establish further or

complete standardization of the corner elements, a number of extra connection points can be provided, although they not necessarily need to be used in the different tower segments.

The invention is not restricted to the given examples, but allows many variations. The shown example is a tower for a 1.8 MW wind turbine, but the concept can be applied to both smaller and larger wind turbines as well.

Examples of possible alternatives are listed below:

- In the shown example, the flanges are perpendicular to the longitudinal axis of the corner elements.

  However, this angle not necessarily needs to be exactly 90 degrees. Some degree of inclination (i.e. 2-5 degrees) can be considered as well, resulting in a corresponding taper angle for the tower segment (reduction of the tower segment section with increasing height).

  However, such inclination will require a more complicated production technique.

  In the preferred production method, the flanges will be welded onto the tube ends, by means of full automatic, submerged, robot welding equipment. This welding method requires that the torch is located in a stationary position, on top of the tube, for the deposition of the inert powder deck, and the deposition of the weld, while the tube is revolving, with controlled speed, by means of a rotating manipulator.

  For perpendicular flanges, this procedure is relatively simple, but more difficult for inclined flanges, although not impossible.

• In the shown methods, the subsequent tower segments are stacked onto each other, one by one.
However, a two by two stacking method, or other, is equally possible as well.

• In the shown example, the bottom tower segment is mounted on a pile foundation that makes use of the same tube elements as the tower construction. However, the tower concept is equally valid for mounting on a conventional concrete slab foundation, or other type of foundation with a top plane situated at some elevation above ground level.

• In the shown examples, the tower supports a wind turbine. However, the tower concept is equally valid for other applications such as, electrical overhead lines, ski lifts, transmission poles, telephone lines, etc ….

• In **figure 7**, a method is shown where some tower segments are pre-assembled next to each other.
However, the method also allows the pre-assembly of smaller inside larger tower segments, for example segment MOD 4 inside segment MOD 2.
Segments with different base section can be pre-assembled inside each other, to save space.
In practice, it is logic to first assemble segment MOD 4, and next MOD 2 around it.
A tower of, for instance, 84 meter height, containing 7 tower segments, can be assembled as follows:
The bottom segment MOD 1 direct on the foundation, and the remaining odd and even numbered segments inside each other,

preferably on the left and right hand side of the foundation (MOD 1) to minimize the crane distance.
The possibility to pre-assemble tower segments around previous segments further provides the possibility to use them as work platforms for next tower segments.
The ladders and platforms of previously assembled tower segments can be beneficially used by the assembly crew to mount larger tower segments around previous tower segments.

For the pre-assembly of tower segments, the use of a relatively small crane is sufficient.
Only for the final assembly of the tower, and for example a wind turbine, a larger crane is required.
The final tower assembly is done by mounting the subsequent tower segments MOD 2 through MOD 7 in the proper order onto the base segment MOD 1.
An advantage of the invention is that the odd end even numbered tower segments can be pre-assembled in the close vicinity of the tower foundation. This is especially convenient for building locations with limited free space.
A heavy crane is only required during a brief period of time, and the required action radius is limited, due to the compact pre-assembly space that is required.

Figures 12 and 13 illustrate the intended working method for the construction of a tower, and the intended execution form, according to the invention.
Odd (MOD 3, MOD 5, MOD 7) and even (MOD 2, MOD 4, MOD 6) tower segments, having different base sections, but equal length and similar construction principles, are being pre-

assembled in vertical position, where odd and even numbered segments are stacked into each other.
For the pre-assembly of these tower segments, a small size crane is sufficient (CR).
Due to their similarity, the pre-assembly process of the tower segments can be automated to a large degree.

Figure 12 illustrates how the building kits are being delivered on site, for instance in 40 feet sea containers (CT) by means of trucks (TR).
The bottom tower segment MOD 1 is mounted or assembled on the foundation (FN).
Next, the odd and even numbered tower segments are pre-assembled inside each other, next to the foundation.

Figure 13 shows the result. After all, or at least the majority, of the tower segments are pre-assembled, a large crane is used to stack the tower segments onto each other, in the proper order (see Figure 10 for example).
The time that a high and heavy, and thus costly, crane is required, is considerably less compared to the assembly of classic lattice towers.
Otherwise, the masses to be handled, compared to the classic tubular tower, are also less, also resulting in less lifting capacity requirements.

Claims:

1. Segment for a tower, wherein the segment contains a number of longitudinal corner elements (2), and protruding flanges (3a, 3b) at the bottom and top end extending in planes transverse to the longitudinal direction, the flanges protruding sideways in opposite directions, and the corner elements being interconnected by cross bars (4) , the bottom flanges being located in a bottom plane (BOT) transverse to the longitudinal direction, and the top flanges in a top plane (TOP) transverse to the longitudinal direction, the flanges (3b) at the bottom side being directed outward, and the flanges at the top (3a) being directed inward.
2. Segment, according to claim 1, wherein the longitudinal corner element contains cylindrical tubes, with flanges at both ends, the flanges protruding sideways by a distance larger than the tube diameter.
3. Segment, according to claims 1 or 2, wherein the segment contains 3, 4, 5 or 6 corner elements.
4. Segment, according to claims 1, 2 or 3, wherein the flanges are attached to the tube element in a position perpendicular, or nearly perpendicular, to the longitudinal tube axis.
5. Segment, according to one of the previous claims, wherein the corner elements are equipped with stiffener plates between the tube and the flanges.
6. Corner element, for a segment according to one of the previous claims, the corner element being equipped with flanges at the top and bottom end (3a, 3b) extending in

planes transverse to the longitudinal direction, the flanges protruding sideways in opposite directions.

7. Corner element, according to claim 6, wherein the flanges are attached to the tube element in a position perpendicular, or nearly perpendicular, to the longitudinal tube axis.

8. Corner element, according to claim 6 or 7, wherein the corner element is equipped with stiffener plates (5) for the flanges.

9. Construction kit for a segment for a tower, wherein the construction kit contains a number of longitudinal corner elements , and protruding flanges at the bottom and top end extending in planes transverse to the longitudinal direction, the flanges protruding sideways in opposite directions, and the construction kit contains cross bars for the interconnection of the corner elements.

10. Construction kit, according to claim 9, wherein the kit elements (corner elements and cross connection plates) are packed and transported in a container.

11. Construction kit, according to claim 10, wherein the container is a standard 40 feet sea container or equivalent transport frame or flat bed trailer.

12. Tower, containing at least two tower segments, as claimed in one of the claims 1 to 5, interconnected by the segment flanges.

13. Method for pre-assembling and mounting a number of tower segments, as claimed in one of the claims 1 to 5, wherein a number of segments with different base section are pre-assembled into each other.

14. Method for the assembly of a tower, containing a number of tower segments, as claimed in one of the claims 1 to 5, wherein a number of segments with different base section are pre-assembled into each other, and the pre-assembled tower segments are being mounted on top of each other, and interconnected by the flanges.

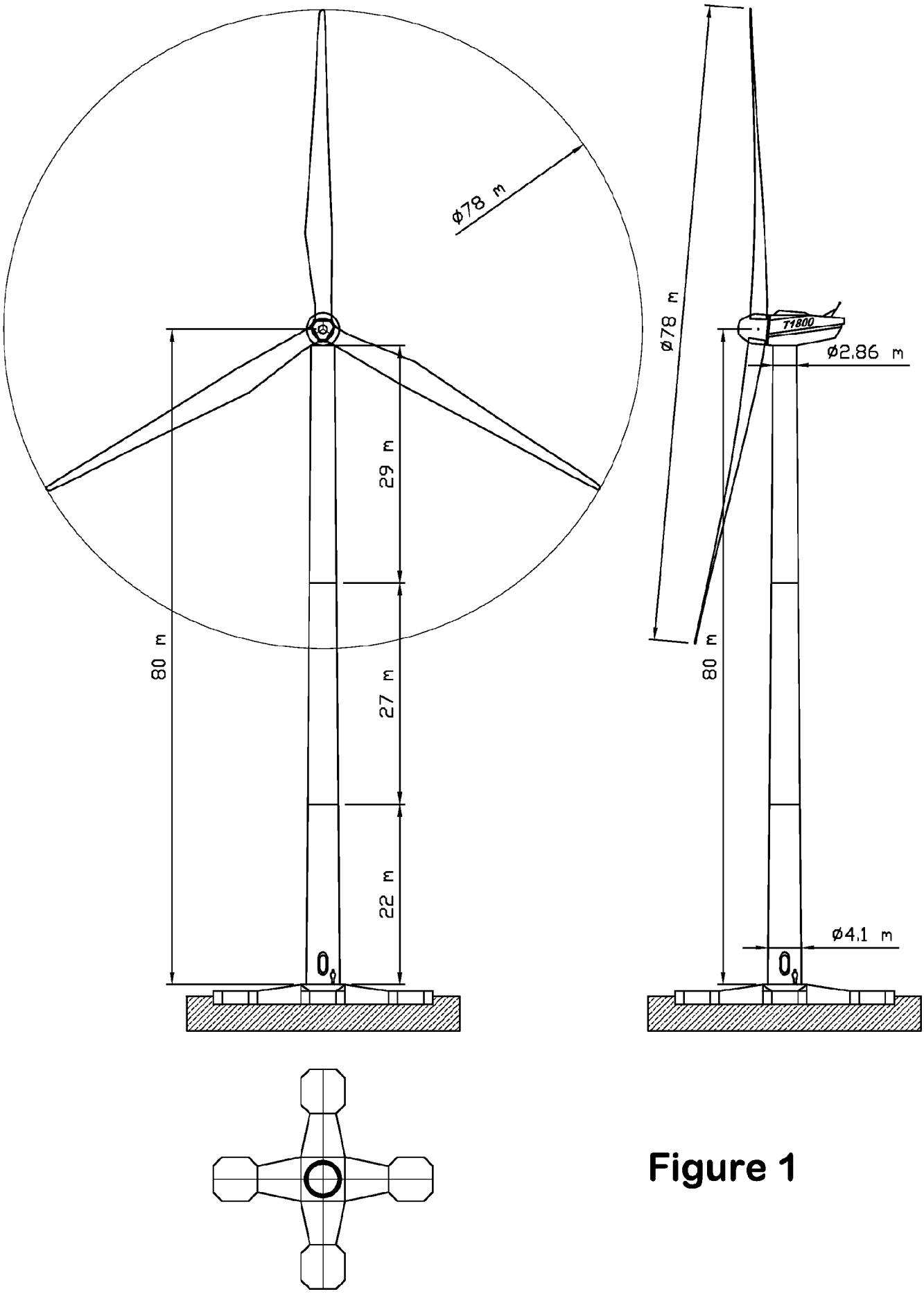


Figure 1

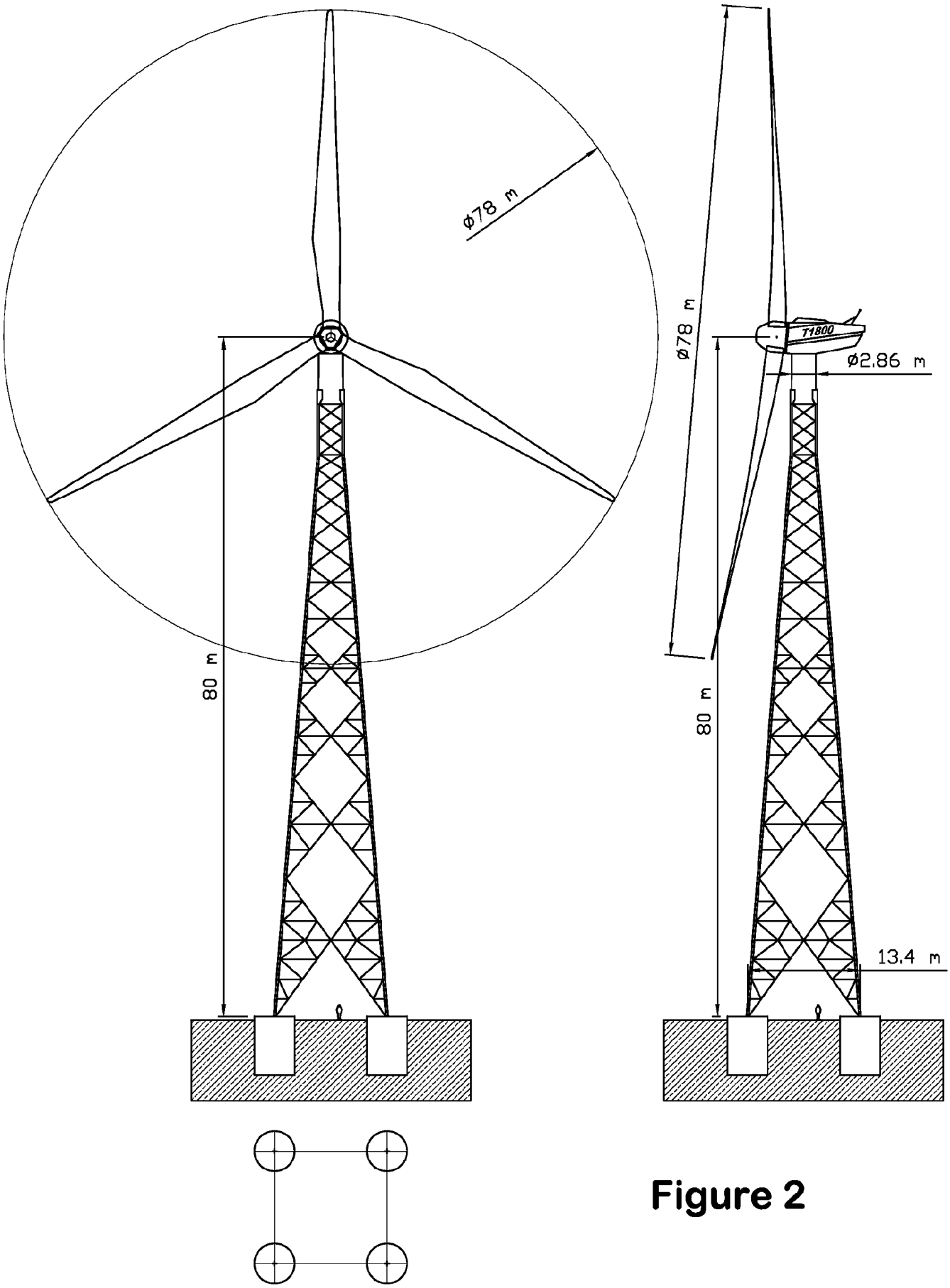


Figure 2

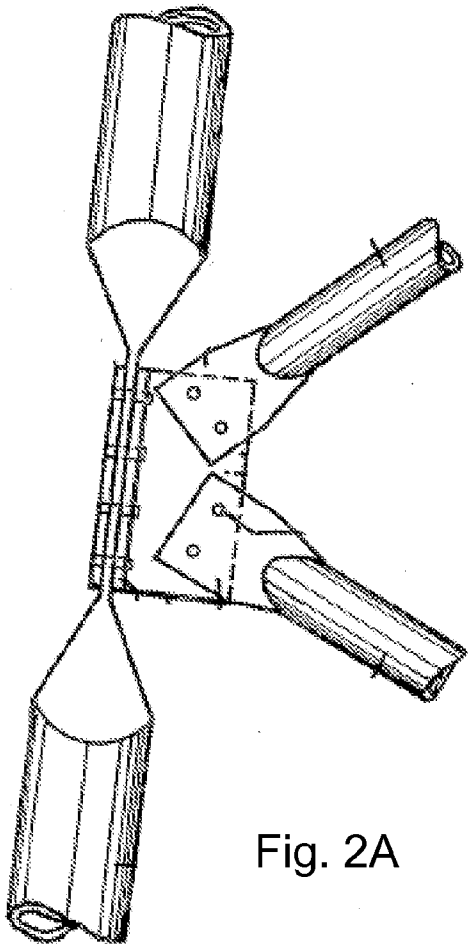


Fig. 2A

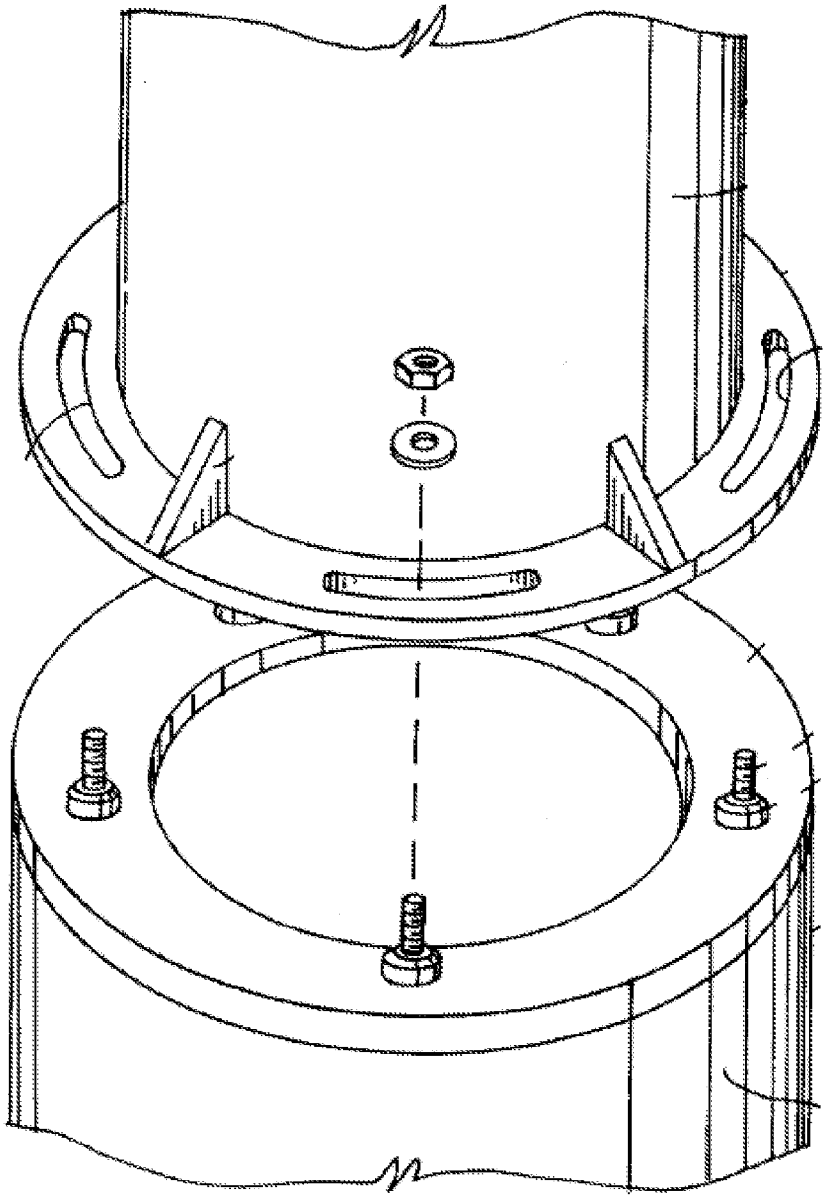


Fig. 2B

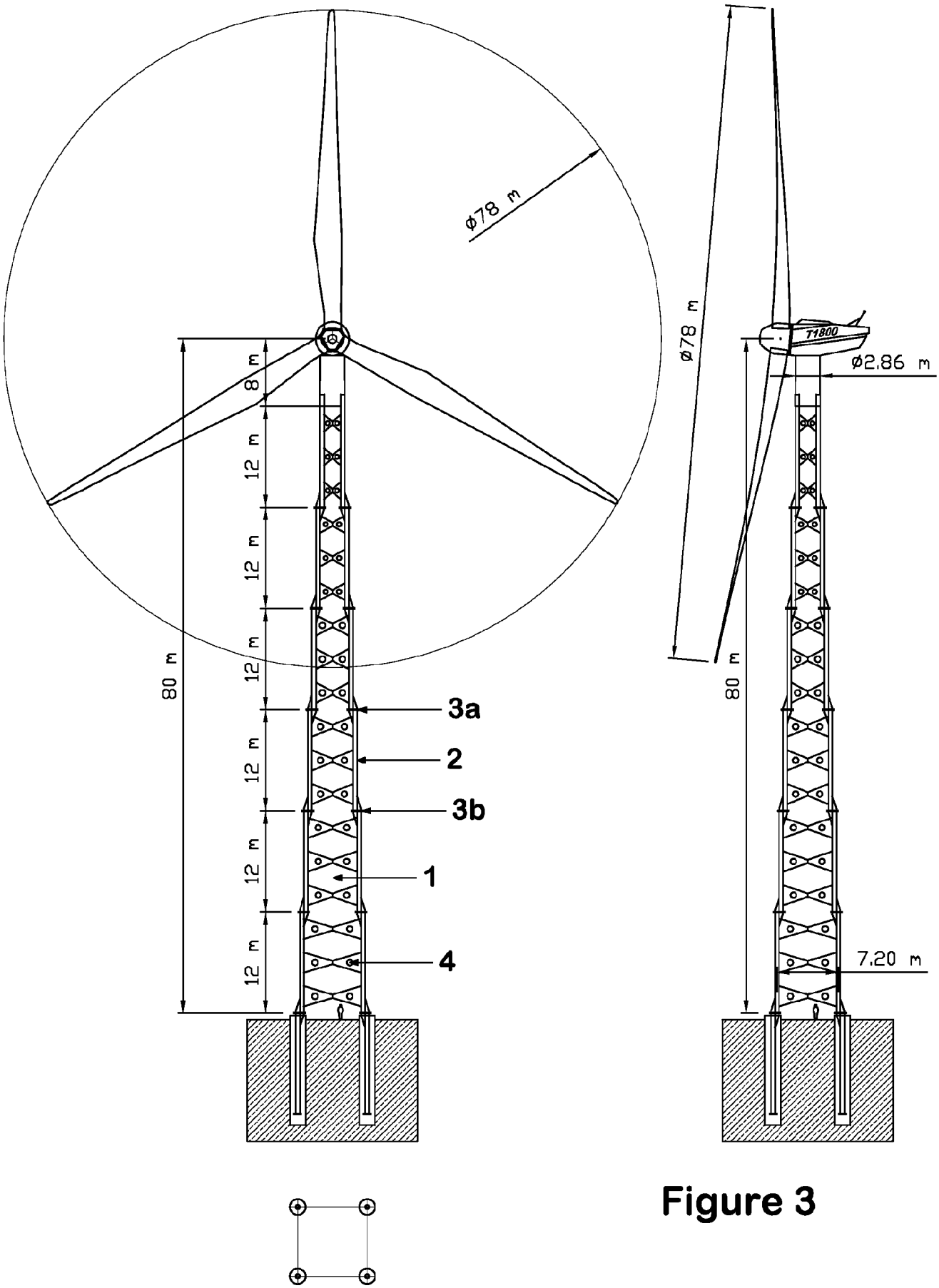

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Figure 3

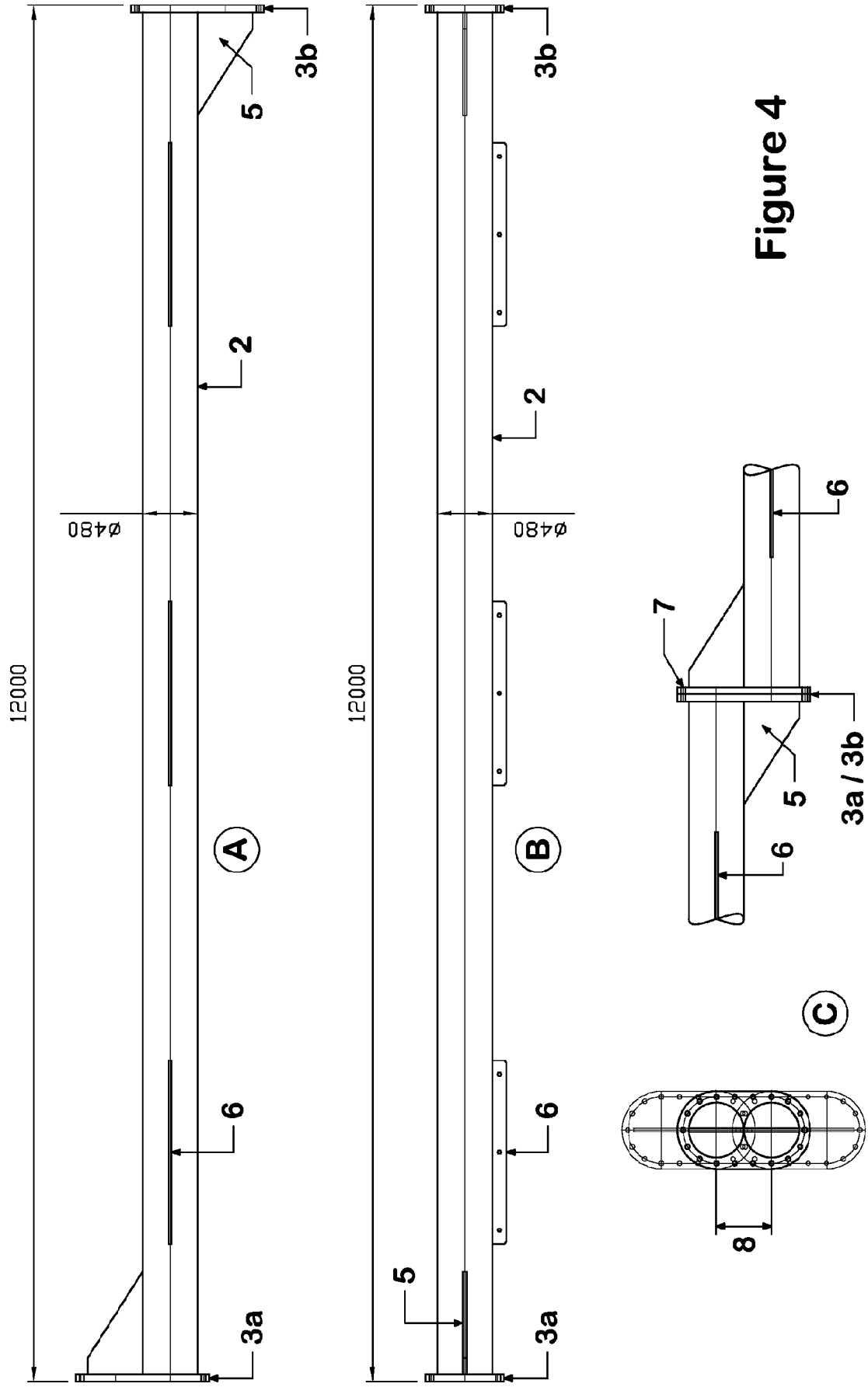


Figure 4

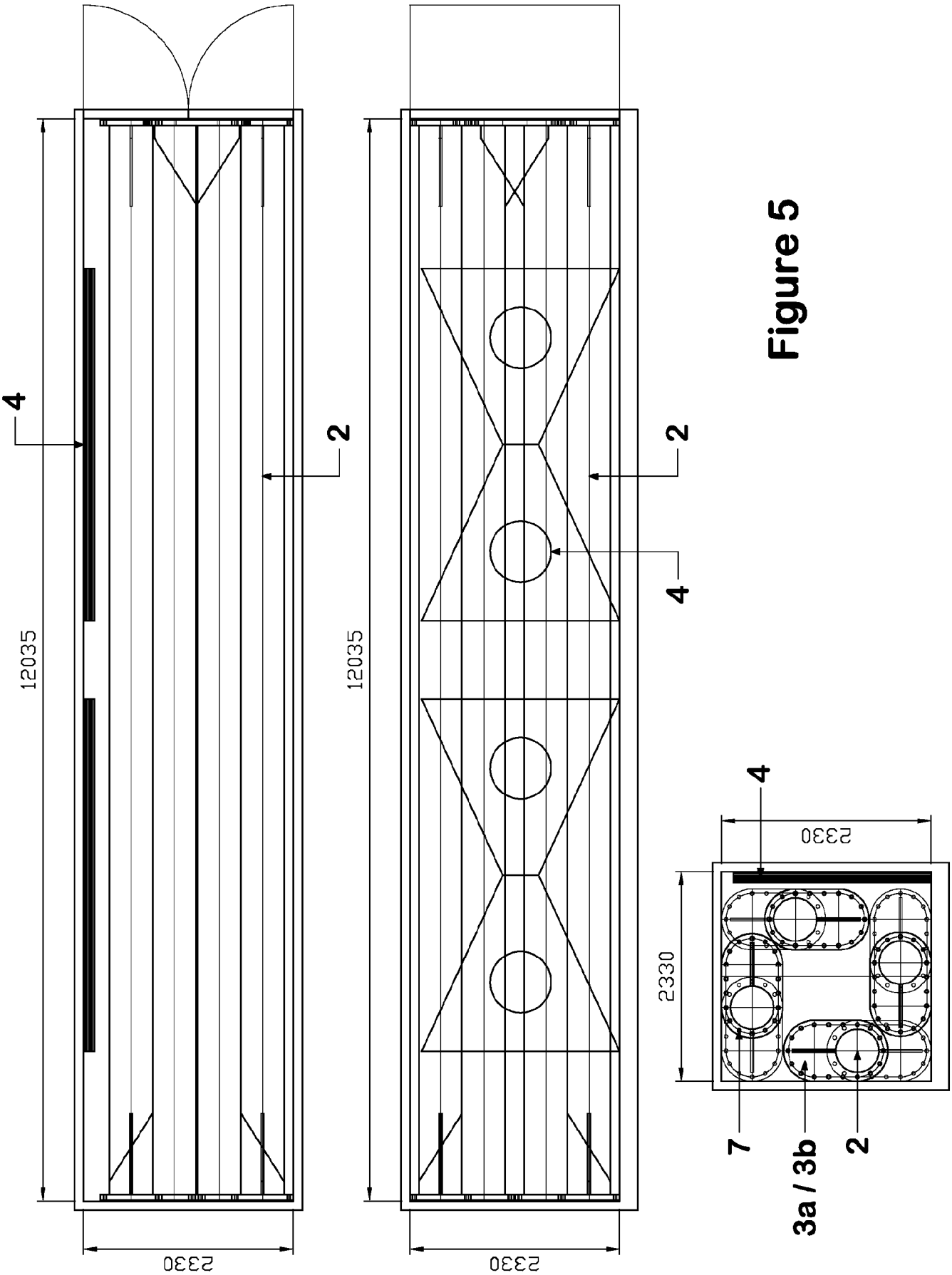


Figure 5

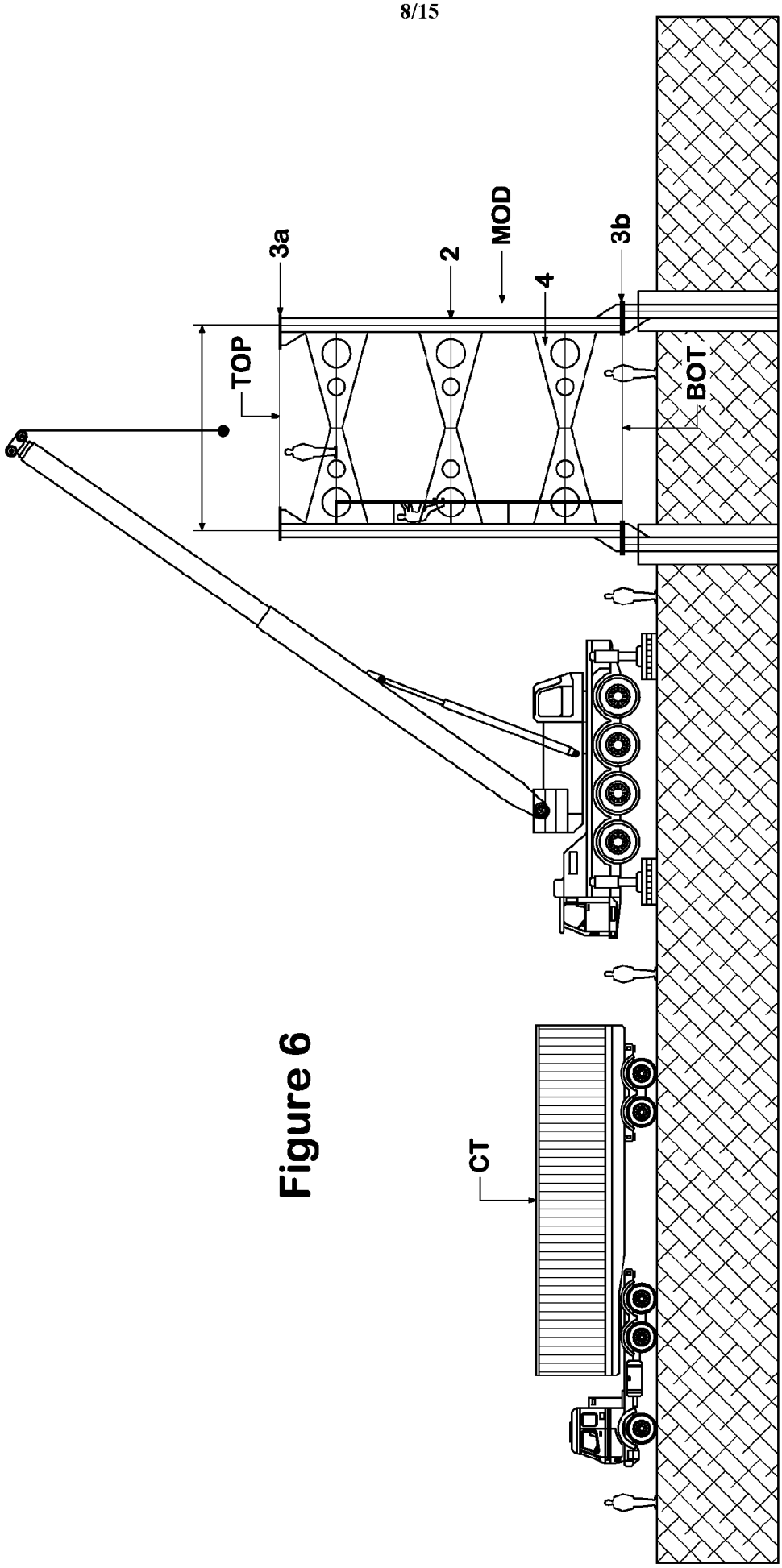
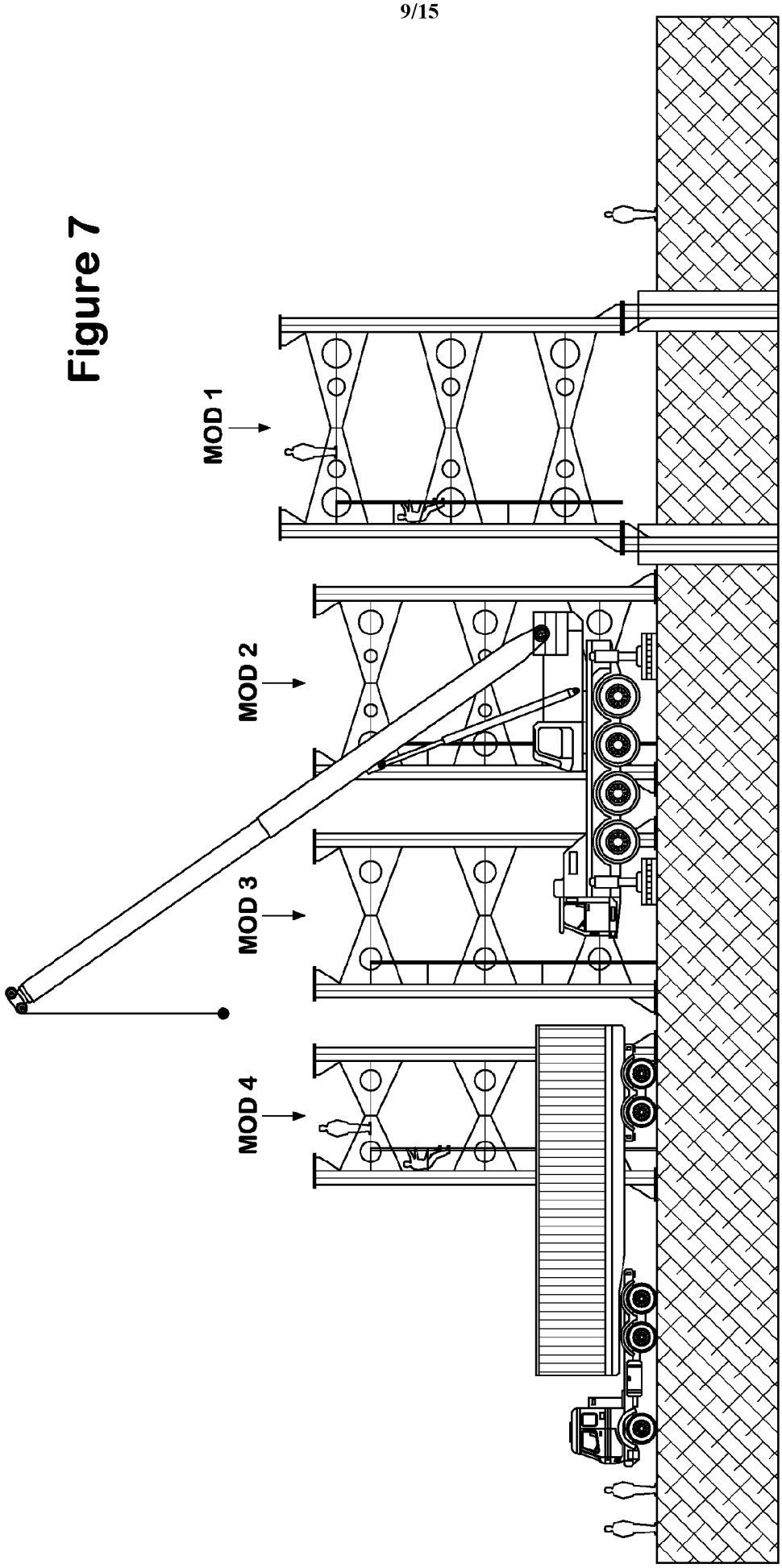


Figure 6

Figure 7



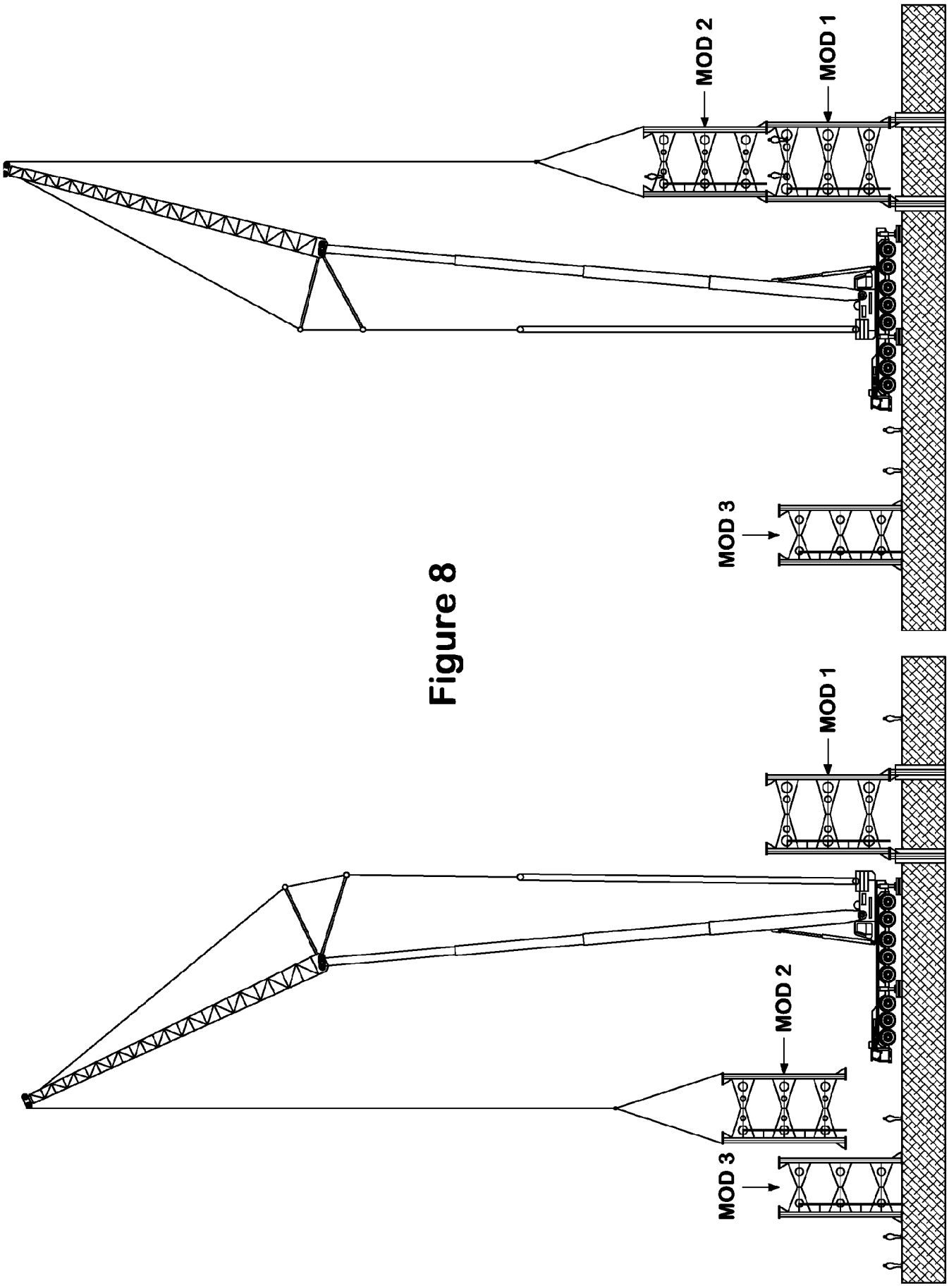


Figure 8

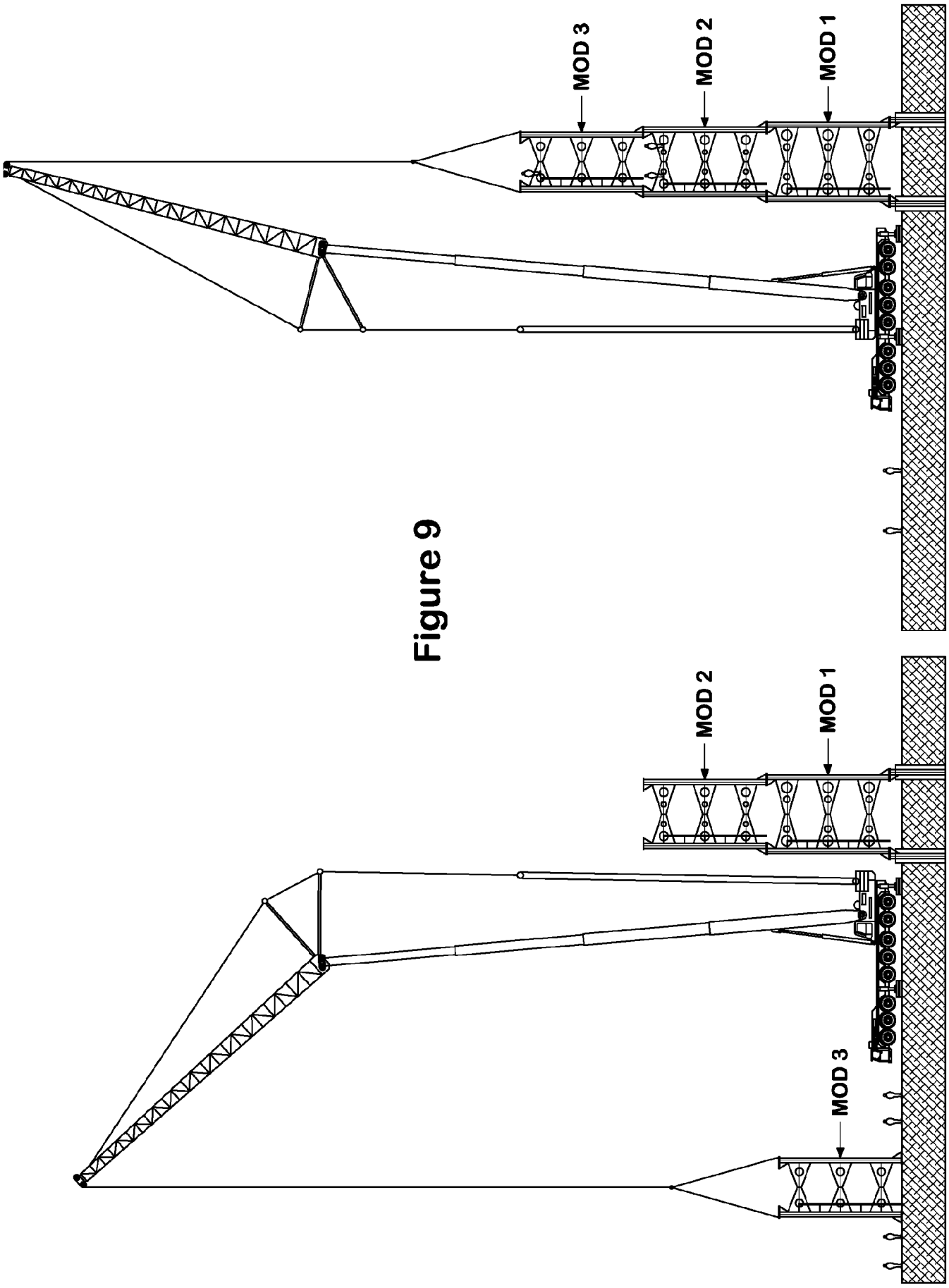


Figure 9

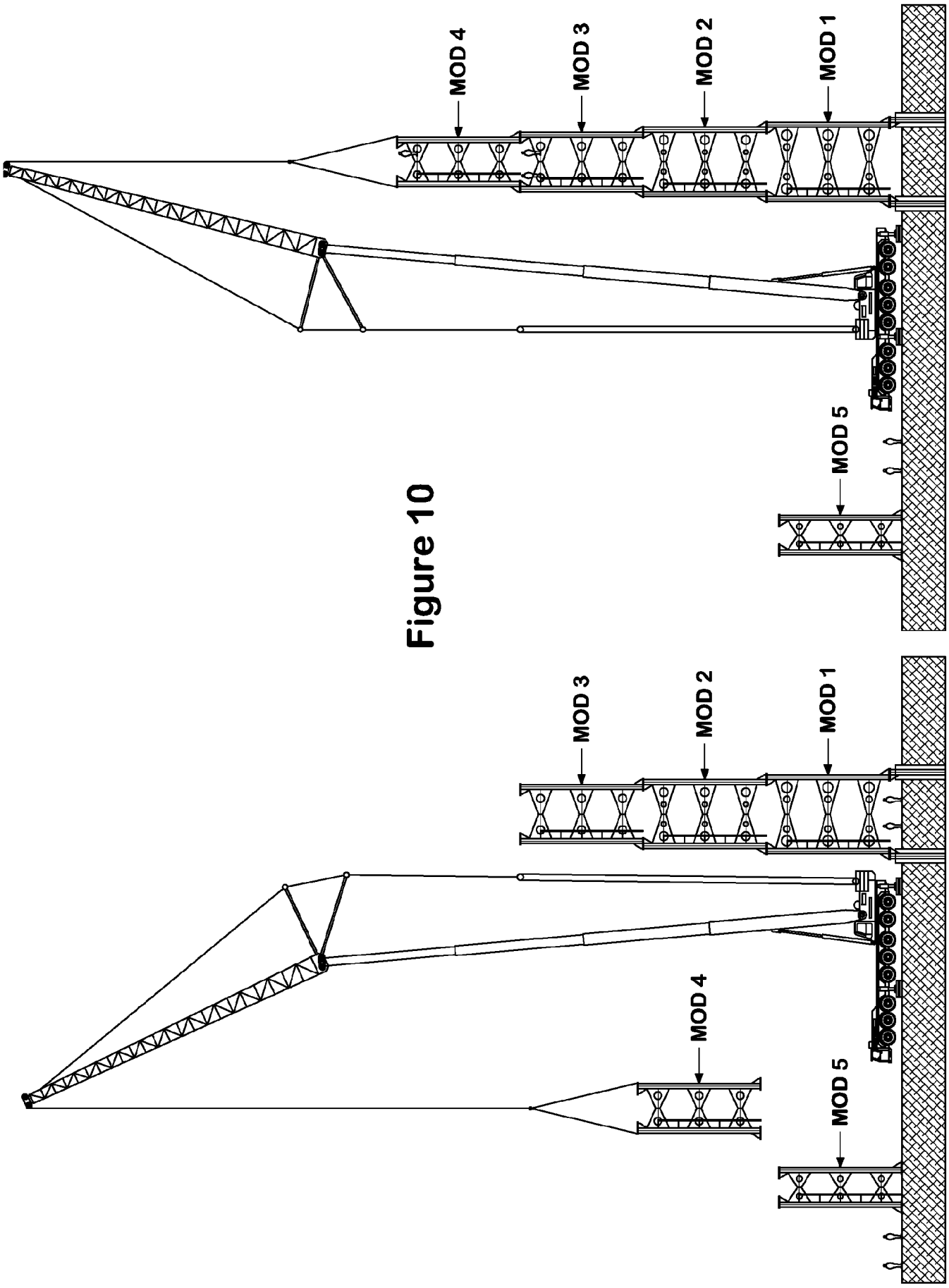
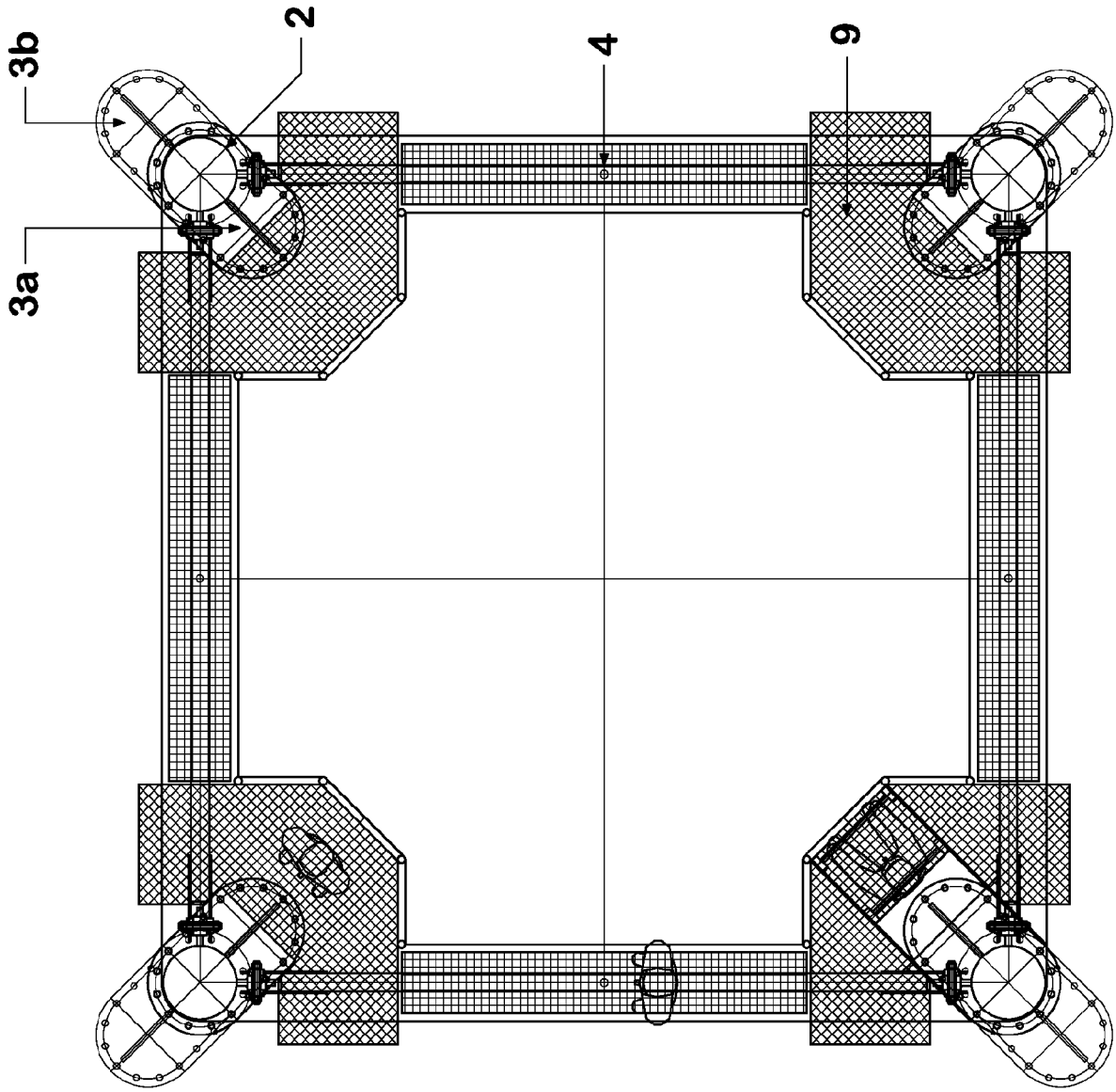


Figure 10

Figure 11



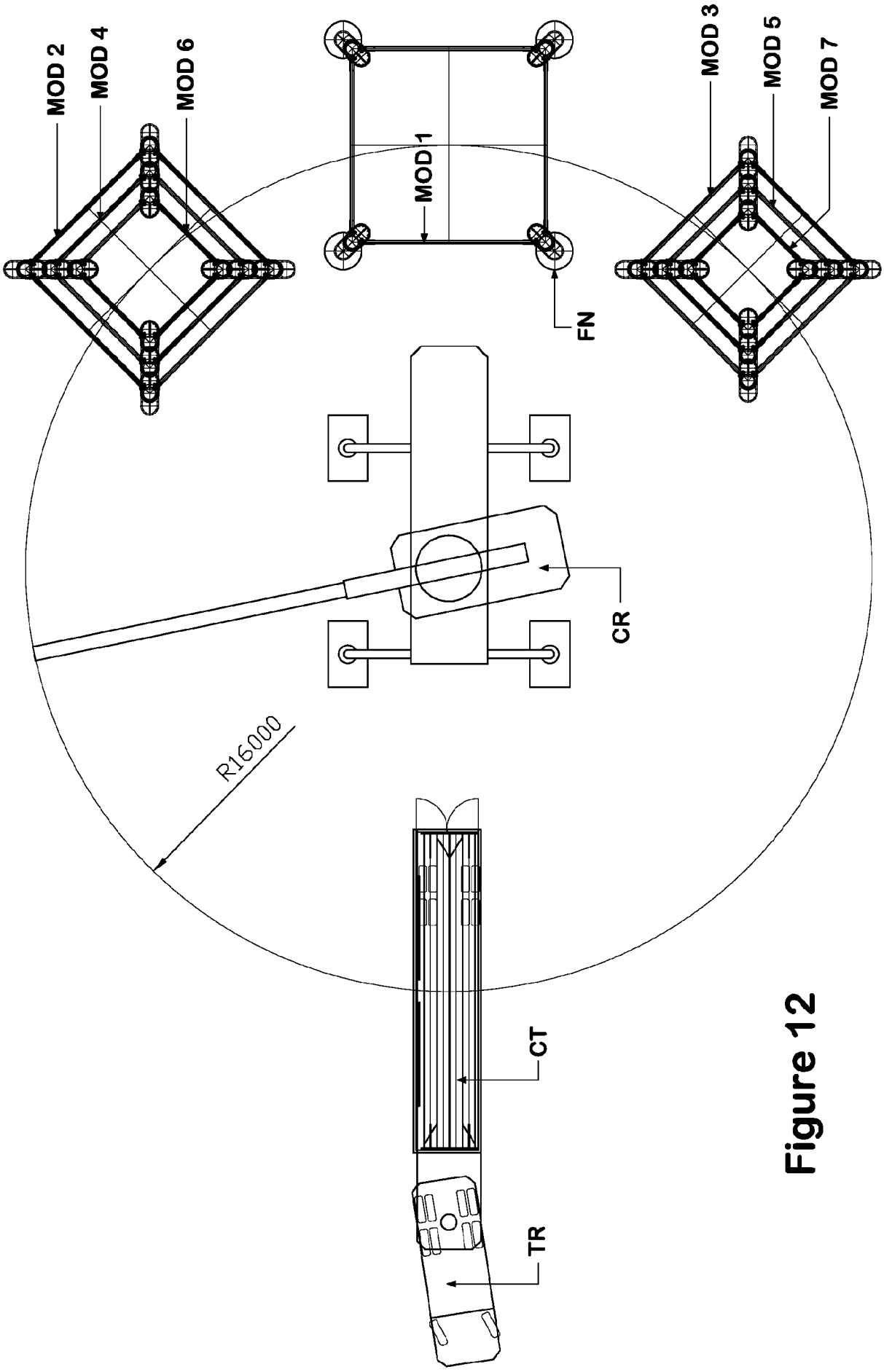


Figure 12

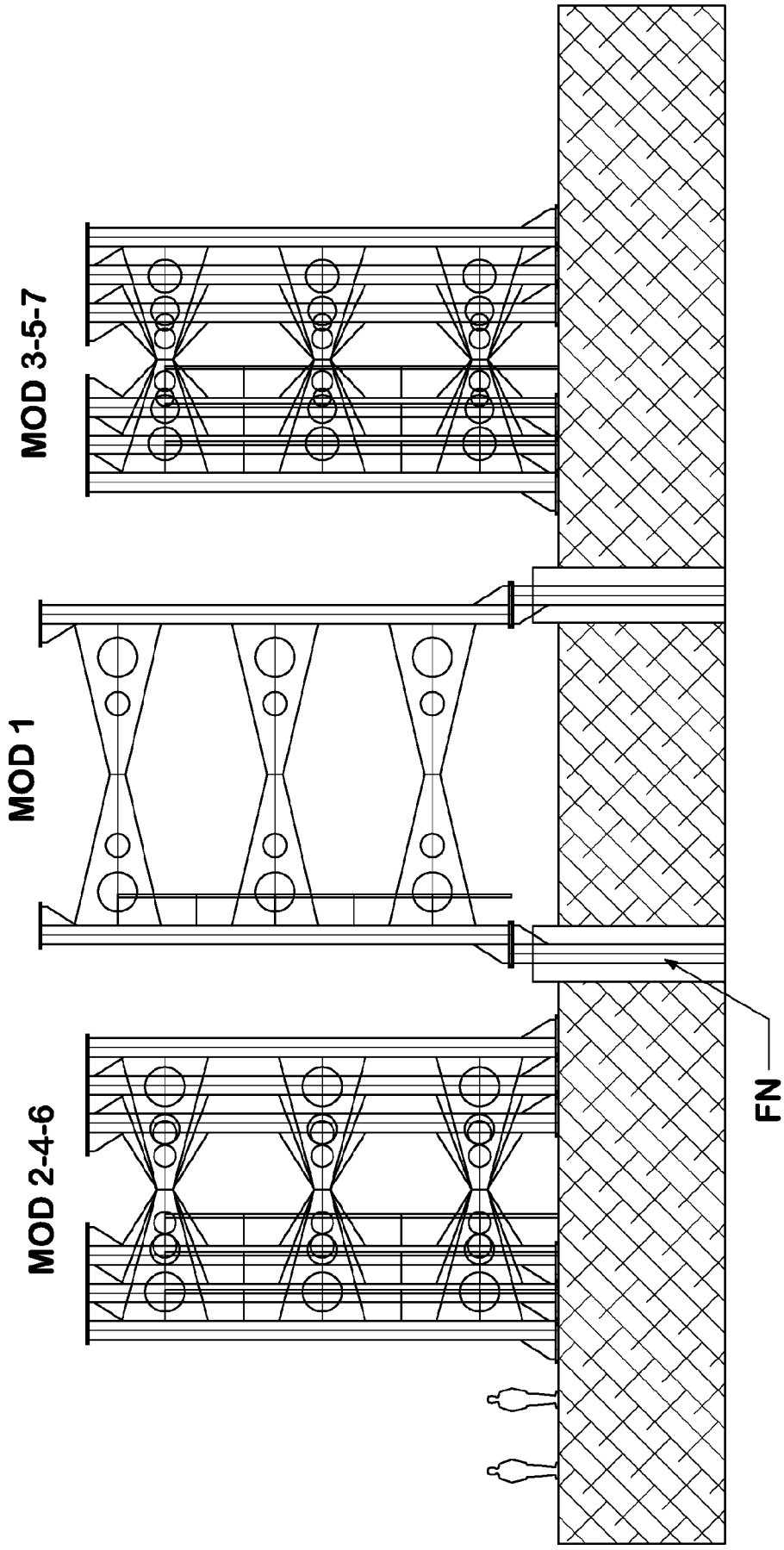


Figure 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/057402

A. CLASSIFICATION OF SUBJECT MATTER
INV. E04H12/10 F03D11/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E04H E04C F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 687 537 A (NOBLE MYRON C [US]) 18 November 1997 (1997-11-18) column 3, line 55 - column 4, line 28; figures 1-5	1-14
A	US 4 187 034 A (DZIEWOLSKI RICHARD [FR]) 5 February 1980 (1980-02-05) column 3, line 33 - column 4, line 9; figures 1-5	1-14
A	US 6 745 539 B1 (HEIM FRED F [US]) 8 June 2004 (2004-06-08)	
A	GB 761 964 A (ELEKTROPROJEKT) 21 November 1956 (1956-11-21)	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 August 2008	27/08/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Zuurveld, Gerben

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2008/057402

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