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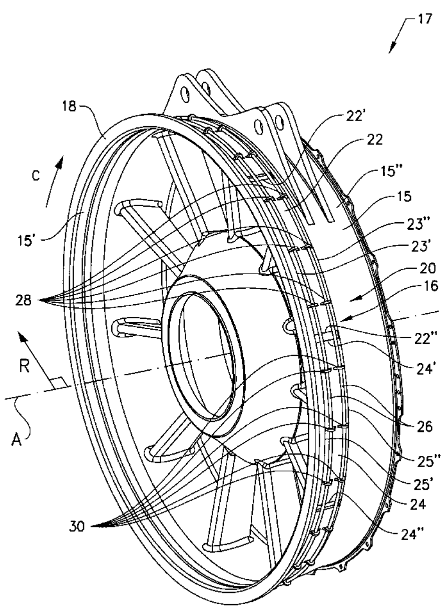

FIG. 2a

(57) Abstract: The present invention relates to a containment assembly (16) adapted to circumscribe a casing (15) for a gas turbine engine (1). The casing (15) has an axial extension in an axial direction (A) and a circumferential extension in a circumferential direction (C). Moreover, the casing (15) comprises an inner casing surface (15') and an outer casing surface (15"). The inner casing surface (15') is adapted to form a part of a duct (6, 7) of the gas turbine engine (1). The containment assembly (16) comprises an enclosing assembly (20) adapted to at least partially enclose the outer casing surface (15") when mounted. The containment assembly (16) further comprises a resilient means (26) adapted to interact with the enclosing assembly (16). According to the present invention, the enclosing assembly (20) comprises at least two enclosing segments (22, 24) that are arranged at least partially in sequence in the circumferential direction (C) of the casing (15) when the containment assembly (16) circumscribes the casing (15).

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CONTAINMENT ASSEMBLY FOR A GAS TURBINE ENGINE

TECHNICAL FIELD

The present disclosure relates to a containment assembly according to the preamble of claim 1. Moreover, the present disclosure relates to a casing assembly for a gas turbine engine according to the preamble of claim 13, a gas turbine engine according to the preamble of claim 17 and an aeroplane according to the preamble of claim 18.

BACKGROUND

Gas turbine engines are known in the art. The expression "gas turbine engine" is meant to include various types of engines which admit air at relatively low velocity, heat it by combustion and expel it at a higher velocity. Accommodated within the term gas turbine engine are, for example, turbojet engines and turbo-fan engines.

A gas turbine engine generally comprises a member that is adapted to be rotated in a duct of the engine. Purely by way of example, such a member may be a rotor of a compressor or a turbine of the engine. In a turbo-fan engine, the fan is another example of such a rotatable member.

During operation of the gas turbine engine, there may be a risk that at least a portion of the rotating member for some reason becomes detached from its original position. The rotating member portion may in such a situation travel in the duct of the engine. The above scenario will hereinafter be referred to as blade-out event.

In a blade-out event, there is a risk that the rotating member portion may impact a surface of a casing of the engine, which surface at least partially delimits the duct. Such an impact may damage or impair the function of the casing.

In an attempt to reduce the damage to a casing in a blade-out event, US 6,394,746 B1 proposes that a containment ring be placed radially outside the casing such that the containment ring is adapted to abut an outer surface of the casing.

However, the containment ring in US 6,394,746 B1 may be cumbersome to install. Moreover, there is a risk that the US 6,394,746 B1 containment ring does not sufficiently absorb impact energy from the rotating member portion.

SUMMARY

One object of the present disclosure is to provide a containment assembly that, at least to an appropriately high extent, absorbs impact energy from a rotating member portion in a blade-out event.

This object is achieved by a containment assembly according to claim 1.

As such, the present disclosure relates to a containment assembly adapted to circumscribe a casing for a gas turbine engine. The casing has an axial extension in an axial direction and a circumferential extension in a circumferential direction. Moreover, the casing comprises an inner casing surface and an outer casing surface. The inner casing surface is adapted to form a part of a duct of the gas turbine engine. The containment assembly comprises an enclosing assembly adapted to at least partially enclose the outer casing surface when mounted. The containment assembly further comprises a resilient means adapted to interact with the enclosing assembly.

According to the present disclosure, the enclosing assembly comprises at least two enclosing segments that are arranged at least partially in sequence in the circumferential direction of the casing when the containment assembly circumscribes the casing.

Preferably, the segments are of a hard and tough material. In the event that a rotating member portion (a blade or part thereof) is detached during operation, it may impact the inner casing surface. The enclosing segment covering the area of the point of impact may then buckle, wherein the resilient means may be stretched. The resilient means may absorb at least a portion of the energy generated when the rotating member portion impacts the casing. The detached rotating member portion will be contained within the casing.

The feature that the enclosing assembly comprises at least two enclosing segments implies that the segments may be displaced in relation to one another in a blade-out event and this in turn implies that the resilient means may absorb at least a portion of the energy generated when a rotating member portion impacts the casing that the containment assembly circumscribes, when mounted.

Moreover, the feature that the enclosing assembly comprises at least two enclosing segments implies that the containment assembly of the present disclosure may be straightforward to install on a casing.

Furthermore, by virtue of the provision of the at least two enclosing segments and the resilient means, the containment assembly may be adapted to be adjustable for a possible thermal expansion of the casing that the containment assembly circumscribes.

Optionally, when the containment assembly circumscribes the casing, each one of the at least two enclosing segments comprises two axial end surfaces each one of which extends at least partially in the axial direction.

Optionally, the casing has, when the containment assembly circumscribes the casing, at least one enclosing segment comprising a first circumferential end surface and a second circumferential end surface, each one of which extending in the circumferential direction. At least one of the axial end surfaces extends between the first circumferential end surface and the second circumferential end surface.

Optionally, each one of the two axial end surfaces of at least one enclosing segment extends in a direction that forms and angle with the axial direction, the absolute value of the angle being smaller than or equal to 30°, preferably smaller than or equal to 10°.

Optionally, each one of the at least two enclosing segments comprises a rectangular plate having a shape corresponding to the circumferential direction of the casing.

Optionally, each one of the at least two enclosing segments comprises an overlapping portion. The overlapping portion of one enclosing segment is adapted to overlap a portion of another enclosing segment when the containment assembly circumscribes the casing.

The provision of overlapping portions may reduce the risk that a rotating member portion protrudes beyond, in a radial direction, the enclosing segments in a blade-out event. This in turn implies that the risk of damaging the casing may be reduced further.

Optionally, at least one of the enclosing segments comprises a flange that is adapted to extend at least partially in the circumferential direction when the containment assembly circumscribes the casing. The flange comprises at least one opening for receiving an attachment means, which attachment means further is adapted to be attached to the casing.

The above flange may be used in order to ensure that an enclosing segment is kept in place, at least in the axial direction, relative to the casing. Moreover, if at least one segment is provided with two flanges, e.g. one at each axial end thereof, which flanges are attached to portions of the casing, the segment may contribute to load transfer, at least for axial loads, through the casing assembly formed by the casing and the containment assembly.

Optionally, the resilient means is made of a metal or a metal alloy.

Optionally, the resilient means comprises a wire, preferably a steel wire.

Optionally, the resilient means is adapted to extend around the circumference of the casing, when the containment assembly circumscribes the casing.

According to one arrangement, the casing has a radial extension in a radial direction, the resilient means being adapted to located outside, in the radial direction, of the at least two enclosing segments when the containment assembly circumscribes the casing.

Optionally, the resilient means is adapted to abut the at least two enclosing segments when the containment assembly circumscribes the casing.

A second aspect of the present disclosure relates to a casing assembly for a gas turbine engine. The casing assembly comprises a casing having an axial extension in an axial direction and comprising an inner casing surface and an outer casing surface. According to the second aspect of the present disclosure, the casing comprises a containment assembly according to the first aspect of the present disclosure.

Optionally, the casing is made of a first material and at least one segment of the enclosing assembly is made of a second material, the first material having a thermal resistance being greater than the thermal resistance of the second material.

Optionally, the casing assembly is adapted to be located downstream of a combustion chamber of the gas turbine chamber, preferably the casing assembly is adapted to be located downstream of a pressure turbine, more preferred a high pressure turbine, of the gas turbine chamber.

Optionally, the casing is a turbine exhaust casing.

A third aspect of the present disclosure relates to a gas turbine engine comprising a casing according to the second aspect of the present disclosure.

A fourth aspect of the present disclosure relates to an aeroplane comprising a gas turbine engine according to the third aspect of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be explained in greater detail by means of non-limiting examples and with reference to the appended drawings in which:

Fig. 1 is a schematic longitudinal sectional view illustration of an exemplary embodiment of an aircraft turbofan gas turbine engine;

Fig. 2a is a schematic view of an embodiment of a casing assembly;

Fig. 2b illustrates a portion of the Fig. 2a assembly;

Fig. 3 is a schematic view of another embodiment of a casing assembly;

Fig. 4a is a schematic view of a further embodiment of a casing assembly;

Fig. 4b illustrates a portion of the Fig. 4a assembly;

Fig. 5 is a schematic view of another embodiment of a casing assembly;

Fig. 6a is a schematic view of a further embodiment of a casing assembly;

Fig. 6b illustrates a portion of the Fig. 6a assembly;

Fig. 7a is a schematic view of another embodiment of a casing assembly;

Fig. 7b illustrates a portion of the Fig. 7a assembly;

Fig. 8a illustrates a portion of an implementation of a biasing means, and

Fig. 8b illustrates a portion of another implementation of a biasing means.

It should be noted that the appended drawings are not necessarily drawn to scale and that the dimensions of some features of the present invention may have been exaggerated for the sake of clarity.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The invention will, in the following, be exemplified by embodiments. It is to be understood, however, that the embodiments are included in order to explain principles of the invention and not to limit the scope of the invention defined by the appended claims.

Fig. 1 illustrates a two-shaft turbofan gas turbine aircraft engine 1, which is circumscribed about an engine longitudinal central axis 2. The engine 1 comprises an outer casing or nacelle 3, an inner casing 4 (rotor) and an intermediate casing 5. The intermediate casing 5 is concentric to the first two casings and divides the gap between them into an inner primary gas channel 6 for the compression of air and a secondary channel 7 through which the engine bypass air flows. Thus, each of the gas channels 6, 7 is annular in a cross section perpendicular to the engine longitudinal central axis 2.

The engine 1 comprises a fan 8 which receives ambient air 9, a booster or low pressure compressor (LPC) 10 and a high pressure compressor (HPC) 11 arranged in the primary gas channel 6, a combustor 12 which mixes fuel with the air pressurized by the high pressure compressor 11 for generating combustion gases which flow downstream through a high pressure turbine (HPT) 13 and a low pressure turbine (LPT) 14 from which the combustion gases are discharged from the engine.

A high pressure shaft joins the high pressure turbine 13 to the high pressure compressor 11 to substantially form a high pressure rotor. A low pressure shaft joins the low pressure turbine 14 to the low pressure compressor 10 to substantially form a low pressure rotor. The low pressure shaft is at least in part rotatably disposed co-axially with, and radially inwardly of, the high pressure rotor.

The Fig. 1 engine 1 further comprises a turbine exhaust casing 15 located downstream of the high pressure turbine 13. Moreover, in Fig. 1, the turbine exhaust casing 15 and a containment assembly 16 of the present invention form a turbine exhaust casing assembly 17.

However, in other embodiments of the present invention, the containment assembly 16 may be located at other positions in the engine 1. Purely by way of example, a containment assembly (not shown in Fig. 1) may be located at the low pressure compressor 10, at the high pressure compressor 11 or between the low pressure and high pressure compressors 10, 11.

Furthermore, in other embodiments of the present invention, the containment assembly 16 may be located in another type of gas turbine engine. Purely by way of example, an embodiment of the containment assembly 16 may be located in a gas turbine engine that includes only one rotating shaft (not shown) connecting a turbine to a compressor. Moreover, and again purely by way of example, an embodiment of the containment assembly 16 may be located in a gas turbine engine that includes three or more rotating shafts (not shown).

In a similar vein, in embodiments of the present invention, a containment assembly (not shown in Fig. 1) may be located at the low pressure turbine 13, at the high pressure turbine 14 or between the low pressure and high pressure turbines 13, 14. Furthermore, in embodiments of the present invention, a containment assembly (not shown in Fig. 1) may be attached to the nacelle 3 at a location upstream, at or downstream the fan 8.

Moreover, it should be noted that an embodiment of the engine 1 of the present invention may comprise a plurality of containment assemblies (not shown).

Fig. 2a illustrates the turbine exhaust casing assembly 17 that has been previously discussed in conjunction with Fig. 1. As has been intimated hereinabove, the turbine exhaust casing assembly 17 comprises a turbine exhaust casing 15 and a containment assembly 16. It should however be reiterated that the turbine exhaust casing 15 merely serves as one example of a casing around which a containment assembly 16 may be circumscribed.

The turbine exhaust casing assembly 17 is adapted to be located downstream of the high pressure turbine 14 of the Fig. 1 engine (not shown in Fig. 2a). To this end, the turbine exhaust casing 15 may preferably comprise a flange 18 for attachment to a portion of the intermediate casing (not shown in Fig. 2a). Purely by way of example, the turbine exhaust casing 15 may be attached to the intermediate casing by means of a weld joint or a bolt joint (not shown in Fig. 2a).

The containment assembly 16 is adapted to circumscribe the casing 15. The casing 15 has an axial extension in an axial direction A and a circumferential extension in a circumferential direction C. In the embodiment illustrated in Fig. 2a, the axial direction A substantially coincides with the engine longitudinal central axis of the Fig. 1 engine. However, in other embodiments, the axial direction A may form an angle with the engine longitudinal central axis.

Fig. 2a further illustrates that the casing 15 comprises an inner casing surface 15' and an outer casing surface 15". As has been discussed previously in relation to Fig. 1, the inner casing surface 15' is adapted to form a part of a duct of the gas turbine engine. In the Fig. 2a implementation of the casing, the inner casing surface 15' is adapted to delimit a portion of the inner primary gas channel (see Fig. 1), i.e. the inner casing surface 15' is in the Fig. 2a embodiment adapted constitute a portion of a core flow duct.

The containment assembly 16 comprises an enclosing assembly 20 adapted to at least partially enclose the outer casing surface 15" when mounted. The containment assembly 16 further comprises a resilient means 26, or a resilient assembly, adapted to interact with the enclosing assembly 20. Such an interaction will be discussed in detail hereinbelow.

Moreover, Fig. 2a illustrates that the enclosing assembly 20 comprises at least two enclosing segments 22, 24 that are arranged at least partially in sequence in the circumferential direction C of the casing 15 when the containment assembly 16 circumscribes the casing 15. The Fig. 2a embodiment of the enclosing assembly 20 comprises twelve enclosing segments, although only two segments 22, 24 are discussed in detail hereinbelow.

Other embodiments of the present invention may comprise more or fewer enclosing segments. Purely by way of example, embodiments of the enclosing assembly 20 of the present invention may comprise at least six, preferably at least eight, enclosing segments. Preferably, an inner surface of each one of the enclosing segments is adapted to abut the outer casing surface 15".

The expression "at least partially in sequence in the circumferential direction C" is intended to clarify that each one the at least two enclosing segments 22, 24 is not in itself a member that fully encloses the casing.

Preferably, each one of the at least two enclosing segments 22, 24 comprises two axial end surfaces 22', 22", 24', 24", each one of which extends at least partially in the axial direction A. By the wording "axial end surface" is meant a surface that extends at least partially in the axial direction and faces at least partially in the circumferential direction. In the embodiment of the containment assembly 16 shown in figure 2a, there is a gap between the axial end surfaces 22", 24' of two adjacent enclosing segments 22, 24. In another embodiment of the containment assembly 16 of the present invention, one axial end surface of one enclosing segment 22 may be adapted to abut an axial end surface of an adjacent enclosing segment 24.

In the Fig. 2a embodiment of the containment assembly 16, the axial end surfaces 22', 22", 24', 24" extend in a direction that is substantially parallel to the axial direction A. However, in other embodiments of the containment assembly 16, each one of the two axial end surfaces 22', 22", 24', 24" of at least one enclosing segment 22, 24 extends in a direction that forms an angle with the axial direction A. Preferably, the absolute value of the angle is smaller than or equal to 30°, more preferred smaller than or equal to 10°.

An example of such an embodiment is illustrated in Fig. 3, wherein the absolute value of the angle a between each one of two axial end surfaces 22", 24' and the axial direction A is approximately 30°. When determining the angle between an axial end surface and the axial direction A, the following method may preferably be employed. In the method hereinbelow, the axial end surface 22" of the first containment segment 22 is used as an example.

Firstly, a Cartesian coordinate system (X, Y, Z) is established. The axial direction A is preferably parallel to one of the dimensions of the Cartesian coordinate system (X, Y, Z). In the Fig. 3 example, the axial direction A is parallel to the X dimension. A normal vector *n* extending in the normal direction of the axial end surface 22", as well as a vector *v* extending along the axial direction A, both expressed in the Cartesian coordinate system (X, Y, Z), are thereafter determined. If the normal direction of the axial end surface 22" varies along the axial direction A, the normal vector *n* for the portion of the axial end surface 22" that is located in the intended upstream portion of the first containment segment 22 is used. The angle between the vector *v* and the axial end surface 22" is then determined by the following equation:

$$\cos(90° - \alpha) = \frac{|vn|}{|v|\cdot|n|} .$$

As may be realized from Fig. 3, a containment segment 22 may have axial end surfaces 22', 22" that extend in different directions, i.e. that form different angles α, β with the axial direction A.

Turning back to Fig. 2a, it is illustrated therein that at least one enclosing segment 22, 24 comprises a first circumferential end surface 23', 25' and a second circumferential end surface 23", 25", each one of which extending in the circumferential direction C. By the wording "circumferential end surface" is meant a surface that extends at least partially in the circumferential direction and faces at least partially in the axial direction. Preferably, at least one of the axial end surfaces 22', 22", 24', 24" extends between the first circumferential end surface 23', 25' and the second circumferential end surface 23", 25". In the Fig. 2a embodiment, as well as the Fig. 3 embodiment, for each one of the enclosing segments 22, 24, each one of the axial end surfaces 22', 22", 24', 24" extends between the first circumferential end surface 23', 25' and the second circumferential end surface 23", 25".

Moreover, in the embodiment illustrated in Fig. 2a, each one of the at least two enclosing segments 22, 24 comprises a polygonal plate, preferably a substantially rectangular plate, having a curved shape that corresponds to the circumferential extension of the casing 15. Two opposite sides of the polygonal plate are preferably in parallel with each other and extend at least partially in the circumferential direction. A length of the plate (in the circumferential direction) is preferably substantially larger than a width of the plate (in the axial direction).

As regards the resilient means 26, when the containment assembly 16 is mounted to a casing 15 with a circumferential extension in a circumferential direction C, the resilient means 26 preferably provides a stiffness in the circumferential direction which is less than 50%, preferably less than 25%, more preferred less than 10%, of the stiffness of one of the enclosing segments 22, 24 in the circumferential direction C.

The choice of material for the resilient means 26 may be dependent on the location of the containment assembly 16. Purely by way of example, when the containment assembly 16 is adapted to circumscribe at least a portion of the nacelle (not shown in Fig, 2), the resilient means 26 may comprise a polymer material such as KEVLAR®. However, if the containment assembly 16 is adapted to be located in a hot region, i.e. downstream of the combustion portion, of an engine the resilient means preferably comprises a material with an appropriate thermal resistance.

Purely by way of example, the resilient means 26 may be made of a metal or a metal alloy. In the Fig. 2a implementation, the resilient means 26 comprises a wire, preferably a metal wire and more preferred a steel wire. In fact, the Fig. 2a implementation comprises two steel wires, although other embodiments of the containment assembly 16 of the present invention may only comprise one wire whilst other embodiments may comprise three or more wires (not shown). The wires 26 are preferably arranged in parallel with each other and at a distance from each other in the axial direction.

Preferably, the resilient means 26, i.e. the steel wires in the Fig. 2a implementation, is adapted to extend around the circumference of the casing 15, when the containment assembly 16 circumscribes the casing 15.

In order to obtain a desired stiffness of the one or more wires that the resilient means 26 may comprise, at least one, although preferably each one, of the wires is preferably prestressed to a predetermined stress level. To this end, although purely by way of example, each one of the wires may have end portions (not shown) that are provided with a threaded arrangement (not shown) and a wire may be prestressed by operating the threaded arrangement. Optionally, a wire may be prestressed by clamping the end portions of a wire and subsequently pulling the end portions towards one another, for instance by using a tool such as a jack. The end portions of wire may then be fixedly attached to one another, for instance by means of welding.

Moreover, the casing 15 has a radial extension in a radial direction R and the resilient means 26 is preferably adapted to be located outside, in the radial direction R, of the at least two enclosing segments 22, 24.

In order to keep the resilient means 26, e.g. the steel wires in the Fig. 2a embodiment, in place in relation to the least two enclosing segments 22, 24, each one of the enclosing segments 22, 24 preferably is attached to one or more loops 28, 30 through which a portion of the resilient means 26, e.g. a portion of a steel wire in the Fig. 2a embodiment, may run.

Instead of, or in addition to, the loops, each one of the enclosing segments 22, 24 may be provided with one or more grooves (not shown in Fig. 2a) adapted to accommodate at least a portion of the resilient means 26.

Purely by way of example, the resilient means 26 may be adapted to abut the at least two enclosing segments 22, 24 when the containment assembly circumscribes the casing 15. To this end, reference is made to Fig. 2b, for instance, that illustrates that each one of the two wires 26', 26" of the Fig. 2a implementation of the resilient means 26 abuts the first enclosing segment 22 of the enclosing assembly 20.

Fig. 2b further illustrates that at least a portion of the enclosing assembly 20 preferably may be located in a groove 27 in the casing 15 in order to prevent, or at least reduce the risk, that the enclosing assembly 20 is displaced, at least in the axial direction A, relative to the casing 15. Purely by way of example, the groove 27 may be circumferentially extending around the casing 15.

It should be noted that the resilient means 26 need not necessarily be in contact with the enclosing segments 22, 24 of the enclosing assembly 20. To this end, reference is made to Fig. 4a illustrating an embodiment of a containment assembly 16 wherein the resilient means 26, which means in Fig. 4a is implemented as two wires 26', 26", is located at a distance, in the radial direction R, from the enclosing segments 22, 24.

With reference to Fig. 4b, at least some of the loops 28 attached to an enclosing segment 22 may comprise a spacing portion 28' for providing a space between the enclosing segment 22 and the intended position of the resilient means 26.

Fig. 5 illustrates another implementation of a resilient means 26. As may be gleaned from Fig. 5, the implementation of the resilient means 26 illustrated therein comprises a plurality of resilient members 32, 34, each one of which connects at least two enclosing segments 22, 24. Purely by way of example, a resilient member 32 may be constituted by a bent sheet metal member. Moreover, and again purely by way of example, each one of the resilient members 32, 34 may be fixedly attached to two enclosing segments 22, 24, for instance by means of a weld joint (not shown) or a bolt joint (not shown).

Another option for fixedly attaching each one of the resilient members 32, 34 to two enclosing segments 22, 24 may be to furnish each one of the enclosing segments 22, 24 with flanges (not shown) that extend parallel to the axial end surfaces of the corresponding enclosing segments. A resilient member may then be connected to one flange of each one of two adjacent enclosing segments, for instance by means of bolt joints, in order to thereby obtain a resilient connection between the two segments 22, 24.

Purely by way of example, the resilient member between the flanges may be manufactured of a periodic cellular material (PCM), preferably a periodic cellular metal. For instance, and again purely by way of example, the periodic cellular material may be manufactured as a honeycomb and/or sandwich structure. As another example, the above resilient member may comprise a metal foam. Generally a metal foam has a cellular structure that constists of metal and a large volume fraction of gas-filled pores. Purely by way of example, the metal foam may be applied to the flanges by means of metal deposition.

Fig. 6a illustrates an implementation of the enclosing assembly 20 wherein each one of the enclosing segments 22, 24 comprises an overlapping portion 36, 38. The overlapping portion 36 of one of the enclosing segments 22 is adapted to overlap, i.e. to assume a position at least partially radially outside and circumferentially coincident with, a portion of an adjacent enclosing segment 24. The Fig. 6a embodiment comprises a resilient means 26 that is implemented as two wires 26', 26", though the implementation of the enclosing assembly 20 with overlapping portions 36, 38 could also be used with any other implementation of the resilient means 26. Purely by way of example, the implementation of the enclosing assembly 20 with overlapping portions 36, 38 could be used with separate resilient members, such as the resilient members 32, 34 discussed hereinabove in relation to Fig. 5.

Fig. 6b illustrates an enlarged portion of the Fig. 6a embodiment illustrating only two of the enclosing segments 22, 24. As may be gleaned from Fig. 6b, an overlapping portion may preferably be furnished with guide means, such as protrusions, for guiding at least a portion of the resilient means 26. In the Fig. 6b implementation of the enclosing assembly 20, the overlapping portion 36 is provided with two grooves 36', 36" each one of which being adapted to accommodate a portion of a corresponding wire 26', 26".

As has been discussed hereinabove with relation to e.g. Fig. 2b, a casing 15 may preferably be provided with a groove 27. Instead of, or in addition to, the grove 27, the casing may be provided with one or more shoulders (not shown) for preventing, or at least reducing, at least and axial displacement of the containment assembly 16 relative to the casing 15. Preferably, at least one of the shoulders may be located downstream of the enclosing assembly 20.

However, instead of, or in addition to, a groove in the casing 15 and/or shoulder(s) attached to the casing 15, at least some of the enclosing segments 22, 24 of an enclosing assembly may comprise a flange with openings for receiving attachment means that are also attached to a portion of the casing 15.

To this end, reference is made to Figs. 7a and 7b illustrating an embodiment of the containment assembly 16 wherein each one of the enclosing segments 22, 24 comprises an upstream flange 42 and a downstream flange 44 (with reference to the intended direction of flow through the engine). In the Fig. 7b implementation of the enclosing segment 22, both of the flanges 42, 44 extend along the full length of the enclosing segment 22 in the circumferential direction C. However, in other implementations of an enclosing segment, at least one of the flanges may be shorter than the length of the corresponding enclosing segment (not shown in Fig. 7b).

The upstream flange 42 of the Fig. 7b enclosing segment 22 is adapted to be connected to the attachment flange 18 of the casing 15. Moreover, the downstream flange 44 is adapted to be connected to a second flange 45 of the casing 15, which second flange 45 is located upstream an engine support assembly 46 of the casing 15.

On advantage with furnishing at least some of the enclosing segments 22 with an upstream flange 42 as well as a downstream flange 44 is that the enclosing segment 22 may be prevented from being displaced, at least in the axial direction A, in relation to the attachment flange 18 as well as the second flange 45 of the casing 15. As such, the enclosing segments 22 may contribute to a load transfer from the attachment flange 18 to the second flange 45, at least for axial loads.

In order to make possible that the enclosing segments 22 are displaced, e.g. radially, in a blade-out event to thereby enable that the resilient means 26 absorbs at least some of the impact energy possibly generated therefrom, each one of the openings 48 in at least one of the flanges 40, 42 preferably has a larger cross-section than the cross-section of the corresponding attachment means, which in Fig. 7b are exemplified as bolts 50, that are adapted to extend through the openings 48.

The cross-section of each one of the openings 48 need not necessarily be circular. Instead, the openings' cross-section may be elongate, e.g. oval, wherein the larger portion of the elongate cross-section extends at least partially in the radial direction R (not shown in Fig. 7b).

When the containment assembly 16 of the present invention is adapted to form a part of a casing assembly 17 that is adapted to be located downstream of the combustion portion of a gas turbine engine, the casing assembly may be subjected to relatively high thermal loads.

Since the casing 15 in such a case is generally delimiting a duct guiding hot fluids, the casing 15 will often be subjected to larger thermal loads as compared to the containment assembly 16. As such, the casing 15 may preferably be made of a first material and at least one segment 22, 24 of the enclosing assembly 20 may preferably be made of a second material. The first material may preferably have a thermal resistance that is greater than the thermal resistance of the second material.

Purely by way of example, the first material may be a nickel alloy or a steel alloy manufactured as cast, forge or sheet. Moreover, and again purely by way of example, the second material may be a nickel alloy, a steel alloy or a high containment capability material manufactured as forging or sheet.

As another opinion, the casing 15 and the enclosing segments 22, 24 of the enclosing assembly 20 may be made of the same, or at least similar, material but the components may be manufactured by different manufacturing methods. Purely by way of example, the casing 15 may be made of a cast material and the enclosing segments may be made of a forged material or a sheet material, e.g. a sheet metal or a sheet metal alloy.

While there have been shown and described and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art.

For instance, although various implementations of the resilient means 26 have been discussed hereinabove, additional implementations of the resilient means 26 may be used instead of, or in addition to, the previously disclosed implementations (e.g. the metal wires 26', 26" or the resilient members 32, 34).

To this end, reference is made to Fig. 8a that illustrates another implementation of the resilient means 26. As may be gleaned from Fig. 8a, the resilient means 26 may be a spring, preferably a leaf spring, that is enclosed by portions of two adjacent enclosing segments 22, 24. Preferably, the end portions of two adjacent enclosing segments 22, 24 may be designed such that the spring is substantially prevented from being displaced at least in the circumferential direction C as well as the radial direction R relative to the adjacent enclosing segments 22, 24.

Purely by way of example, one of the enclosing segments 22 may be provided with a groove 52 into which a portion 54 of the other enclosing segment 24 may be accommodated. Moreover, the end portions of the enclosing segments 22, 24 may be shaped such that a cavity 56 is formed therebetween. Preferably, the cavity 56 is delimited by the first and/or second enclosing segment 22, 24 at least in the circumferential direction C and the radial direction R.

The cavity 56 may preferably have a substantially rectangular cross-section and may for instance be delimited on three sides by one of the enclosing segments 24, such as is illustrated in Fig 8a. Optionally, the cavity 56 may be delimited on two sides by one of enclosing segments 22 and on the two other sides by the other enclosing segment 24, such as is illustrated in Fig. 8b.

Either one of the embodiments of the containment assemblies 16 illustrated in Fig. 8a or Fig. 8b may preferably be combined with circumferentially extending flanges that have been discussed hereinabove, e.g. with reference to Fig. 7a and Fig. 7b.

In order to install either one of the embodiments of the containment assemblies 16 illustrated in Fig. 8a or Fig. 8b, the cavity portions 58, 60 of the first and second enclosing segments 22, 24 that form the cavity 56 may preferably firstly be provided as separate members. The separate members and the spring 26 are then connected to one another and the each one of the cavity portions 58, 60 is then fixedly attached, preferably by weld joints, to the remaining portion of its corresponding enclosing segment 22, 24.

For each one of the implementations discussed hereinabove with reference to Fig. 8a and 8b, the spring 26 may for instance be made of, or at least comprise, a periodic cellular material and/or a metal foam.

It should be noted that it is expressly intended that all combinations of those elements and/or method steps which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention.

Moreover, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

CLAIMS

1. A containment assembly (16) adapted to circumscribe a casing (15) for a gas turbine engine (1), said casing (15) having an axial extension in an axial direction (A) and a circumferential extension in a circumferential direction (C) and comprising an inner casing surface (15') and an outer casing surface (15"), said inner casing surface (15') being adapted to form a part of a duct (6, 7) of said gas turbine engine (1), said containment assembly (16) comprising an enclosing assembly (20) adapted to at least partially enclose said outer casing surface (15") when mounted, said containment assembly (16) further comprising a resilient means (26) adapted to interact with said enclosing assembly (16), characterized in that said enclosing assembly (20) comprises at least two enclosing segments (22, 24) that are arranged at least partially in sequence in said circumferential direction (C) of said casing (15) when said containment assembly (16) circumscribes said casing (15).

2. The containment assembly (16) according to claim 1, when said containment assembly (16) circumscribes said casing (15), each one of said at least two enclosing segments (22, 24) comprises two axial end surfaces (22', 22", 24', 24"), each one of which extending at least partially in said axial direction (A).

3. The containment assembly (16) according to claim 2, wherein, when said containment assembly (16) circumscribes said casing (15), at least one enclosing segment (22, 24) comprises a first circumferential end surface (23', 25') and a second circumferential end surface (23", 25"), each one of which extending in said circumferential direction (C), at least one of said axial end surfaces (22', 22", 24', 24") extending between said first circumferential end surface (23', 25') and said second circumferential end surface (23", 25").

4. The containment assembly (16) according to claim 2 or 3, wherein each one of said two axial end surfaces (22', 22", 24', 24") of at least one enclosing segment (22, 24) extends in a direction that forms and angle with said axial direction (A), the absolute value of said angle being smaller than or equal to 30°, preferably smaller than or equal to 10°.

5. The containment assembly (16) according to any one of the preceding claims, wherein each one of said at least two enclosing segments (22, 24) comprises a rectangular plate having a shape corresponding to said circumferential direction (C) of said casing (15).

6. The containment assembly (16) according to any one of the preceding claims, wherein each one of said at least two enclosing segments (22, 24) comprises an overlapping portion (36, 38), said overlapping portion (36) of one enclosing segment (22) being adapted to overlap a portion of another enclosing segment (24) when said containment assembly (16) circumscribes said casing (15).

7. The containment assembly (16) according to any one of the preceding claims, wherein at least one of said enclosing segments (22, 24) comprises a flange (40) that is adapted to extend at least partially in said circumferential direction (C) when said containment assembly (16) circumscribes said casing (15), said flange (40) comprising at least one opening (48) for receiving an attachment means (50), which attachment means (50) further is adapted to be attached to said casing (15).

8. The containment assembly (16) according to any one of the preceding claims, wherein said resilient means (26) is made of a metal or a metal alloy.

9. The containment assembly (16) according to any one of the preceding claims, wherein said resilient means (26) comprises a wire, preferably a steel wire.

10. The containment assembly (16) according to any one of the preceding claims, wherein said resilient means (26) is adapted to extend around the circumference of said casing (15), when said containment assembly (16) circumscribes said casing (15).

11. The containment assembly (16) according to any one of the preceding claims, wherein said casing (15) has a radial extension in a radial direction (R), said resilient means (26) being adapted to be located outside, in said radial direction (R), said at least two enclosing segments (22, 24) when said containment assembly (16) circumscribes said casing (15).

12. The containment assembly (16) according to any one of the preceding claims, wherein said resilient means (26) is adapted to abut said at least two enclosing segments (22, 24) when said containment assembly (16) circumscribes said casing (15).

13. A casing assembly (17) for a gas turbine engine (1), said casing assembly (17) comprising a casing (15) having an axial extension in an axial direction (A) and a circumferential extension in a circumferential direction (C), said casing (15) comprising an inner casing surface (15') and an outer casing surface (15"), c h a racte rize d i n t h a t said casing assembly (17) comprises a containment assembly (16) according to any one of the preceding claims.

14. The casing assembly (17) according to claim 13, wherein said casing (15) is made of a first material and at least one segment (22, 24) of said enclosing assembly (20) is made of a second material, said first material having a thermal resistance being greater than the thermal resistance of said second material.

15. The casing assembly (17) according to claim 13 or 14, wherein said casing assembly (17) is adapted to be located downstream of a combustion chamber of said gas turbine chamber, preferably said casing assembly is adapted to be located downstream of a pressure turbine, more preferred a high pressure turbine, of said gas turbine chamber.

16. The casing assembly (17) according to any one of claims 13 to 15, wherein said casing (15) is a turbine exhaust casing.

17. A gas turbine engine (1), c h a r a cte rized i n t h a t it comprises a casing assembly (17) according to any one of claims 13 to 16.

18. An aeroplane, c h a racte rized i n t h a t it comprises a gas turbine engine (1) according to claim 17.

19. A containment assembly adapted to circumscribe a casing for a gas turbine engine, said casing having an axial extension in an axial direction and a circumferential extension in a circumferential direction and comprising an inner casing surface and an outer casing surface, said inner casing surface being

adapted to form a part of a duct of said gas turbine engine, said containment assembly comprising an enclosing assembly adapted to at least partially enclose said outer casing surface when mounted, said containment assembly further comprising a resilient assembly adapted to interact with said enclosing assembly, wherein said enclosing assembly comprises at least two enclosing segments that are arranged at least partially in sequence in said circumferential direction of said casing when said containment assembly circumscribes said casing.

20. The containment assembly according to claim 19, when said containment assembly circumscribes said casing, each one of said at least two enclosing segments comprises two axial end surfaces, each one of which extending at least partially in said axial direction.

21. The containment assembly according to claim 20, wherein, when said containment assembly circumscribes said casing, at least one enclosing segment comprises a first circumferential end surface and a second circumferential end surface, each one of which extending in said circumferential direction, at least one of said axial end surfaces extending between said first circumferential end surface and said second circumferential end surface.

22. The containment assembly according to claim 20 or 21, wherein each one of said two axial end surfaces of at least one enclosing segment extends in a direction that forms and angle with said axial direction, the absolute value of said angle being smaller than or equal to 30°, preferably smaller than or equal to 10°.

23. The containment assembly according to any one of the claims 19 to 22, wherein each one of said at least two enclosing segments comprises a rectangular plate having a shape corresponding to said circumferential direction of said casing.

24. The containment assembly according to any one of the claims 19 to 23, wherein each one of said at least two enclosing segments comprises an overlapping portion, said overlapping portion of one enclosing segment being adapted to overlap a portion of another enclosing segment when said containment assembly circumscribes said casing.

25. The containment assembly according to any one of the claims 19 to 24, wherein at least one of said enclosing segments comprises a flange that is adapted to extend at least partially in said circumferential direction when said containment assembly circumscribes said casing, said flange comprising at least one opening for receiving an attachment means, which attachment means further is adapted to be attached to said casing.

26. The containment assembly according to any one of the claims 19 to 25, wherein said resilient assembly is made of a metal or a metal alloy.

27. The containment assembly according to any one of the claims 19 to 26, wherein said resilient assembly comprises a wire, preferably a steel wire.

28. The containment assembly according to any one of the claims 19 to 27, wherein said resilient assembly is adapted to extend around the circumference of said casing, when said containment assembly circumscribes said casing.

29. The containment assembly according to any one of the claims 19 to 28, wherein said casing has a radial extension in a radial direction, said resilient assembly being adapted to be located outside, in said radial direction, said at least two enclosing segments when said containment assembly circumscribes said casing.

30. The containment assembly according to any one of the claims 19 to 29, wherein said resilient assembly is adapted to abut said at least two enclosing segments when said containment assembly circumscribes said casing.

31. A casing assembly for a gas turbine engine, said casing assembly comprising a casing having an axial extension in an axial direction and a circumferential extension in a circumferential direction, said casing comprising an inner casing surface and an outer casing surface, wherein said casing assembly comprises a containment assembly according to any one of the claims 19 to 30.

32. The casing assembly according to claim 31, wherein said casing is made of a first material and at least one segment of said enclosing assembly is made of a second material, said first material having a thermal resistance being greater than the thermal resistance of said second material.

33. The casing assembly according to claim 31 or 32, wherein said casing assembly is adapted to be located downstream of a combustion chamber of said gas turbine chamber, preferably said casing assembly is adapted to be located downstream of a pressure turbine, more preferred a high pressure turbine, of said gas turbine chamber.

34. The casing assembly according to any one of claims 31 to 33, wherein said casing is a turbine exhaust casing.

35. A gas turbine engine comprising a casing assembly according to any one of claims 31 to 34.

36. An aeroplane, comprising a gas turbine engine according to claim 35.

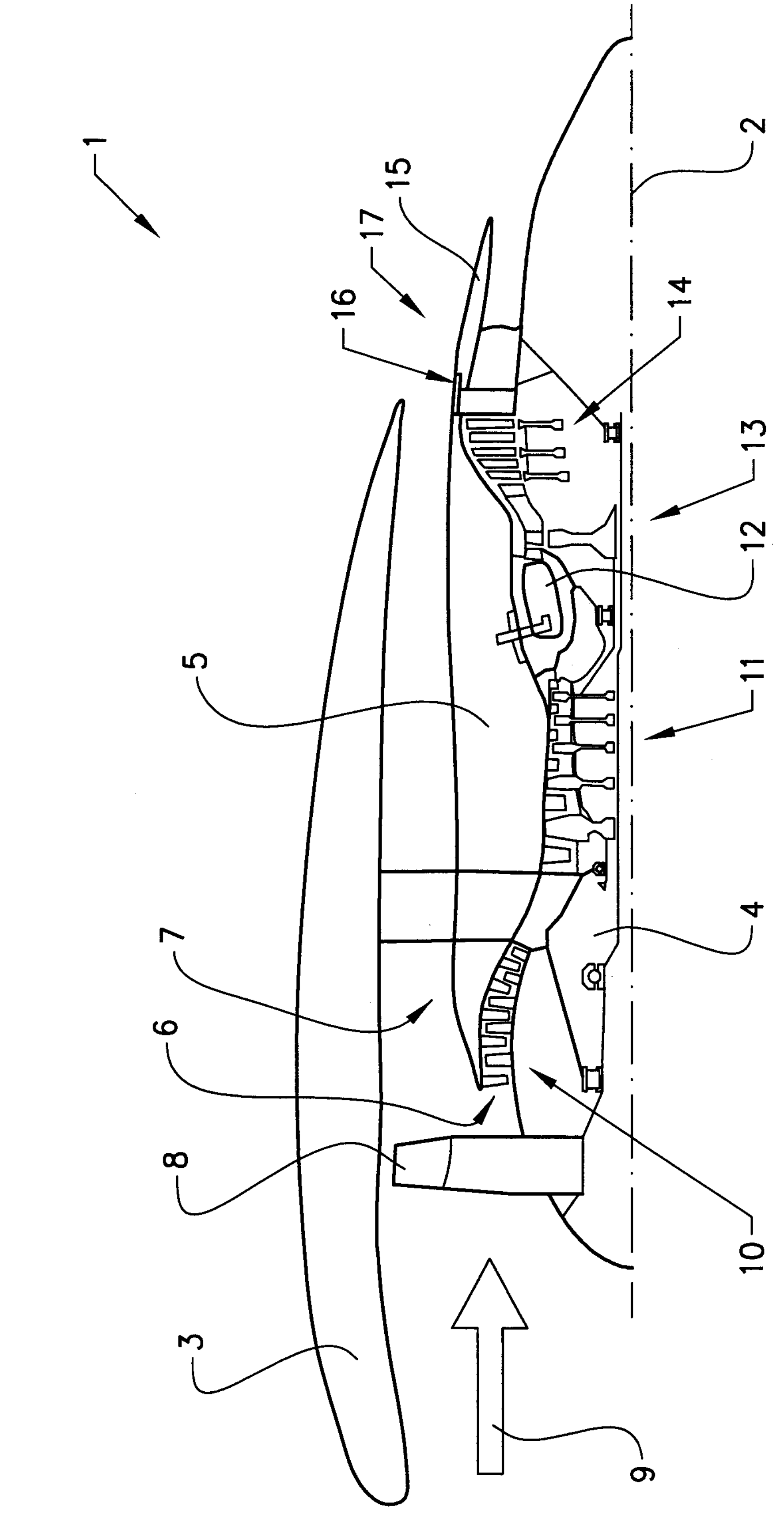

FIG. 1

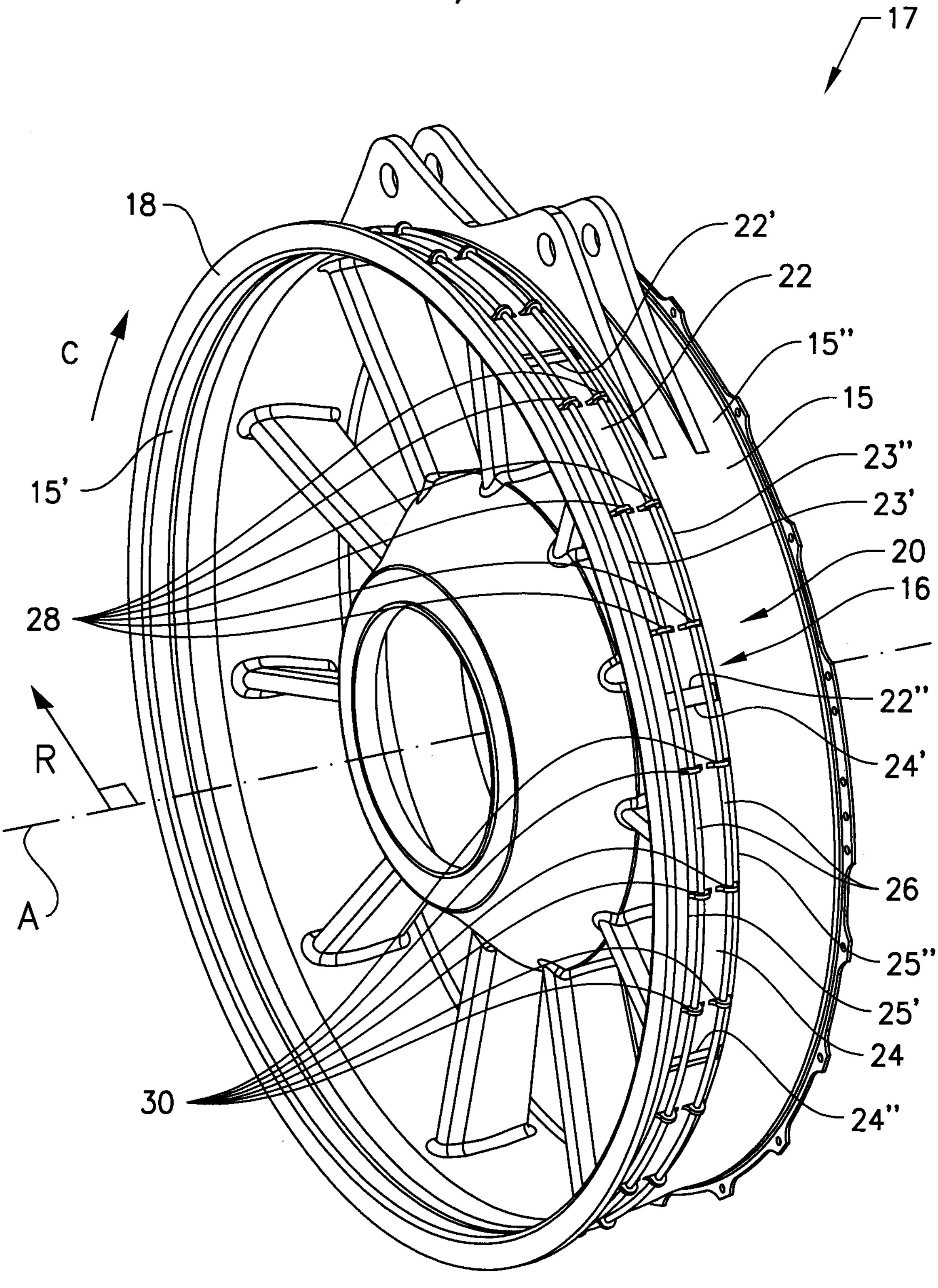

FIG. 2a

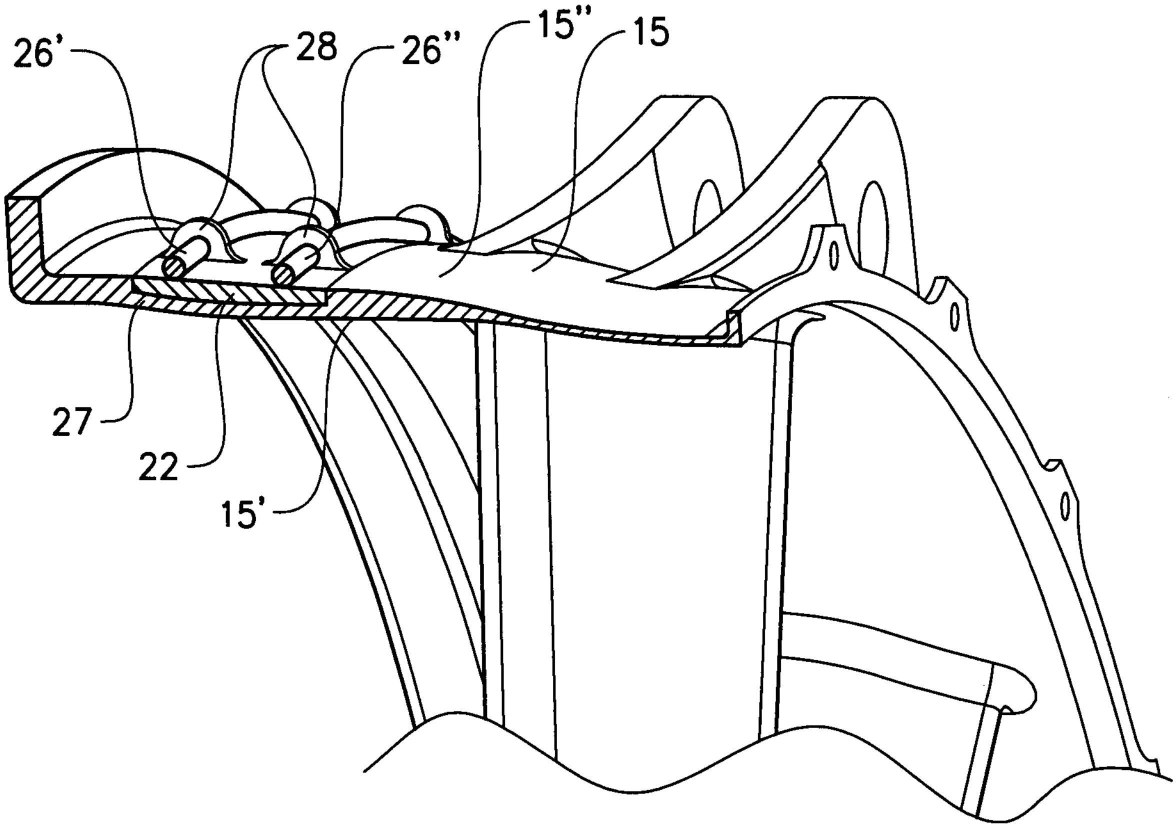

FIG. 2b

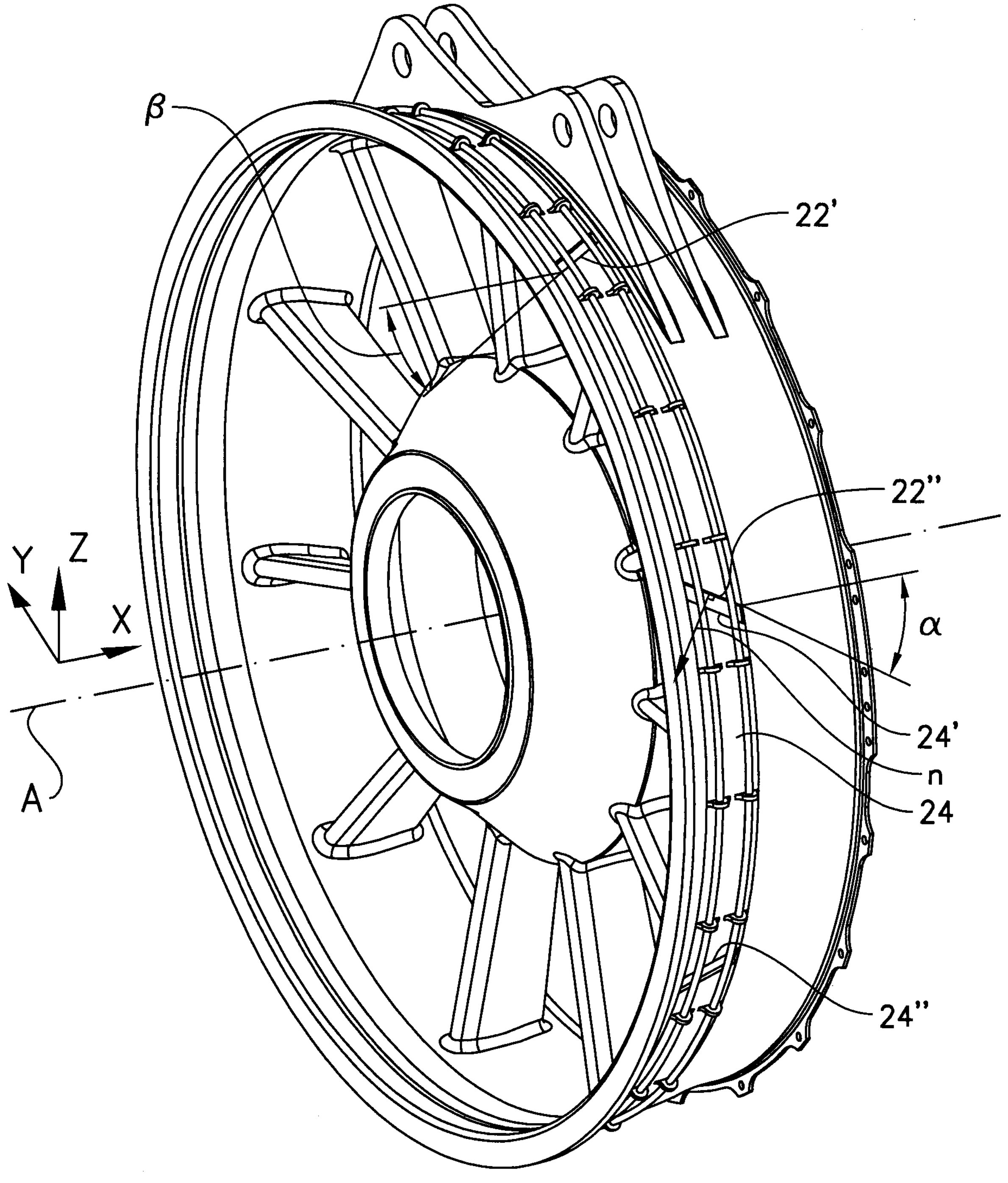

FIG. 3

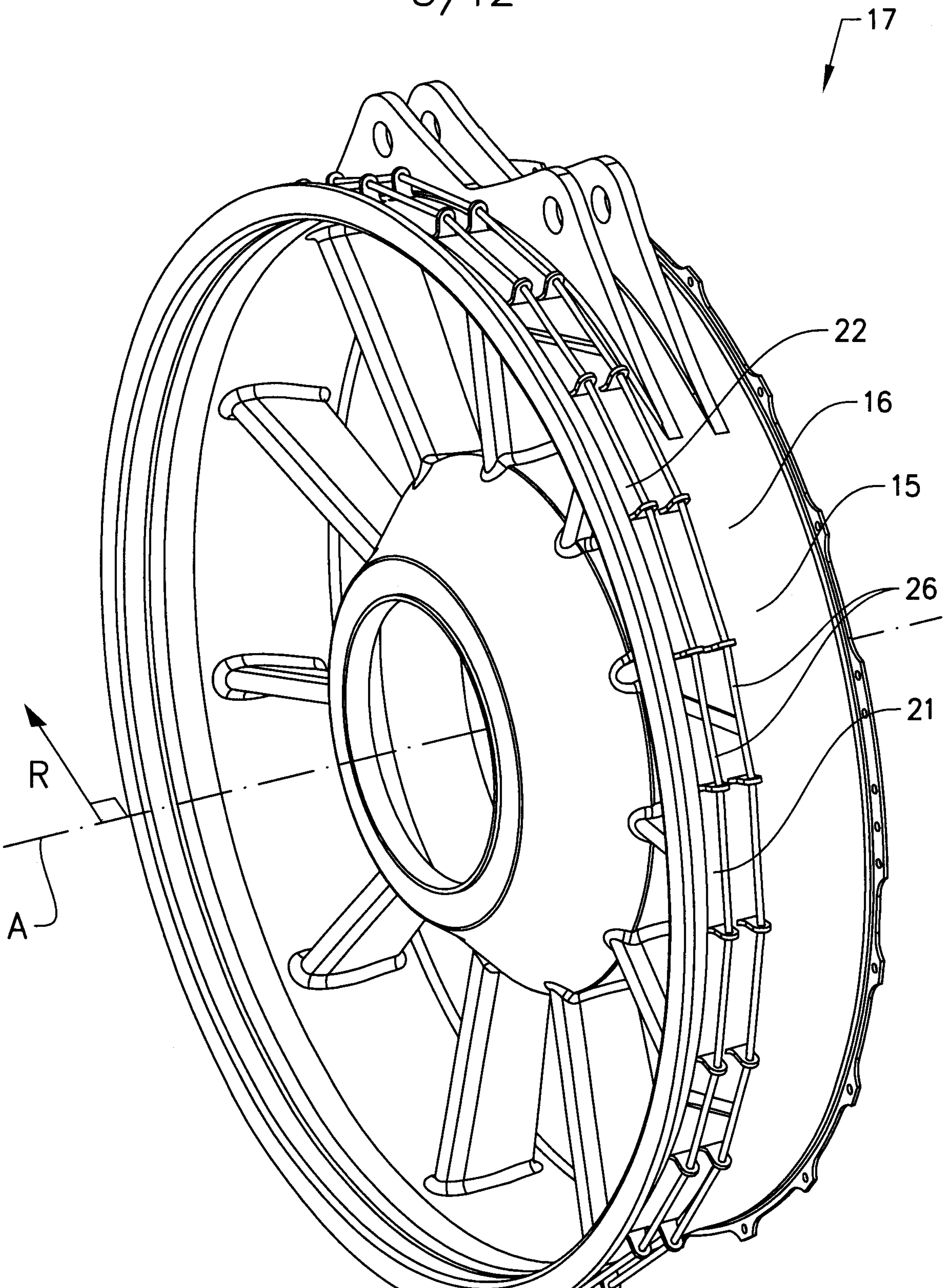

FIG. 4a

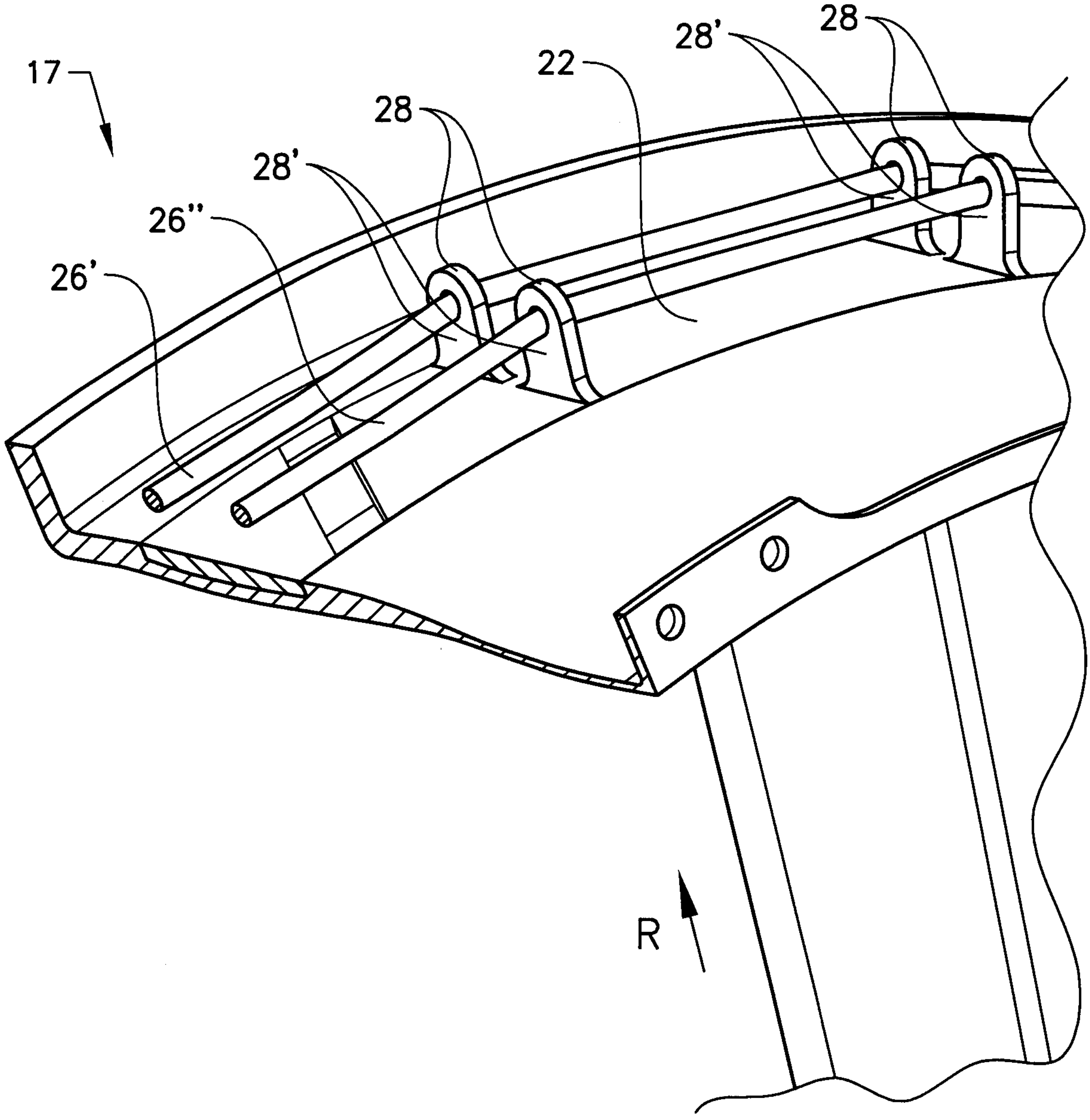

FIG. 4b

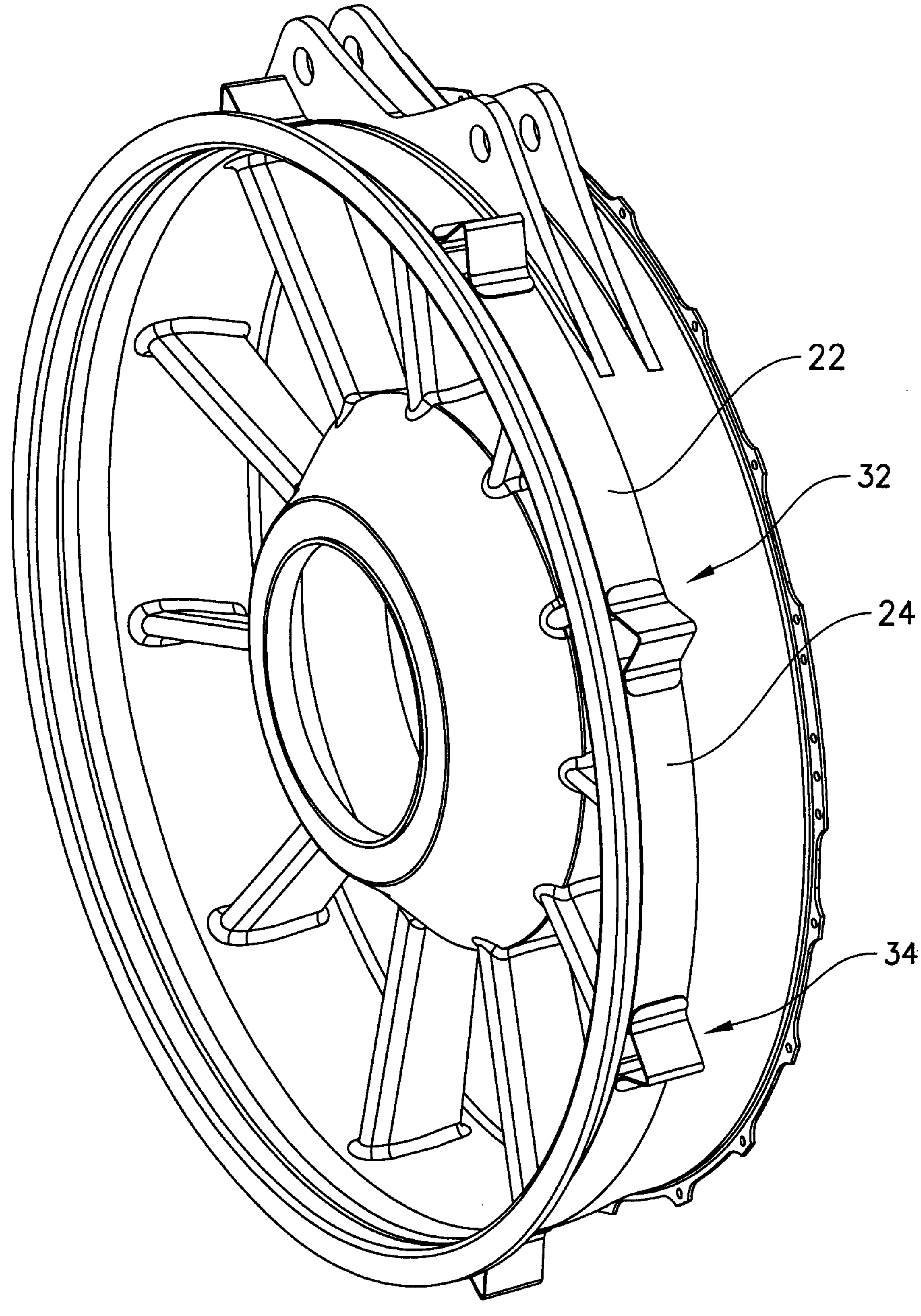

FIG. 5

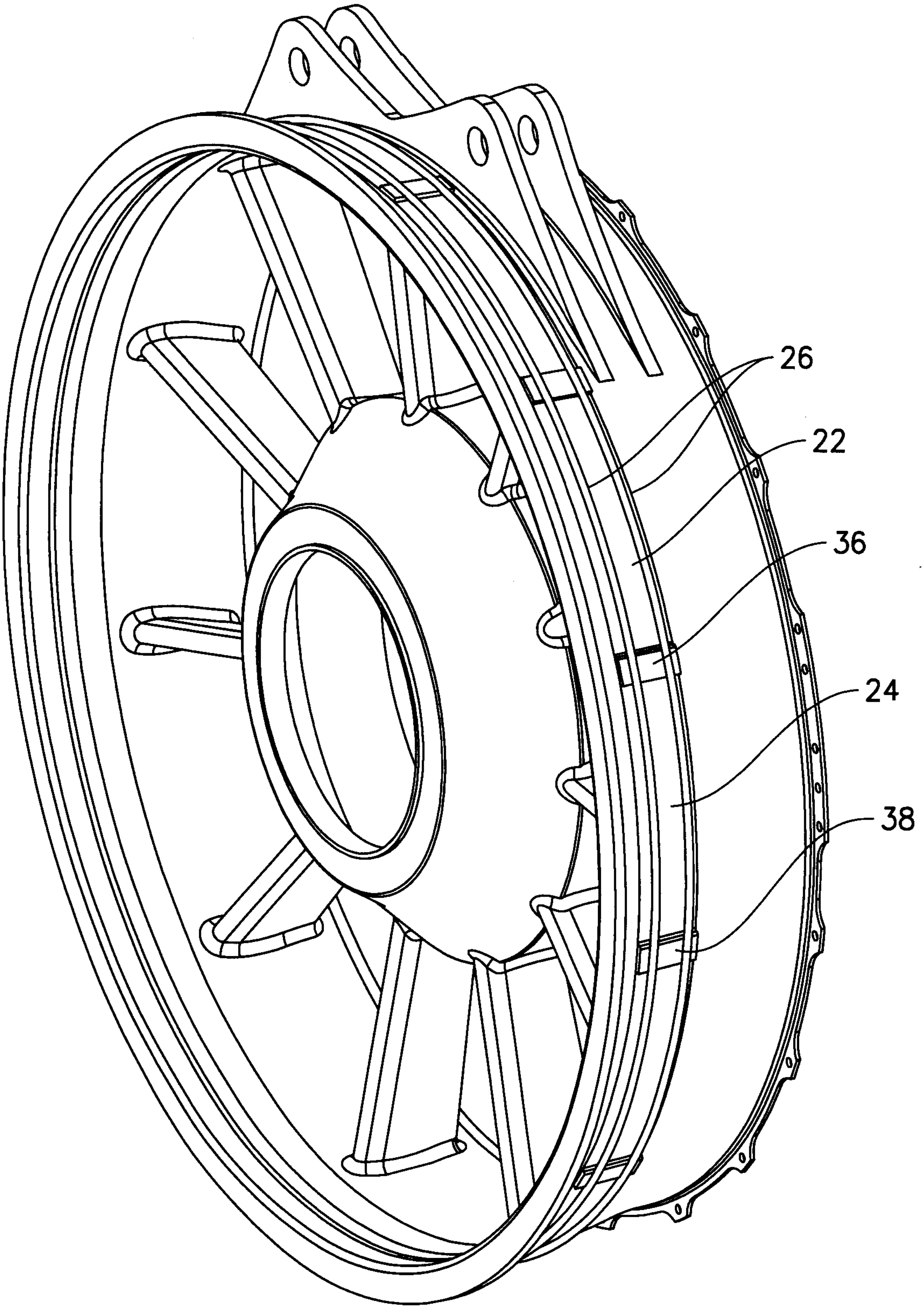

FIG. 6a

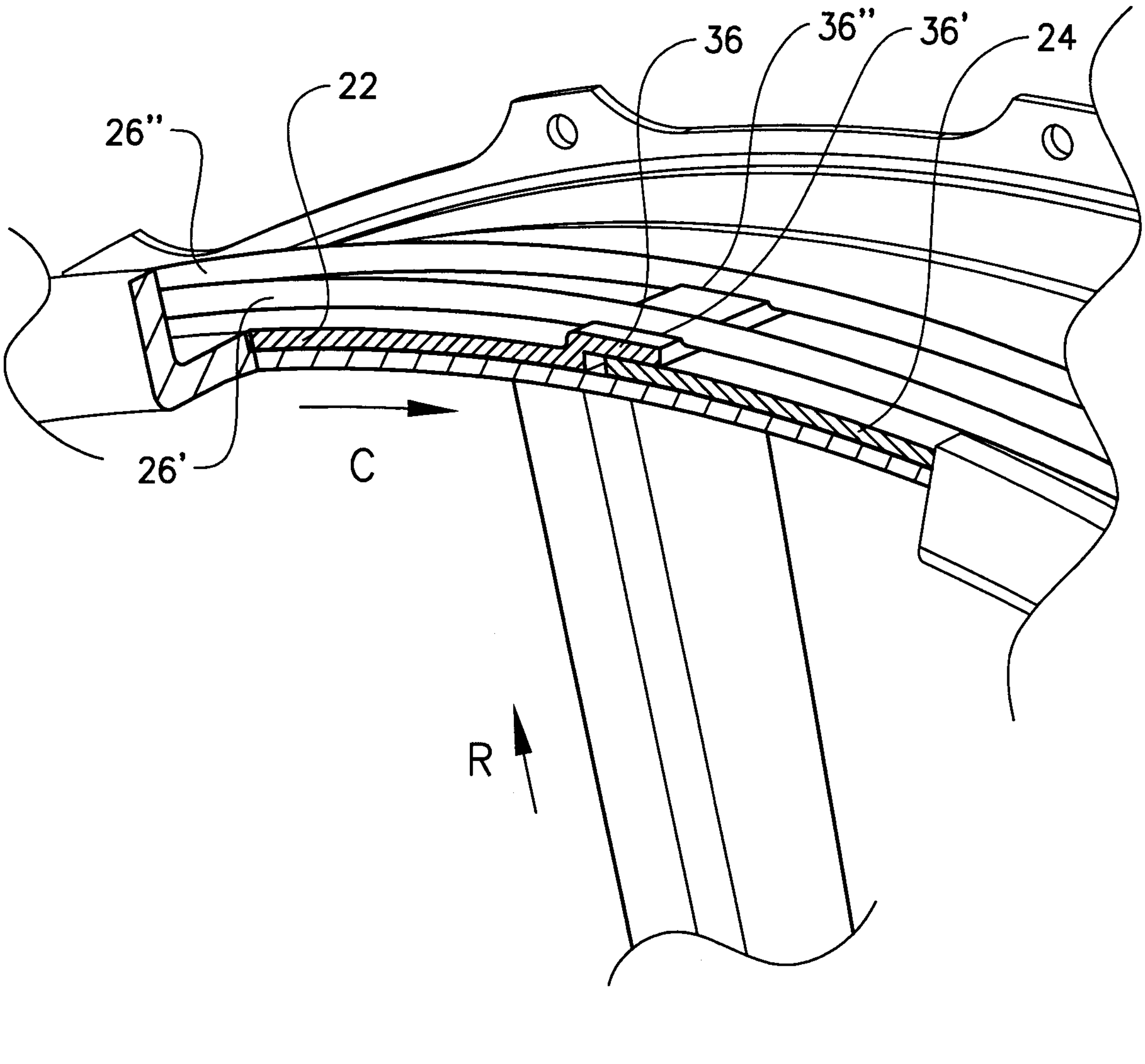

FIG. 6b

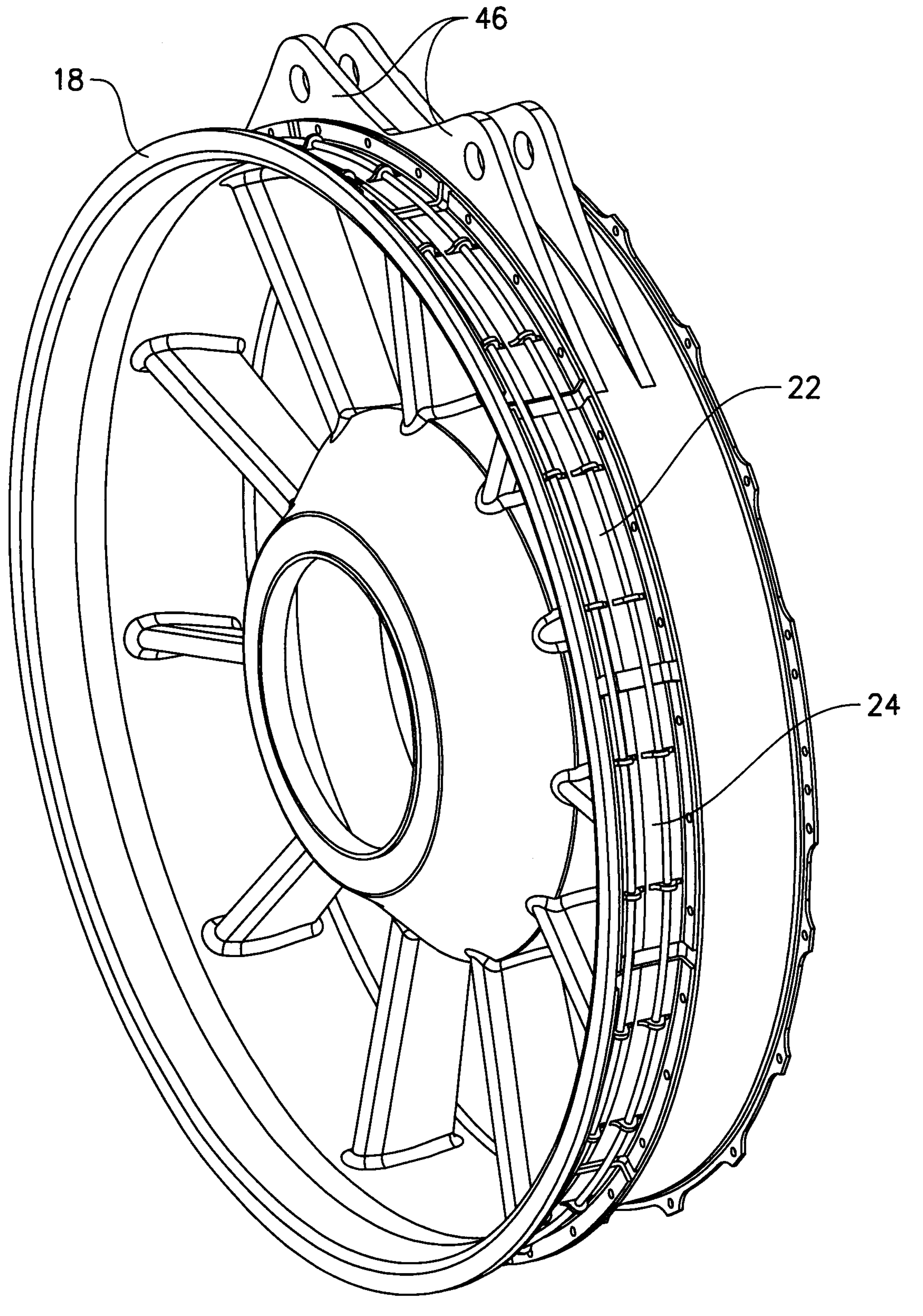

FIG. 7a

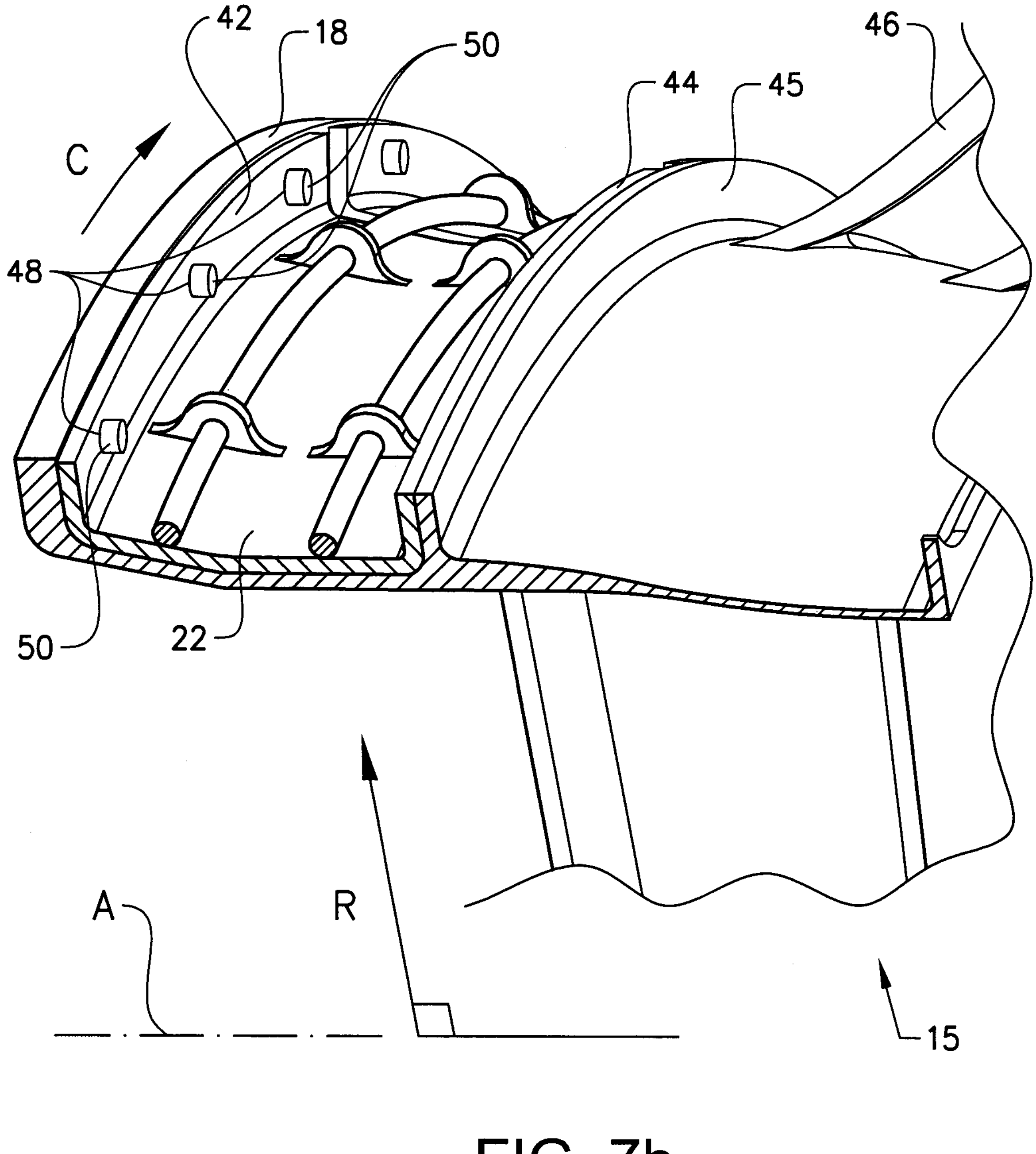

FIG. 7b

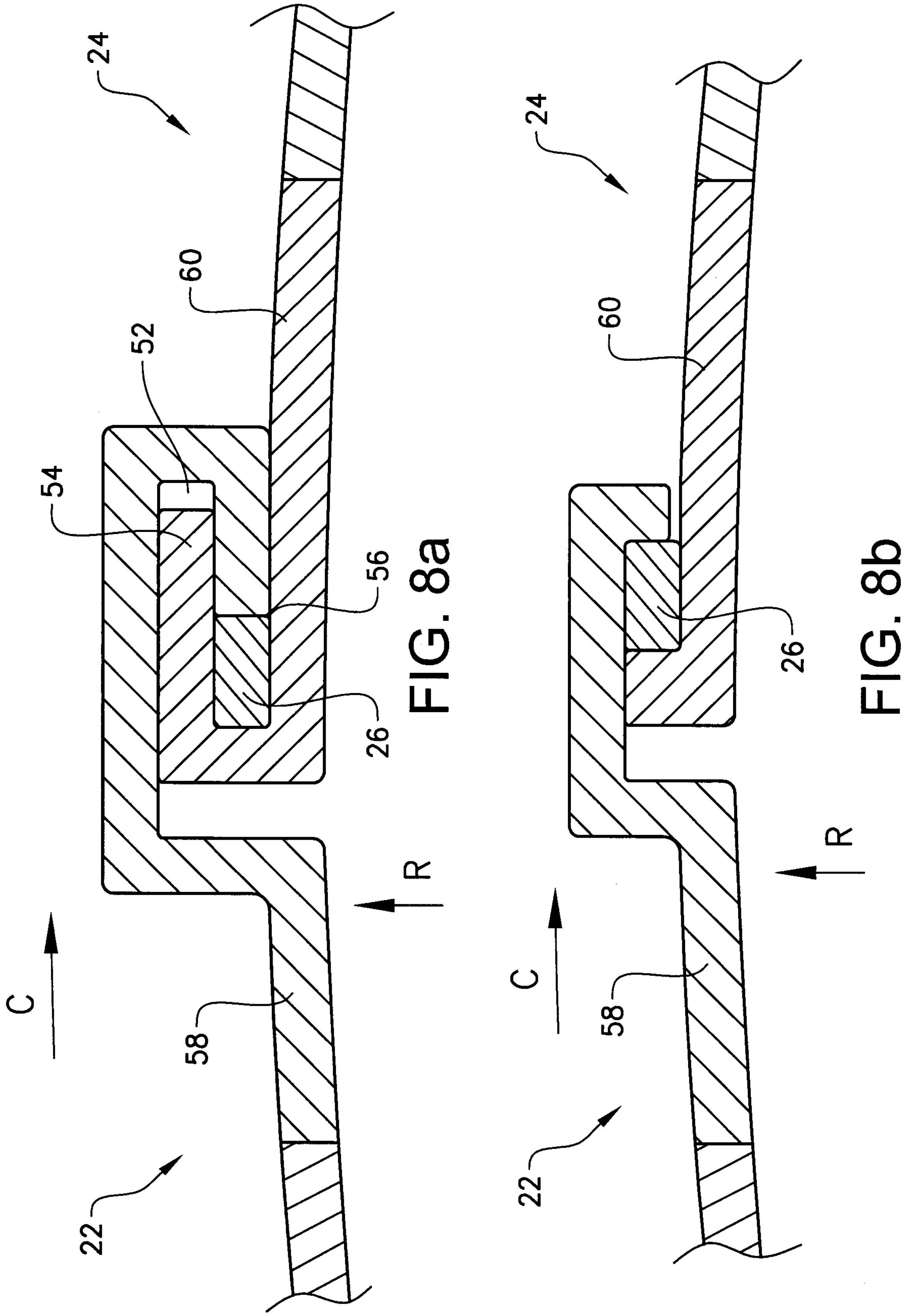

FIG. 8a

FIG. 8b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE201 1/000244

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F01 D, F02C

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

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 200901 10538 A 1 (KOSTKA RICHARD A ET AL), 30 April 2009 (2009-04-30); abstract; paragraphs [0006], [001 4]-[001 8]; figures 1-3 --	1-36
A	US 201 001 50696 A 1 (LENK OLAF), 17 June 201 0 (201 0-06-17); abstract; paragraphs [0037]-[0040], [0043]-[0044]; figures 1-2 --	1-36
A	WO 9961 757 A 1 (PRATT & WHITNEY CANADA), 2 December 1999 (1 999-1 2-02); abstract; page 9, line 9 - page 9, line 21; figures 1-4 --	1-36

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29-08-201 2	03-09-201 2
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-1 02 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Barbara Silen Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE201 1/000244

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 200901 7571 4 A 1 (CACACE ANTHONY), 9 July 2009 (2009-07-09); abstract; figures --	1-36
A	DE 371 2830 A 1 (MTU MUENCHEN GMBH), 3 November 1988 (1988-1 1-03); abstract; column 2, line 25 - column 3, line 42; figures 1,2 -- --------	1-36

Continuation of: second sheet

International Patent Classification (IPC)

F01D 21/04 (2006.01)
F01D 25/24 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

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