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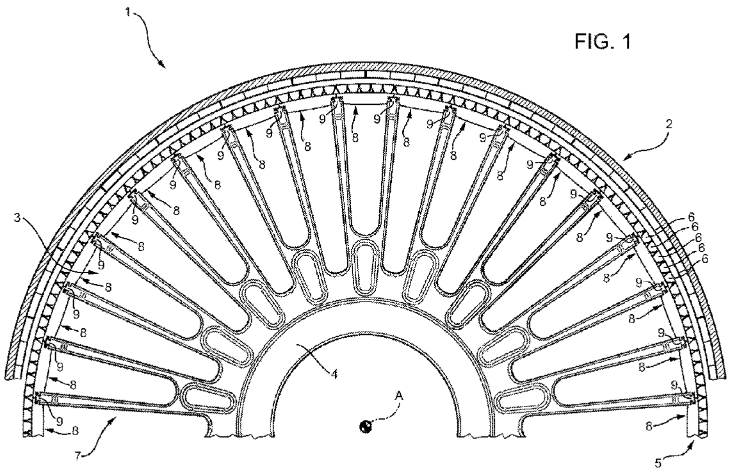
(54) Title: LARGE-DIAMETER ROTARY ELECTRIC MACHINE ROTOR AND ROTARY ELECTRIC MACHINE

FIG. 1



(57) Abstract: A rotor (3) of a wind turbine large-diameter rotary electric machine (1) has a hub (4) designed to rotate about an axis of rotation (A); a tubular structure (25) extending about the hub (4) and supporting a plurality of active segments (6) arranged about the axis of rotation (A); and a radial structure (7) for connecting the hub (4) to the tubular structure (25), which is divided into a plurality of sectors connectable selectively to the radial structure (7).

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LARGE-DIAMETER ROTARY ELECTRIC MACHINE ROTOR, AND ROTARY ELECTRIC MACHINE

TECHNICAL FIELD

The present invention relates to a large-diameter rotary electric machine rotor.

More specifically, the present invention relates to a large-diameter rotary electric machine rotor for a wind turbine.

BACKGROUND ART

Electric energy is known to be produced using direct-drive wind turbines, i.e. of the type comprising a blade assembly on which the wind blows; and a rotary electric machine comprising a rotor connected directly to the blade assembly. In this type of wind turbine, the rotary electric machine rotor rotates at the same, i.e. relatively slow, speed as the blade assembly, and the wind turbine has the advantages of not requiring a transmission between the blade assembly and the rotor, and of being cheaper to produce and maintain.

This design, however, calls for large-diameter electric machines, especially in the case of permanent-magnet rotary electric machines, which call for a large plurality of poles to compensate for the slow rotation speed of the blade assembly.

Moreover, the need for high-power wind turbines significantly affects the size of the rotary electric machines.

The trend is therefore towards increasing the diameter of wind turbine rotary electric machines. Electric machines used on wind turbines, however, must have specific characteristics : they must be relatively lightweight and easy to access for maintenance, and their component parts must be easy to assemble, disassemble and transport at both the first-time installation and repair stages.

One type of rotor described in Patent Application WO 2002/099950 comprises a hub designed to rotate about an axis of rotation; a tubular structure extending about the hub and designed to support a plurality of active segments arranged about the axis of rotation; and a spider-type radial structure for connecting the hub to the tubular structure. Though apparently extremely lightweight, this type of rotor is not easy to assemble, and is extremely complicated to maintain.

DISCLOSURE OF INVENTION

The main object of the present invention is to provide a large-diameter rotary electric machine rotor which is relatively lightweight, permits easy component part replacement, and is easy to produce.

According to the present invention, there is provided a large-diameter rotary electric machine rotor for a wind turbine; the rotor comprising :

- a hub designed to rotate about an axis of rotation;

- a tubular structure extending about the hub and supporting a plurality of active segments arranged about the axis of rotation; and

- a radial structure for connecting the hub to the tubular structure;

and wherein the tubular structure is divided into a plurality of sectors connectable selectively to the radial structure.

In the present invention, the tubular structure is segmented, i.e. divided into a plurality of small sectors or modules that can be produced cheaply and easily in the desired form.

In a preferred embodiment of the present invention, each sector is connectable selectively to the radial structure independently of the other sectors.

The tubular structure is thus easier to assemble, at both the first-time installation and maintenance stages.

In a preferred embodiment of the present invention, the radial structure comprises a plurality of connecting members for supporting the sectors on the radial structure.

In the present invention, each sector is fitted to the radial structure using dedicated connecting members. In other words, the tubular structure is a modular structure in which each sector can be removed from the radial structure and replaced with a new sector.

Preferably, each connecting member of the radial structure is located between two adjacent sectors. And the connecting members advantageously do not interrupt the continuity of the tubular structure.

In a preferred embodiment of the present invention, each sector is supported by two angularly spaced connecting members, to provide stable support for the sector.

In a preferred embodiment of the present invention, each sector is connectable to the radial structure to slide in a direction parallel to the axis of rotation.

This characteristic enables the sectors to be extracted and inserted axially.

Each sector preferably has an axially constant cross section.

This characteristic makes the sectors easy to construct. And appropriately shaping the axially constant cross section makes the sectors highly functional.

In fact, each sector has at least one axial seat for housing an active segment. The active segments can be slid axially into and out of the respective seats, thus enabling each active segment to be changed relatively easily.

Each axial seat is preferably defined by two facing ribs extending substantially radially.

The ribs serve to hold the active segment in position, preferably by means of a form-fit joint and by slightly compressing the active segment.

Preferably, each sector comprises at least one opening extending axially.

This solution makes it possible to circulate cooling gas or liquid inside the sector.

Preferably, each sector comprises two axial guides designed to form an axially sliding joint with the radial structure.

The axially constant cross section structure of the sectors enables the sectors to be extruded.

More specifically, a bar is produced with a constant cross section shaped to define the seat ribs, the openings and the guides; and the bar is then cut to the required length.

Alternatively, each sector is made of stacked laminations of the same shape. In this case, the technique used is the same as for constructing electric machine magnetic guides. Sectors made from laminations have the advantage of reducing heat loss.

In a preferred embodiment of the present invention, the radial structure comprises a plurality of spokes, each extending from the hub and joined at its free end to a connecting member connectable to a sector.

The hub and the radial structure define the supporting structure of the rotor and the sectors.

In a preferred embodiment of the present invention, the spokes, the connecting members and the hub are formed in one piece.

This solution has the advantage of enabling the whole supporting structure of the rotor to be cast, for example, from aluminium.

Alternatively, the spokes are fitted to the hub. The advantage of this solution lies in the modular design and easy transport of the rotor.

Preferably, each spoke is substantially straight and oriented substantially radially, whereas the connecting member is oriented axially.

The connecting members of the radial structure are aligned axially to form an axially sliding joint with the sectors.

The spokes may be made of different shapes to combine structural rigidity of the rotor and light weight.

In one solution, each spoke is V-shaped, and each connecting member comprises two separate, axially aligned portions.

In another solution, each spoke is Y-shaped, and each connecting member comprises two separate, axially aligned portions.

In an alternative embodiment of the present invention, the radial structure comprises a plurality of tie spokes for connecting the hub to the tubular structure.

This solution produces an extremely lightweight rotor that can be assembled on site.

The present invention also relates to a large-diameter rotary electric machine.

According to the present invention, there is provided a large-diameter rotary electric machine designed for installation on a wind turbine for producing electric energy; the rotary electric machine comprising a stator and a rotor coupled magnetically, and wherein the rotor is formed in accordance with any one of the characteristics described.

BRIEF DESCRIPTION OF THE DRAWINGS

A plurality of non-limiting embodiments of the present invention will be described by way of example with reference to the attached drawings, in which :

Figure 1 shows a schematic side view, with parts removed for clarity, of a rotary electric machine in accordance with the present invention;

Figure 2 shows a larger-scale view in perspective, with parts removed for clarity, of the rotor of the Figure 1 rotary electric machine;

Figure 3 shows a partly exploded, smaller-scale view in perspective, with parts removed for clarity, of a variation of the sector of the rotor according to the present invention;

Figure 4 shows a larger-scale view in perspective, with parts removed for clarity, of another variation of the sector of the rotor according to the present invention;

Figure 5 shows a side view, with parts removed for clarity, of a component part of the rotor according to the present invention;

Figure 6 shows a partly sectioned, larger-scale view in perspective, with parts removed for clarity, of the Figure 5 component part and a sector;

Figures 7 and 8 show partly sectioned, larger-scale views in perspective, with parts removed for clarity, of respective variations of the Figure 5 component part;

Figure 9 shows a schematic side view, with parts removed for clarity, of an alternative embodiment of the rotor according to the present invention;

Figure 10 shows a partly sectioned, larger-scale view in perspective, with parts removed for clarity, of the Figure 9 rotor.

BEST MODE FOR CARRYING OUT THE INVENTION

Number 1 in Figure 1 indicates as a whole a large-diameter rotary electric machine designed for installation on a wind turbine not shown in the attached drawings.

Rotary electric machine 1 comprises an annular stator 2 extending about an axis of rotation A; and a rotor 3, which extends about axis of rotation A, and is mounted to rotate about axis of rotation A with respect to stator 2. In the example shown, rotor 3 is located inside stator 2, but the present invention also applies to applications in which the rotor surrounds the stator.

Rotor 3 comprises a hub 4 designed to rotate about axis of rotation A; a tubular structure 5 extending about hub 4 and designed to support a plurality of active segments 6 arranged about axis of rotation A; and a radial structure 7 for connecting hub 4 to tubular structure 5.

Tubular structure 5 comprises a plurality of sectors 8 connectable selectively to radial structure 7, i.e. each sector 8 defines an angular sector of tubular structure 5. In other words, tubular structure 5 is defined by an endless succession of adjacent sectors 8 fitted to radial structure 7. Sectors 8 are preferably the same size and equally spaced about axis of rotation A.

Radial structure 7 comprises a plurality of connecting members 9 for connecting radial structure 7 to sectors 8. Connecting members 9 are located along the outside diameter of radial structure 7 and equally spaced about axis of rotation A. More specifically, each connecting member 9 of radial structure 7 is located between two sectors 8.

In the example shown, each sector 8 is fitted to two angularly spaced connecting members 9.

Each sector 8 is connectable to radial structure 7 to slide axially i.e. in a direction parallel to axis of rotation A.

With reference to Figure 2, each sector 8 has an axially constant cross section. In fact, each sector 8 comprises a rectangular-sector-shaped main body 11.

More specifically, each sector 8 is designed to fit to radial structure 7 and to support a plurality of active segments 6. For this purpose, each sector 8 has a plurality of axial seats 10 for housing active segments 6. Each seat 10 is designed to house an active segment 6, and comprises two facing ribs 12 extending axially and projecting substantially radially with respect to main body 11.

Each active segment 6 is defined by a prismatic assembly comprising permanent magnets and magnetic guides. Each active segment 6 and each two facing ribs

12 are designed to form an axially prismatic joint by which to fit and remove active segment 6 to and from sector 8.

Ribs 12 are designed to flex circumferentially to grip, and at the same time selectively permit axial slide of, active segments 6.

Each sector 8 comprises at least one through opening 13 extending axially and formed in main body 11. Preferably, each sector 8 comprises a plurality of openings 13 extending axially and formed in main body 11. Openings 13 are relatively large, and serve to form a trellis-like cross section of sector 8 to achieve a high degree of resistance to deformation combined with light weight. Openings 13 also provide for circulating cooling liquid or gas.

Figure 3 shows a variation of the Figure 2 sector 8. In Figure 3, any parts identical or similar to those in Figure 2 are indicated using the same reference numbers. As shown more clearly in Figure 3, each sector 8 comprises two axial guides 14 designed to form an axially sliding joint with radial structure 7. In the example shown, each guide 14 is defined by an axial groove designed to fit prismatically to a portion of a connecting member 9.

With reference to Figure 2, sectors 8 are locked in position with respect to radial structure 7 by fasteners, such as bolts, engaging radial structure 7, and more specifically connecting members 9.

Each sector 8 is preferably extruded from aluminium. That is, a bar of appropriate cross section is extruded and cut into sectors.

Figure 4 shows another variation of sector 8, with a different cross section from those in Figures 2 and 3. As opposed to being extruded from aluminium, each sector 8 may be made from stacks of identical ferromagnetic laminations secured by traction bars not shown in the drawings.

With reference to Figure 5, radial structure 7 comprises a plurality of spokes 15, each extending from hub 4 and having a connecting member 9 on its free end.

Hub 4, spokes 15, and connecting members 9 are preferably formed in one piece, and preferably cast from aluminium alloy. Spokes 15 extend radially with respect to axis of rotation A, and are designed to be self-supporting, i.e. each spoke 15 is designed to withstand in-service bending, tensile and compressive stress.

With reference to Figure 6, each connecting member 9 is oriented axially.

In the Figure 6 example, each spoke 15 is V-shaped, and each connecting member 9 comprises two separate, axially aligned portions. With reference to Figure 3, each connecting member 9 is a section oriented axially and designed to fit prismatically to guides 14 of sectors 8.

In the Figure 7 variation, radial structure 7 comprises Y-shaped radial spokes 16; connecting members 17, each having two separate, axially aligned portions; an emergency bearing 18; and a brake disk 19.

In the Figure 8 variation, radial structure 7 comprises straight radial spokes 20; connecting members 20, each having one axial portion; an emergency bearing 18; a brake disk 19; and weight-reducing openings 22 a hub 4.

Number 23 in Figure 9 indicates a rotor comprising a hub 24; a tubular structure 25 designed to support active segments 26; and a radial structure 27 for connecting hub 24 to tubular structure 25. Tubular structure 25 comprises a plurality of sectors 28 equally spaced about axis of rotation A. Radial structure 27 comprises a plurality of axial connecting members 29; and a plurality of tie spokes 30 for supporting connecting members 29. Tie spokes 30 are arranged in two circles along hub 24 and in two circles along tubular structure 25, as shown more clearly in Figure 10. Sectors 28 and active segments 26 are similar or identical to those shown and described with reference to the preceding drawings.

With reference to Figure 10, each connecting member

29 is a bar section oriented axially, and is connected to tubular structure 25 by a plurality of tie spokes 30 arranged in pairs. In the Figure 10 example, each connecting member is supported by three pairs of tie spokes 30. Two pairs of tie spokes 30 converge circumferentially, and one pair of tie spokes 30 cross axially to support connecting member 29 even without sectors 28.

Tie spokes 30 are mainly designed to withstand tensile stress, and are adjustable in length by means of nipples not shown in the drawings. Once all the sectors 28 are positioned, tie spokes 30 can be adjusted in length to support tubular structure 25 at the appropriate circumferential compression, and to adjust the roundness of tubular structure 25.

Clearly, changes may be made to the rotor according to the present invention without, however, departing from the scope of the accompanying Claims.

CLAIMS

1) A large-diameter rotary electric machine rotor for a wind turbine, the rotor (3; 23) comprising :

- a hub (4; 24) designed to rotate about an axis of rotation (A);

- a tubular structure (5; 25) extending about the hub (4; 24) and supporting a plurality of active segments (6; 26) arranged about the axis of rotation (A); and

- a radial structure (7; 27) for connecting the hub (4; 24) to the tubular structure (5; 25);

and wherein the tubular structure (5; 25) is divided into a plurality of sectors (8; 28) connectable selectively to the radial structure (7; 27).

2) A rotor as claimed in Claim 1, wherein each sector (8; 28) is connectable selectively to the radial structure (7; 27) independently of the other sectors (8; 28).

3) A rotor as claimed in Claim 1 or 2, wherein the radial structure (7; 27) comprises a plurality of connecting members (9; 17; 21; 29) for supporting the sectors (8; 28).

4) A rotor as claimed in Claim 3, wherein each connecting member (9; 17; 21; 29) of the radial structure (7; 27) is located between two adjacent sectors (8; 28).

5) A rotor as claimed in Claim 3 or 4, wherein each sector (8; 28) is supported by two angularly spaced connecting members (9; 17; 21; 29).

6) A rotor as claimed in any one of the foregoing Claims, wherein each sector (8; 28) is connectable to the radial structure (7; 27) to slide in a direction parallel to the axis of rotation (A).

7) A rotor as claimed in any one of the foregoing Claims, wherein each sector (8; 28) has an axially constant cross section.

8) A rotor as claimed in any one of the foregoing Claims, wherein each sector (8; 28) has at least one axial seat (10) for housing an active segment (6; 26).

9) A rotor as claimed in Claim 8, wherein each axial seat (10) is defined by two facing ribs (12) extending substantially radially.

10) A rotor as claimed in any one of the foregoing Claims, wherein each sector (8; 28) comprises at least one opening (13) extending axially.

11) A rotor as claimed in any one of the foregoing Claims, wherein each sector (8; 28) comprises two axial guides (14) designed to form an axially sliding joint with the radial structure (7; 27).

12) A rotor as claimed in any one of the foregoing Claims, wherein the sector (8; 28) is extruded from aluminium.

13) A rotor as claimed in any one of Claims 1 to 11, wherein the sector (8; 28) is made of stacked laminations.

14) A rotor as claimed in any one of the foregoing Claims, wherein the radial structure (7) comprises a plurality of spokes (15; 16; 20), each extending from the hub (4) and joined at its free end to a connecting member (9; 17; 21) connectable to a sector (8).

15) A rotor as claimed in Claim 14, wherein the spokes (15; 16; 20), the connecting members (9; 17; 21) and the hub (4) are formed in one piece.

16) A rotor as claimed in Claim 14, wherein the spokes (15; 16; 20) are fitted to the hub (4).

17) A rotor as claimed in one of Claims 14 to 16, wherein each spoke (20) is substantially straight and oriented substantially radially, whereas the connecting member (21) is oriented axially.

18) A rotor as claimed in one of Claims 14 to 16, wherein each spoke (15) is V-shaped, and the connecting member (9) comprises two separate, axially aligned portions.

19) A rotor as claimed in one of Claims 14 to 16, wherein each spoke (16) is Y-shaped, and the connecting member (9) comprises two separate, axially aligned portions.

20) A rotor as claimed in any one of Claims 1 to

13, wherein the radial structure (27) comprises a plurality of tie spokes (30) for connecting the hub (24) to the tubular structure (25).

21) A large-diameter rotary electric machine designed for installation on a wind turbine for producing electric energy; the rotary electric machine (1) comprising a stator (2) and a rotor (3) coupled magnetically, and wherein the rotor (3) is as claimed in any one of the foregoing Claims.

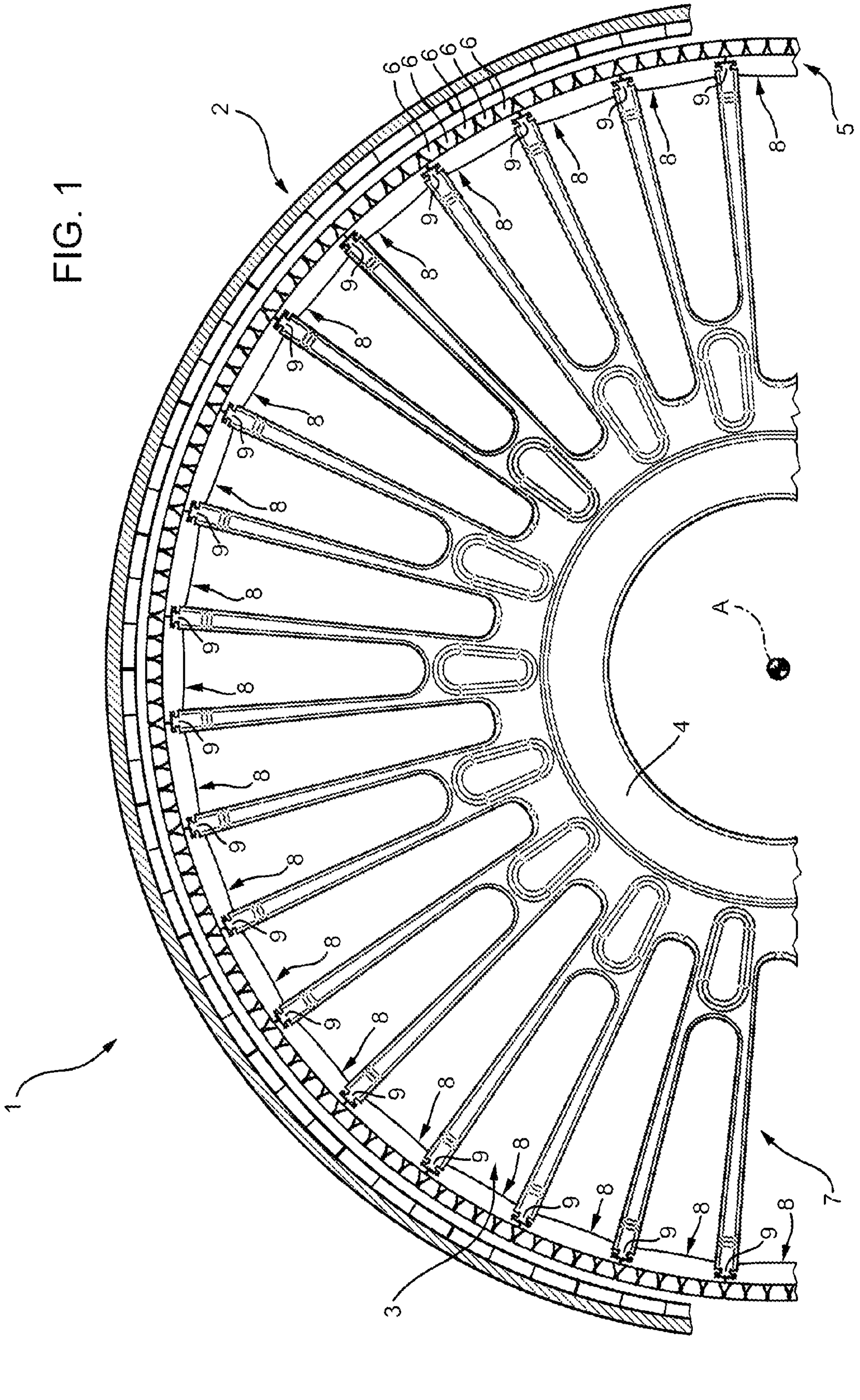

FIG. 1

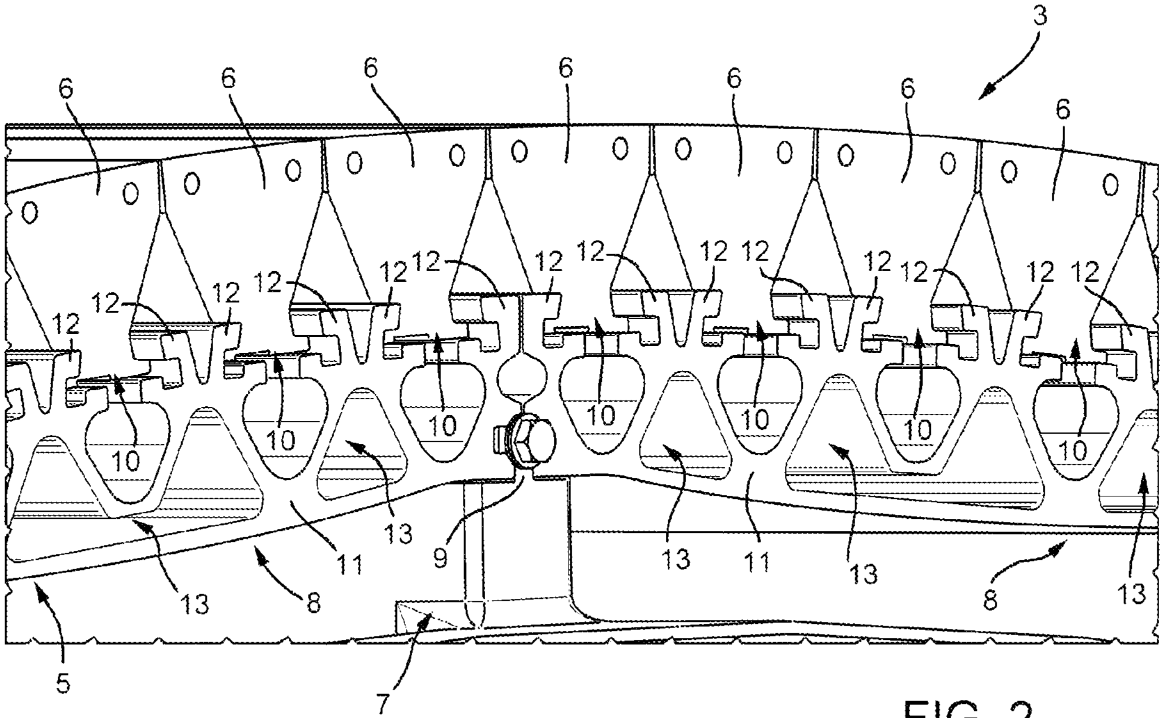

FIG. 2

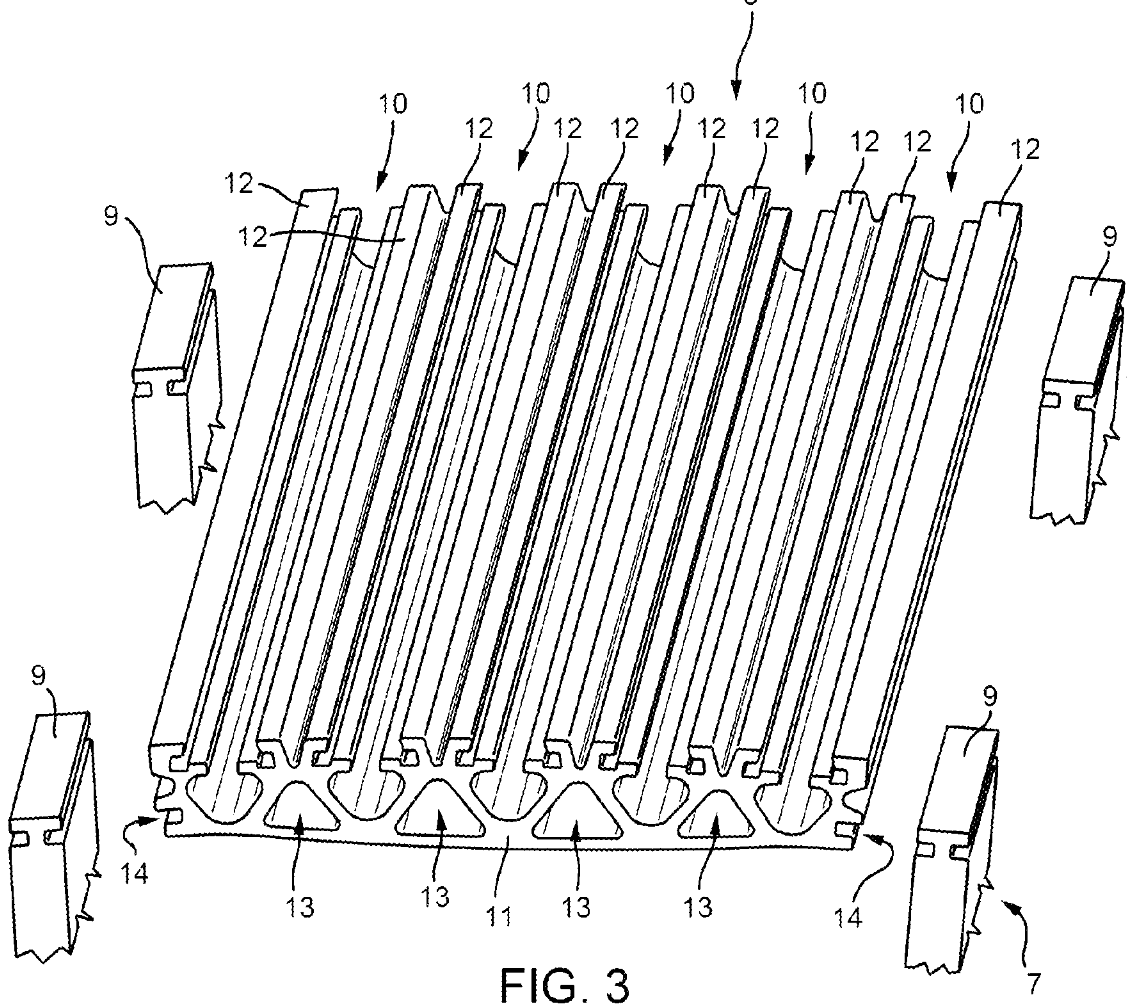

FIG. 3

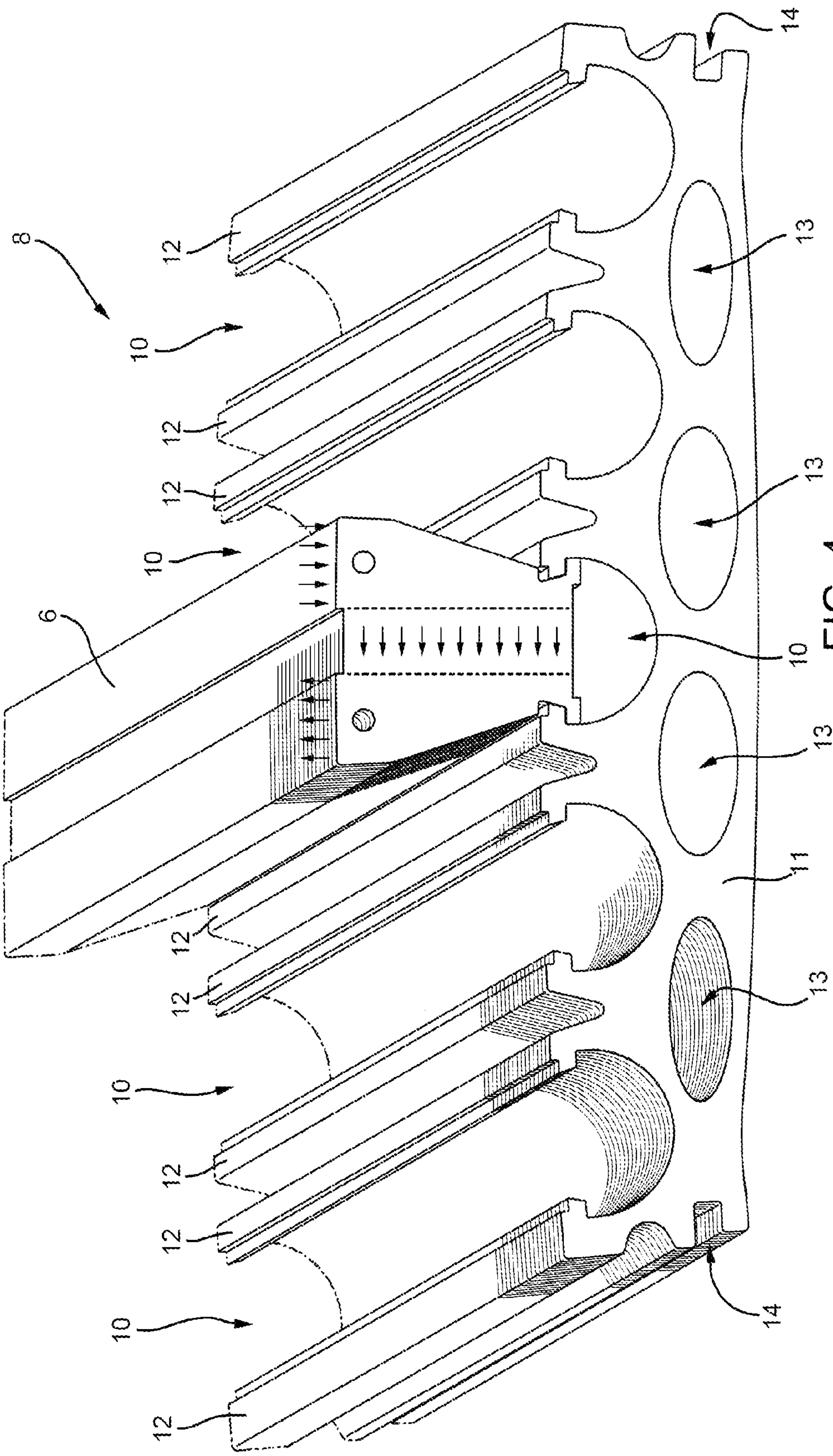

FIG. 4

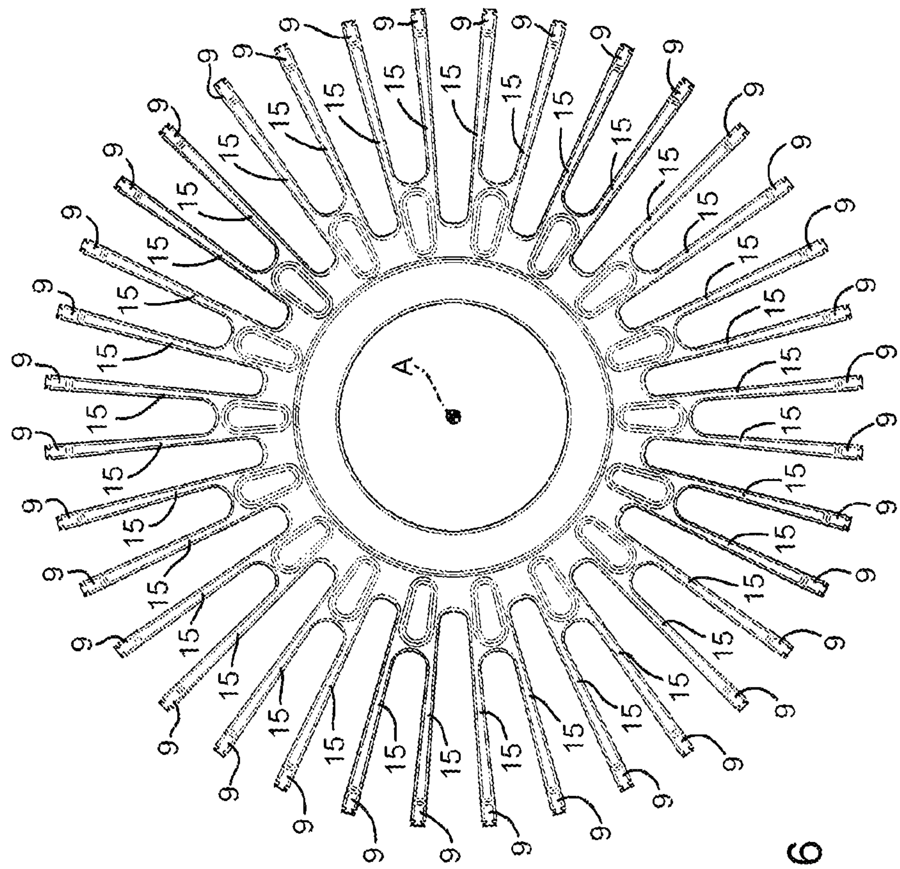

FIG. 5

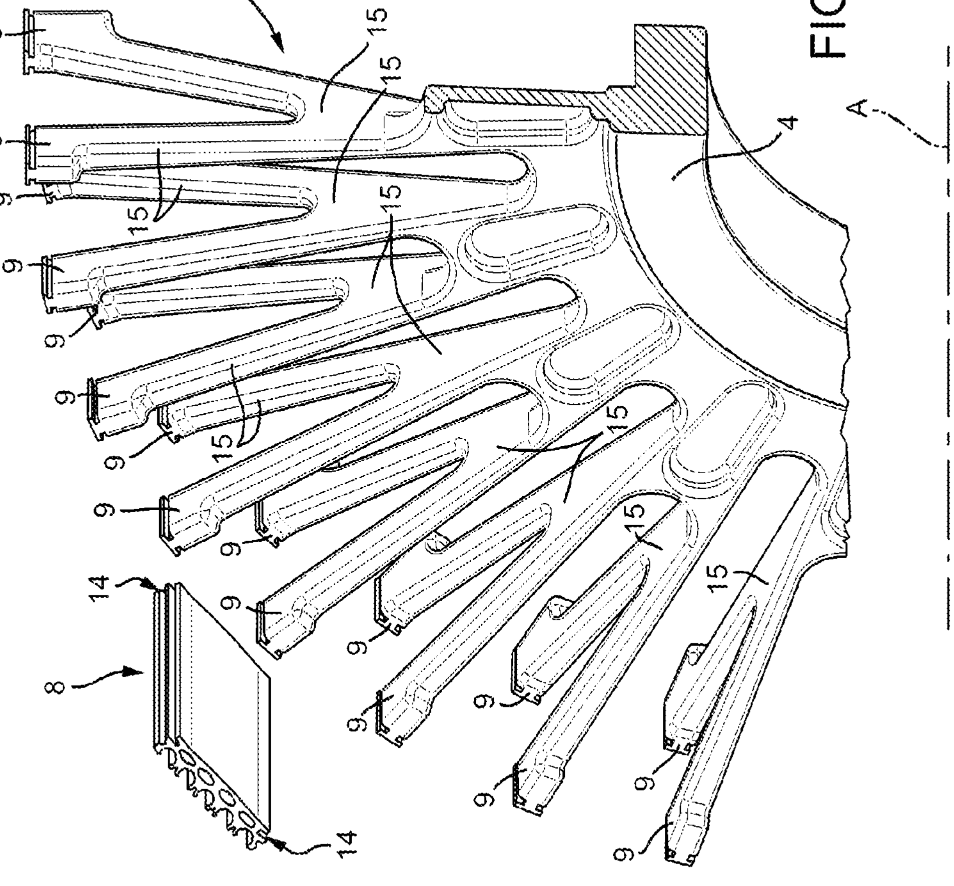

FIG. 6

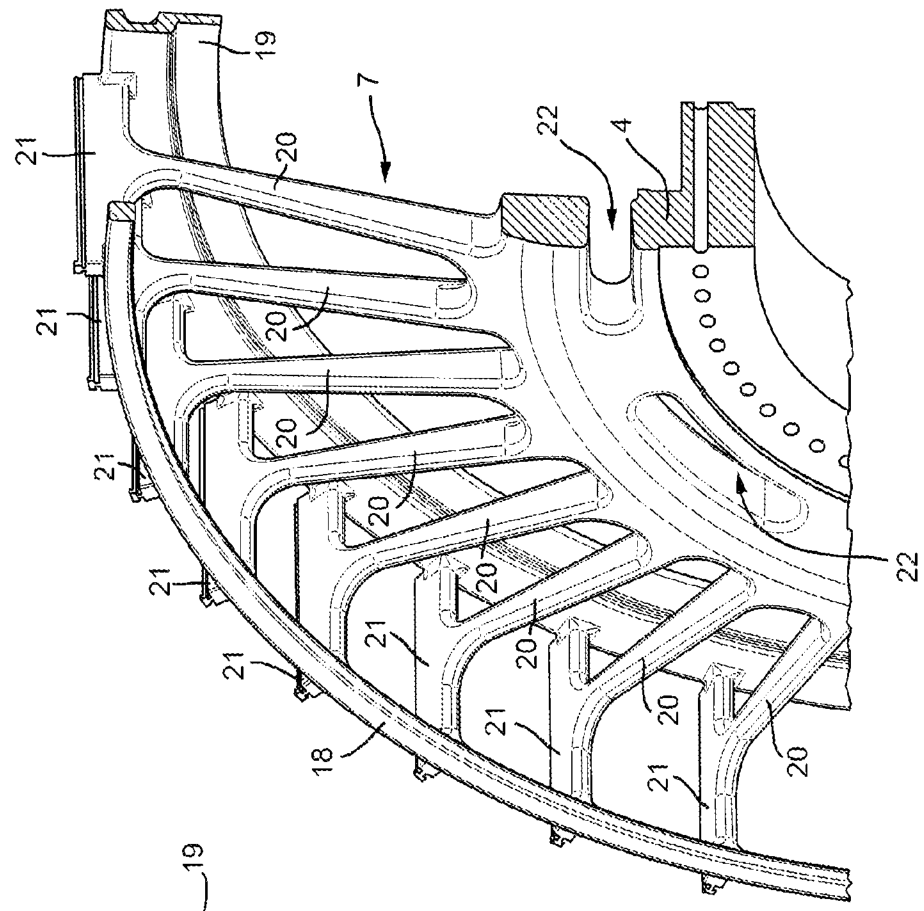

FIG. 8

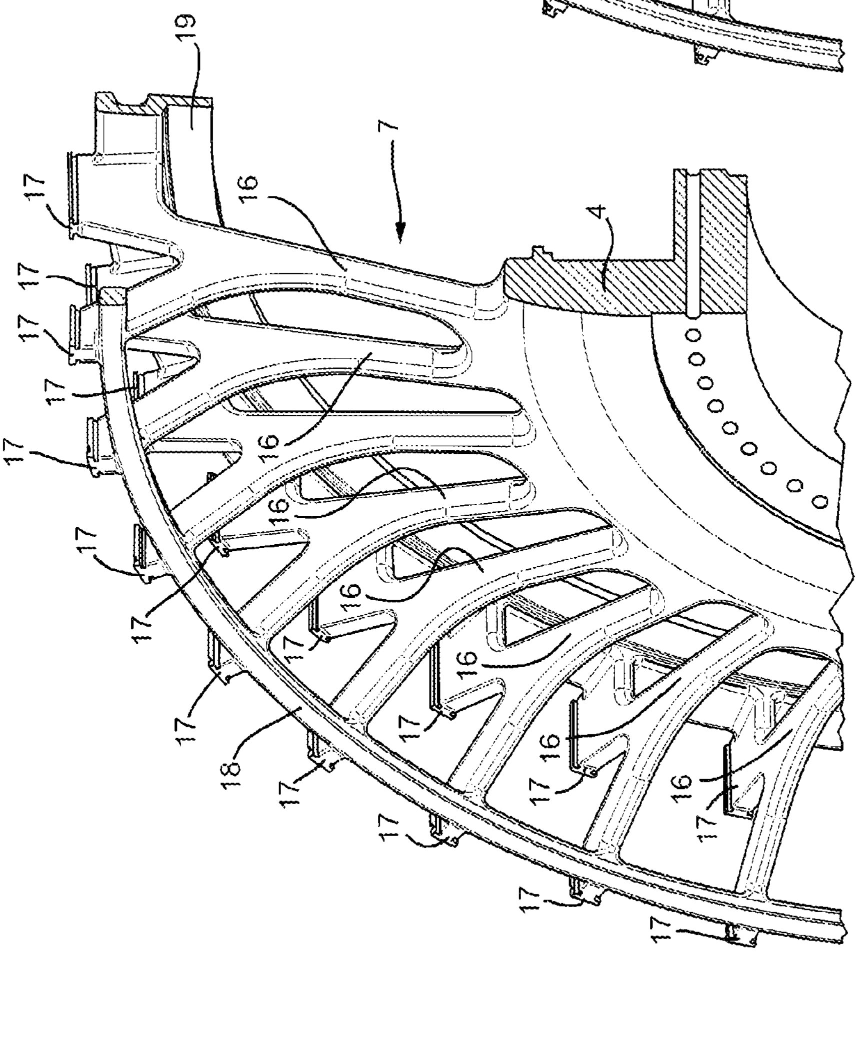

FIG. 7

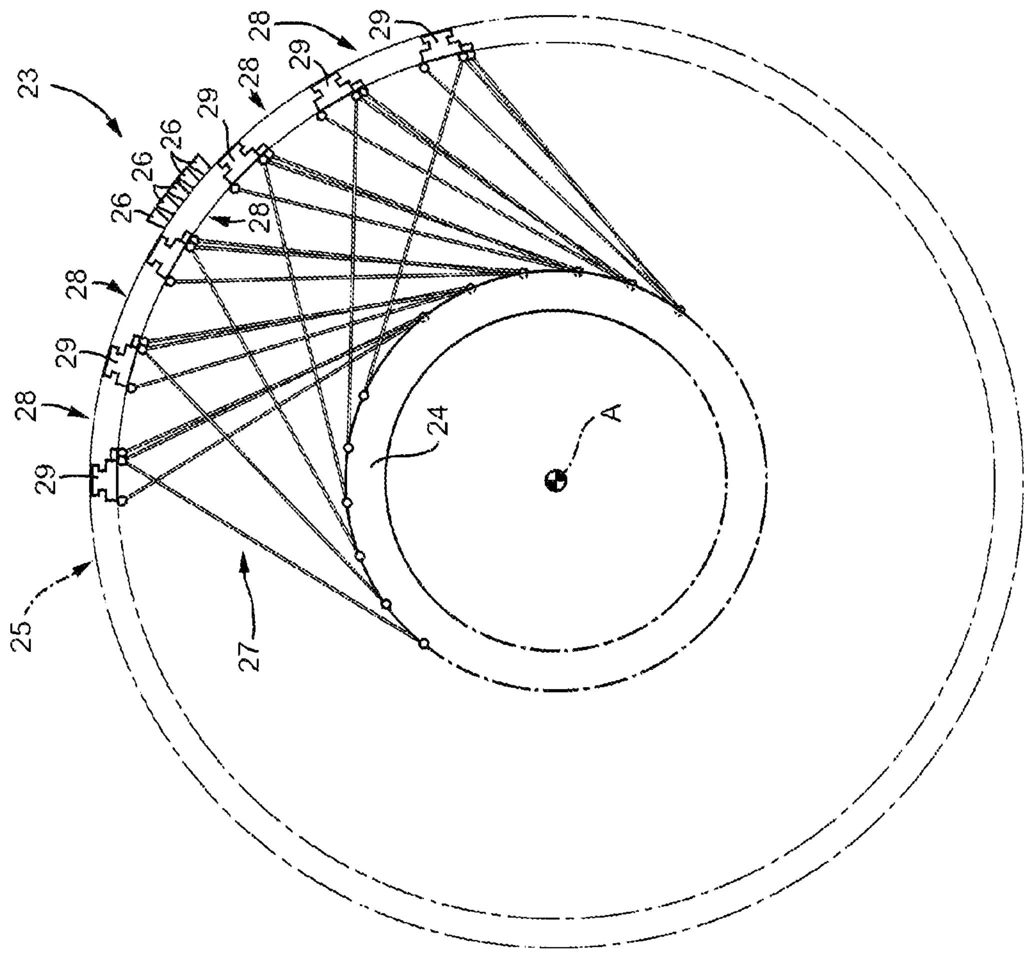

FIG. 9

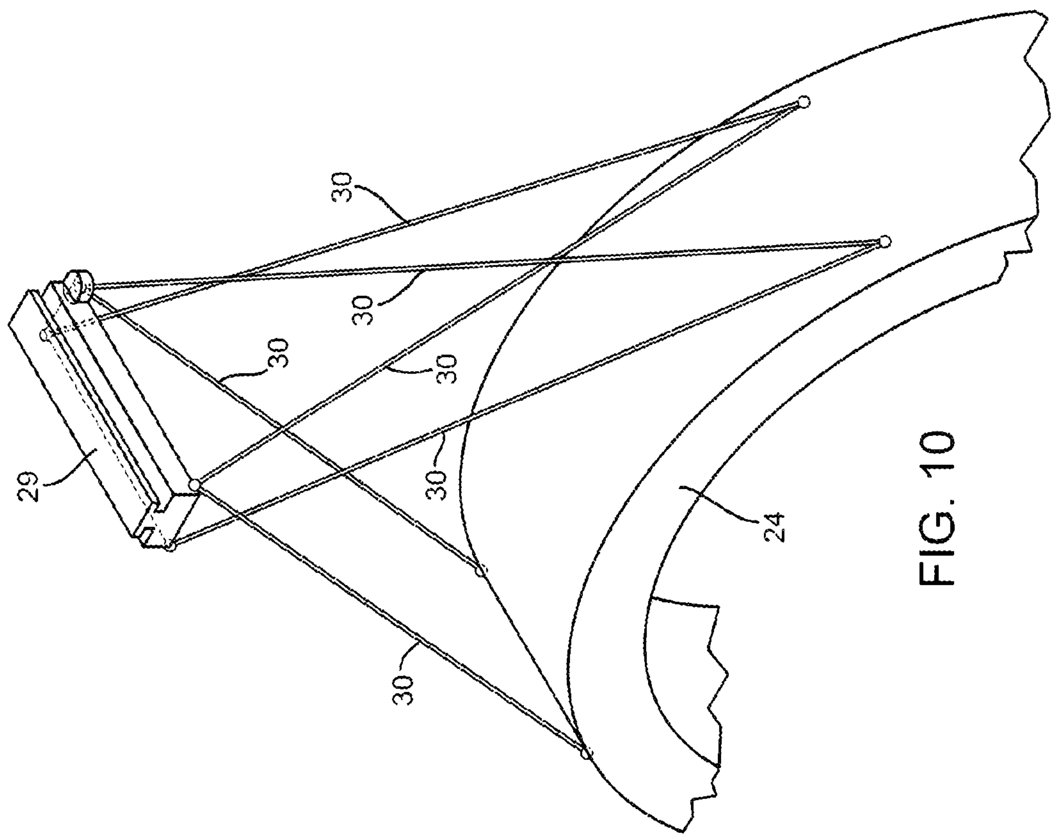

FIG. 10