(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 2 586 971 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.05.2013 Bulletin 2013/18

(21) Application number: 12190276.1

(22) Date of filing: 26.10.2012

(51) Int Cl.:
F01D 5/08 (2006.01) F01D 5/30 (2006.01)
F01D 11/00 (2006.01) F01D 25/12 (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: 28.10.2011 US 201113283710
28.10.2011 US 201113283689
28.10.2011 US 201113283733

(71) Applicant: United Technologies Corporation
Hartford, CT 06101 (US)

(72) Inventors:
- Suciu, Gabriel L.
Glastonbury, CT Connecticut 06033 (US)
- Muron, Stephen P.
Columbia, CT Connecticut 06237 (US)
- Dye, Christopher M.
San Diego, CA California 92117 (US)
- Alvanos, Ioannis
West Springfield, MA Massachusetts 01089 (US)
- Merry, Brian D.
Andover, CT Connecticut 06232 (US)
- Salve, Arthur M.
Tolland, CT Connecticut 06084 (US)
- Norris, James W.
Lebanon, CT Connecticut 06249 (US)

(74) Representative: Leckey, David Herbert
Dehns
10 Salisbury Square
London
Greater London EC4Y 8JD (GB)

(54) A spacer, a rotor, a spool and a method of orienting a rotor stack load path

(57) A spacer (62C) for a gas turbine engine includes a rotor ring (84) defined along an axis of rotation. The rotor ring (84) defines a forward circumferential flange (92) which defines a first thickness and an aft circumferential flange (94) which defines a second thickness, the first thickness different than the second thickness. A plurality of core gas path seals (82) which extend from the rotor ring (84) opposite the flanges (92, 94).

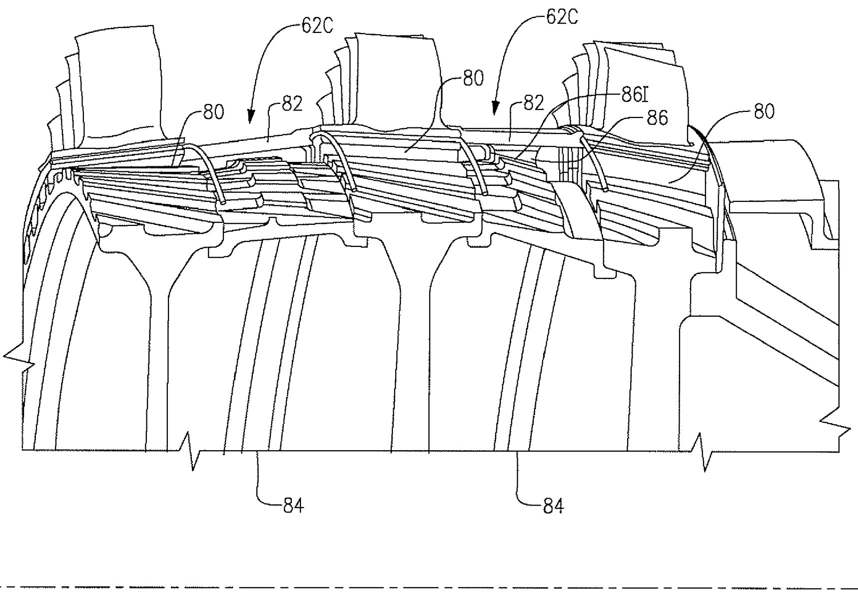

FIG.6

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Description

BACKGROUND

[0001] The present disclosure relates to a gas turbine engine, and more particularly to a rotor system therefor.

[0002] Gas turbine rotor systems include successive rows of blades, which extend from respective rotor disks that are arranged in an axially stacked configuration. The rotor stack may be assembled through a multitude of systems such as fasteners, fusion, tie-shafts and combinations thereof to generate a rotor stack preload. The rotor stack preload is typically carried through a non-straight, torturous path. Although effective, the non-straight tortuous path may thereby require relatively greater rotor stack preload forces and associated hardware.

SUMMARY

[0003] A spacer for a gas turbine engine according to an exemplary aspect of the present invention includes a rotor ring defined along an axis of rotation. The rotor ring defines a forward circumferential flange which defines a first thickness and an aft circumferential flange which defines a second thickness. The first thickness is different than the second thickness. A plurality of core gas path seals extend from the rotor ring. Each of the plurality of core gas path seals extend from the rotor ring at an interface, the interface defined along a spoke.

[0004] A rotor for a gas turbine engine according to an exemplary aspect of the present invention includes a rotor disk defined along an axis of rotation, said rotor disk axially asymmetric. A plurality of blades extend from said rotor disk. Each of said plurality of blades extend from said rotor disk at an interface, said interface defined along a spoke.

[0005] A spool for a gas turbine engine according to an exemplary aspect of the present invention includes a rotor ring defined along an axis of rotation. The rotor ring is in contact with a rotor disk. The rotor disk and the rotor ring are contoured to define a smooth rotor stack load path.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various features will become apparent to those skilled in the art from the following detailed description of the disclosed non-limiting embodiment. The drawings that accompany the detailed description can be briefly described as follows:

Figure 1 is a schematic cross-sectional view of a gas turbine engine;
Figure 2 is an exploded view of the gas turbine engine separated into primary build modules;
Figure 3 is an enlarged schematic cross-sectional view of a high pressure compressor section of the gas turbine engine;
Figure 4 is a perspective view of a rotor of the high pressure compressor section;
Figure 5 is an expanded partial sectional perspective view of the rotor of Figure 4;
Figure 6 is an expanded partial sectional perspective view of a portion of the high pressure compressor section;
Figure 7 is a top partial sectional perspective view of a portion of the high pressure compressor section with an outer directed inlet;
Figure 8 is a top partial sectional perspective view of a portion of the high pressure compressor section with an inner directed inlet;
Figure 9 is an expanded partial sectional view of a portion of the high pressure compressor section;
Figure 10 is an expanded partial sectional perspective view of a portion of the high pressure compressor section illustrating a rotor stack load path;
Figure 11 is a RELATED ART expanded partial sectional perspective view of a portion of the high pressure compressor section illustrating a more tortuous rotor stack load path;
Figure 12 is an expanded partial sectional perspective view of a portion of the high pressure compressor section illustrating a wire seal structure;
Figure 13 is an expanded schematic view of the wire seal structure;
Figure 14 is an expanded partial sectional perspective view of a high pressure turbine section;
Figure 15 is an expanded exploded view of the high pressure turbine section; and
Figure 16 is an expanded partial sectional perspective view of the rotor of Figure 15.

DETAILED DESCRIPTION

[0007] Figure 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 is disclosed herein as a two-spool turbofan that generally incorporates a fan section 22, a compressor section 24, a combustor section 26 and a turbine section 28. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section 22 drives air along a bypass flowpath while the compressor section 24 drives air along a core flowpath for compression and communication into the combustor section 26 then expansion through the turbine section 28. Although depicted as a turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with turbofans as the teachings may be applied to other types of turbine engines, such as three-spool architectures.

[0008] The engine 20 generally includes a low speed spool 30 and a high speed spool 32 mounted for rotation about an engine central longitudinal axis A relative to an engine static structure 36 via several bearing systems 38. It should be understood that various bearing systems 38 at various locations may alternatively or additionally be provided.

[0009] The low speed spool 30 generally includes an inner shaft 40 that interconnects a fan 42, a low pressure compressor 44 and a low pressure turbine 46. The inner shaft 40 may be connected to the fan 42 directly or through a geared architecture 48 to drive the fan 42 at a lower speed than the low speed spool 30 which in one disclosed non-limiting embodiment includes a gear reduction ratio of, for example, at least 2.4:1. The high speed spool 32 includes an outer shaft 50 that interconnects a high pressure compressor (HPC) 52 and high pressure turbine (HPT) 54. A combustor 56 is arranged between the high pressure compressor 52 and the high pressure turbine 54. The inner shaft 40 and the outer shaft 50 are concentric and rotate about the engine central longitudinal axis A which is collinear with their longitudinal axes.

[0010] The core airflow is compressed by the low pressure compressor 44 then the high pressure compressor 52, mixed and burned with fuel in the combustor 56, then expanded over the high pressure turbine 54 and low pressure turbine 46. The turbines 54, 46 rotationally drive the respective low speed spool 30 and high speed spool 32 in response to the expansion.

[0011] The gas turbine engine 20 is typically assembled in build groups or modules (Figure 2). In the illustrated embodiment, the high pressure compressor 52 includes eight stages and the high pressure turbine 54 includes two stages in a stacked arrangement. It should be appreciated, however, that any number of stages will benefit hereform as well as other engine sections such as the low pressure compressor 44 and the low pressure turbine 46. Further, other gas turbine architectures such as a three-spool architecture with an intermediate spool will also benefit herefrom as well.

[0012] With reference to Figure 3, the high pressure compressor (HPC) 52 is assembled from a plurality of successive HPC rotors 60C which alternate with HPC spacers 62C arranged in a stacked configuration. The rotor stack may be assembled in a compressed tie-shaft configuration, in which a central shaft (not shown) is assembled concentrically within the rotor stack and secured with a nut (not shown), to generate a preload that compresses and retains the HPC rotors 60C with the HPC spacers 62C together as a spool. Friction at the interfaces between the HPC rotor 60C and the HPC spacers 62C is solely responsible to prevent rotation between adjacent rotor hardware.

[0013] With reference to Figure 4, each HPC rotor 60C generally includes a plurality of blades 64 circumferentially disposed around a rotor disk 66. The rotor disk 66 generally includes a hub 68, a rim 70, and a web 72 which extends therebetween. Each blade 64 generally includes an attachment section 74, a platform section 76 and an airfoil section 78 (Figure 5).

[0014] The HPC rotor 60C may be a hybrid dual alloy integrally bladed rotor (IBR) in which the blades 64 are manufactured of one type of material and the rotor disk 66 is manufactured of different material. Bi-metal construction provides material capability to separately address different temperature requirements. For example, the blades 64 are manufactured of a single crystal nickel alloy that are transient liquid phase bonded with the rotor disk 66 which is manufactured of a different material such as an extruded billet nickel alloy. Alternatively, or in addition to the different materials, the blades 64 may be subject to a first type of heat treat and the rotor disk 66 to a different heat treat. That is, the Bi-metal construction as defined herein includes different chemical compositions as well as different treatments of the same chemical compositions such as that provided by differential heat treatment.

[0015] With reference to Figure 5, a spoke 80 is defined between the rim 70 and the attachment section 74. The spoke 80 is a circumferentially reduced section defined by interruptions which produce axial or semi-axial slots which flank each spoke 80. The spokes 80 may be machined, cut with a wire EDM or other processes to provide the desired shape. An interface 801 that defines the transient liquid phase bond and or heat treat transition between the blades 64 and the rotor disk 66 are defined within the spoke 80. That is, the spoke 80 contains the interface 801. Heat treat transition as defined herein is the transition between differential heat treatments.

[0016] The spoke 80 provides a reduced area subject to the thermo-mechanical fatigue (TMF) across the relatively high temperature gradient between the blades 64 which are within the relatively hot core gas path and the rotor disk 66 which is separated therefrom and is typically cooled with a secondary cooling airflow.

[0017] With reference to Figure 6, the HPC spacers 62C provide a similar architecture to the HPC rotor 60C in which a plurality of core gas path seals 82 are bonded or otherwise separated from a rotor ring 84 at an interface 86I defined along a spoke 86. In one example, the seals 82 may be manufactured of the same material as the blades 64 and the rotor ring 84 may be manufactured of the same material as the rotor disk 66. That is, the HPC spacers 62C may be manufactured of a hybrid dual alloy which are transient liquid phase bonded at the spoke 86. Alternatively, the HPC spacers 62C may be manufactured of a single material but subjected to the differential heat treat which transitions within the spoke 86. In another disclosed non-limiting embodiment, a relatively low-temperature configuration will benefit from usage of a single material such that the spokes 86 facilitate a weight reduction. In another disclosed non-limiting embodiment, low-temperature bi-metal designs may further benefit from dissimilar materials for weight reduction where, for example, low density materials may be utilized where load carrying capability is less critical.

[0018] The rotor geometry provided by the spokes 80, 86 reduces the transmission of core gas path temperature via conduction to the rotor disk 66 and the seal ring 84. The spokes 80, 86 enable an IBR rotor to withstand increased T3 levels with currently available materials.

Rim cooling may also be reduced from conventional allocations. In addition, the overall configuration provides weight reduction at similar stress levels to current configurations.

[0019] The spokes 80, 86 in the disclosed non-limiting embodiment are oriented at a slash angle with respect to the engine axis A to minimize windage and the associated thermal effects. That is, the spokes are non-parallel to the engine axis A.

[0020] With reference to Figure 7, the passages which flank the spokes 80, 86 may also be utilized to define airflow paths to receive an airflow from an inlet HPC spacer 62CA. The inlet HPC spacer 62CA includes a plurality of inlets 88 which may include a ramped flow duct 90 to communicate an airflow into the passages defined between the spokes 80, 86. The airflow may be core gas path flow which is communicated from an upstream, higher pressure stage for use in a later section within the engine such as the turbine section 28.

[0021] It should be appreciated that various flow paths may be defined through combinations of the inlet HPC spacers 62CA to include but not limited to, core gas path flow communication, secondary cooling flow, or combinations thereof. The airflow may be communicated not only forward to aft toward the turbine section, but also aft to forward within the engine 20. Further, the airflow may be drawn from adjacent static structure such as vanes to effect boundary flow turbulence as well as other flow conditions. That is, the HPC spacers 62C and the inlet HPC spacer 62CA facilitate through-flow for use in rim cooling, purge air for use downstream in the compressor, turbine, or bearing compartment operation.

[0022] In another disclosed non-limiting embodiment, the inlets 88' may be located through the inner diameter of an inlet HPC spacer 62CA' (Figure 8). The inlet HPC spacer 62CA' may be utilized to, for example, communicate a secondary cooling flow along the spokes 80, 86 to cool the spokes 80, 86 as well as communicate secondary cooling flow to other sections of the engine 20.

[0023] In another disclosed non-limiting embodiment, the inlets 88, 88' may be arranged with respect to rotation to essentially "scoop" and further pressurize the flow. That is, the inlets 88, 88' include a circumferential directional component.

[0024] With reference to Figure 9, each rotor ring 84 defines a forward circumferential flange 92 and an aft circumferential flange 94 which is captured radially inboard of the associated adjacent rotor rim 70. That is, each rotor ring 84 is captured therebetween in the stacked configuration. In the disclosed tie-shaft configuration with multi-metal rotors, the stacked configuration is arranged to accommodate the relatively lower-load capability alloys on the core gas path side of the rotor hardware, yet maintain the load-carrying capability between the seal rings 84 and the rims 70 to transmit rotor torque.

[0025] That is, the alternating rotor rim 70 to seal ring 84 configuration carries the rotor stack preload - which may be upward of 150,000 lbs (66.7 kN) - through the high load capability material of the rotor rim 70 to seal ring 84 interface, yet permits the usage of a high temperature resistant, yet lower load capability materials in the blades 64 and the seal surface 82 which are within the high temperature core gas path. Divorce of the sealing area from the axial rotor stack load path facilitates the use of a disk-specific alloy to carry the stack load and allows for the high-temp material to only seal the rotor from the flow path. That is, the inner diameter loading and outer diameter sealing permits a segmented airfoil and seal platform design which facilitates relatively inexpensive manufacture and highly contoured airfoils. The disclosed rotor arrangement facilitates a compressor inner diameter bore architectures in which the reduced blade/platform pull may be taken advantage of in ways that produce a larger bore inner diameter to thereby increase shaft clearance.

[0026] The HPC spacers 62C and HPC rotors 60C of the IBR may also be axially asymmetric to facilitate a relatively smooth axial rotor stack load path (Figure 10). The asymmetry may be located within particular rotor rims 70A and/or seal rings 84A. For example, the seal ring 84A includes a thinner forward circumferential flange 92 compared to a thicker aft circumferential flange 94 with a ramped interface 84Ai. The ramped interface 84Ai provides a smooth rotor stack load path. Without tangentially slot assembled airfoils in an IBR, the load path along the spool may be designed in a more efficient manner as compared to the heretofore rather tortuous conventional rotor stack load path (Figure 11; RELATED ART).

[0027] With reference to Figure 12, the blades 64 and seal surface 82 may be formed as segments that include tangential wire seals 96 between each pair of the multiple of seal surfaces 82 and each pair of the multiple of blades 64 as well as axial wire seals 98 between the adjacent HPC spacers 62C and HPC rotors 60C. The tangential wire seals 96 and the axial wire seals 98 are located within teardrop shaped cavities 100 (Figure 13) such that centrifugal forces increase the seal interface forces.

[0028] Although the high pressure compressor (HPC) 52 is discussed in detail above, it should be appreciated that the high pressure turbine (HPT) 54 (Figure 14) is similarly assembled from a plurality of successive respective HPT rotor disks 60T which alternate with HPT spacers 62T (Figure 15) arranged in a stacked configuration and the disclosure with respect to the high pressure compressor (HPC) 52 is similarly applicable to the high pressure turbine (HPT) 54 as well as other spools of the gas turbine engine 20 such as a low spool and an intermediate spool of a three-spool engine architecture. That is, it should be appreciated that other sections of a gas turbine engine may alternatively or additionally benefit herefrom.

[0029] With reference to Figure 14, each HPT rotor 60T generally includes a plurality of blades 102 circumferentially disposed around a rotor disk 124. The rotor disk 124 generally includes a hub 126, a rim 128, and a web 130 which extends therebetween. Each blade 102 generally includes an attachment section 132, a platform section 134, and an airfoil section 136 (Figure 16).

[0030] The blades 102 may be bonded to the rim 128 along a spoke 136 at an interface 136I as with the high pressure compressor (HPC) 52. Each spoke 136 also includes a cooling passage 138 generally aligned with each turbine blade 102. The cooling passage 138 communicates a cooling airflow into internal passages (not shown) of each turbine blade 102.

[0031] It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. It should also be understood that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom.

[0032] Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present disclosure.

[0033] The foregoing description is exemplary rather than defined by the limitations within. Various non-limiting embodiments are disclosed herein, however, one of ordinary skill in the art would recognize that various modifications and variations in light of the above teachings will fall within the scope of the appended claims. It is therefore to be understood that within the scope of the appended claims, the disclosure may be practiced other than as specifically described. For that reason the appended claims should be studied to determine true scope and content.

Claims

1. A spacer (62C) for a gas turbine engine comprising:

a rotor ring (84) defined along an axis of rotation, said rotor ring (84) defining a forward circumferential flange (92) which defines a first thickness and an aft circumferential flange (84) which defines a second thickness, said first thickness different than said second thickness; and
a plurality of core gas path seals (82) which extend from said rotor ring (84), each of said plurality of core gas path seals (82) extending from said rotor ring (84) at an interface (861), said interface (861) defined along a spoke (86).

2. The spacer as recited in claim 1, wherein said rotor ring (84) is manufactured of a first material and said plurality of core gas path seals (82) are manufactured of a second material, said first material different than said second material.

3. The spacer as recited in claim 1 or 2, wherein each spoke (86) is parallel to said axis of rotation.

4. The spacer as recited in claim 1 or 2, wherein each spoke (86) is angled with respect to said axis of rotation.

5. The spacer as recited in any preceding claim, wherein at least one of said plurality of core gas path seals (82) includes an inlet (88), said inlet optionally being to a passage adjacent to said spoke (86).

6. The spacer as recited in any preceding claim, further comprising a ramped interface (84Ai) between said forward circumferential flange (92) and said aft circumferential flange (94), said plurality of gas path seals extending from said ramped interface (84Ai) opposite said ramped interface.

7. A rotor (60C) for a gas turbine engine comprising:

a rotor disk (66) defined along an axis of rotation, said rotor disk (66) axially asymmetric; and
a plurality of blades (64) which extend from said rotor disk (66), each of said plurality of blades (64) extend from said rotor disk (66) at an interface (80I), said interface (801) defined along a spoke (80).

8. The rotor as recited in claim 7, wherein said rotor disk (66) is manufactured of a first material and said plurality of blades (64) are manufactured of a second material, said first material different than said second material.

9. The spacer or rotor as recited in any preceding claim, wherein said interface (86I; 80I) includes a heat treat transition or a bond.

10. A spool for a gas turbine engine comprising:

a rotor disk (66) defined along an axis of rotation; and
a rotor ring (84) defined along said axis of rotation, said rotor ring (84) in contact with said rotor disk (66), said rotor disk (66) and said rotor ring (84) contoured to define a smooth rotor stack load path.

11. The spool as recited in claim 10, further comprising a plurality of blades (64) which extend from said first rotor disk (66), each of said plurality of blades (64) extending from said rotor disk (66) at an interface (801), said interface (801) defined along a spoke (80).

12. The spool as recited in claim 11, further comprising a plurality of core gas path seals (82) which extend from said rotor ring (84), each of said plurality of core gas path seals (82) extending from said rotor ring (84) at an interface (861), said interface (861) defined along a spoke (86), said plurality of core gas path seals (82) optionally interfacing with a platform (76) of said plurality of blades (64).

13. The spool as recited in any of claims 10 to 12, wherein said rotor ring (82) defines a forward circumferential flange (92) which defines a first thickness and an aft circumferential flange (94) which defines a second thickness, said first thickness different than said second thickness.

14. The spool as recited in any of claims 10 to 13, wherein said rotor disk (66) and rotor ring (84) are axially asymmetric.

15. A method of orienting a rotor stack load path comprising:

stacking a rotor ring (84) in contact with a rotor disk (66) along an axis of rotation, the rotor disk (66) and the rotor ring (84) axially asymmetric to define a smooth rotor stack load path.

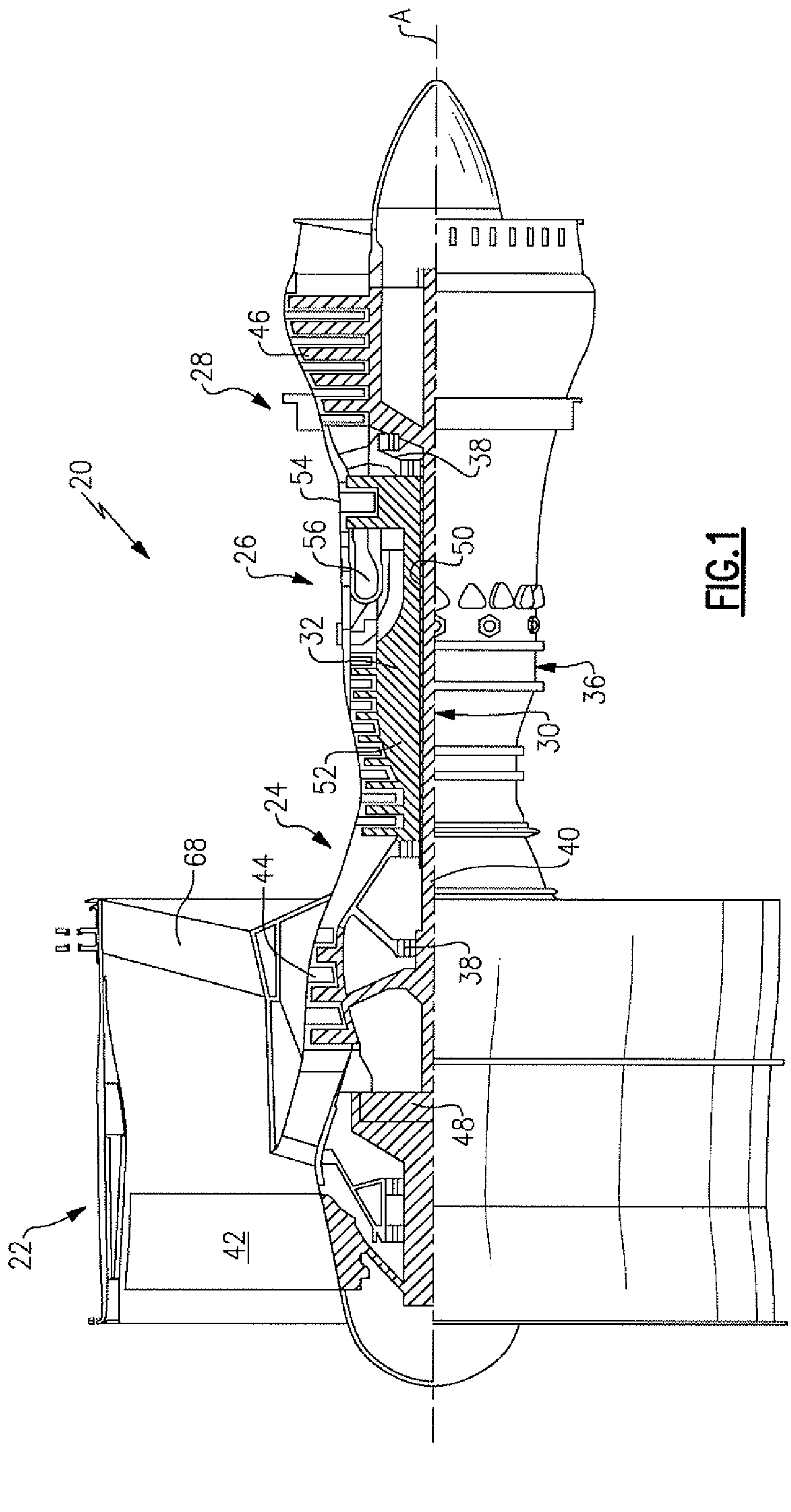


FIG.1

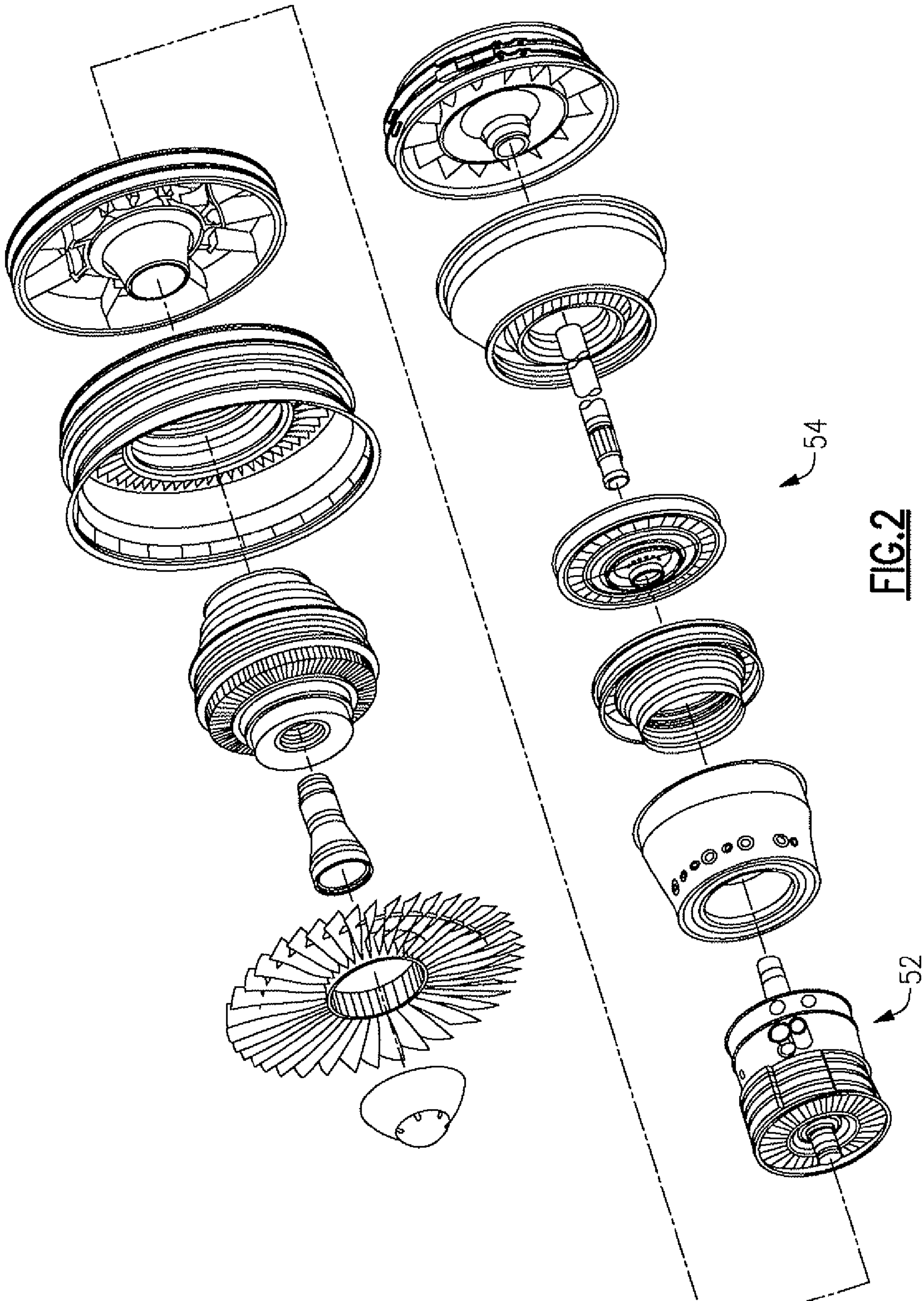


FIG.2

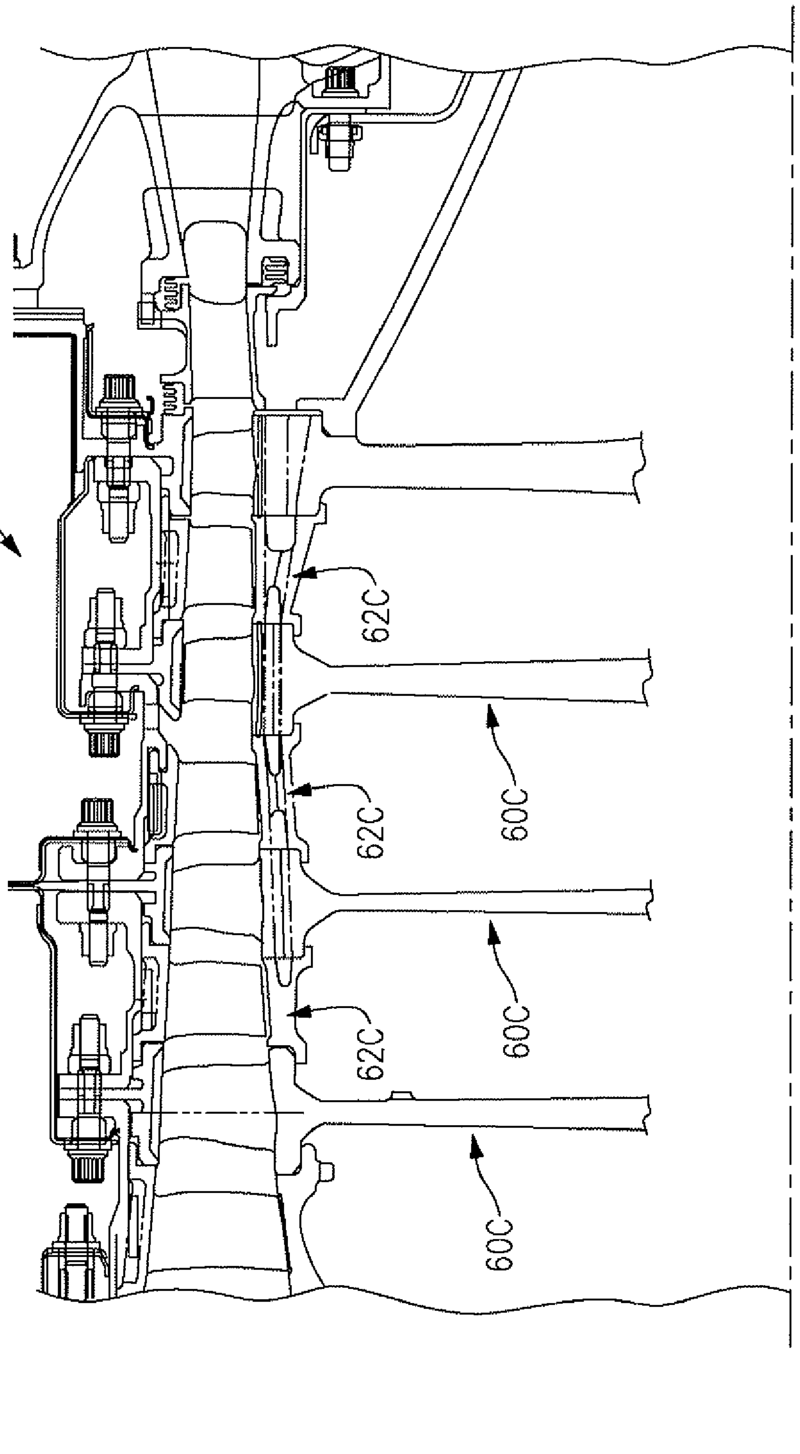


FIG.3

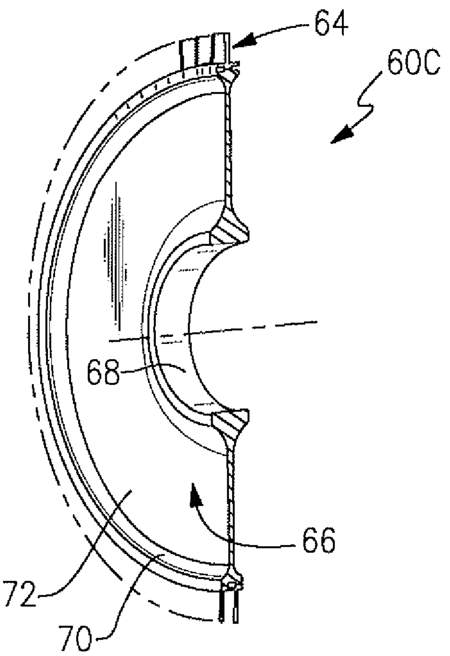


FIG.4

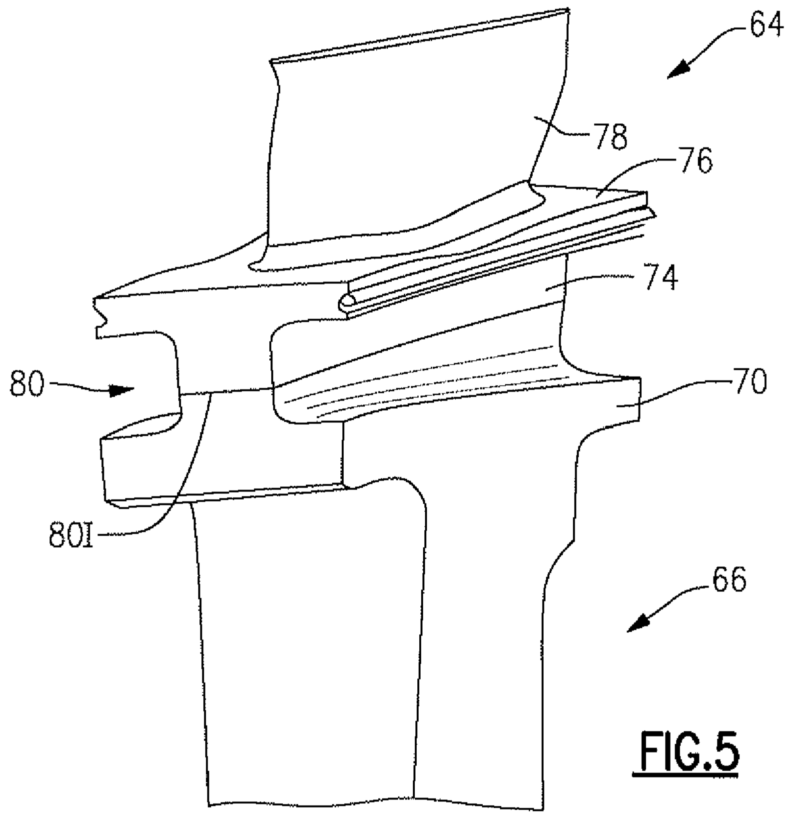


FIG.5

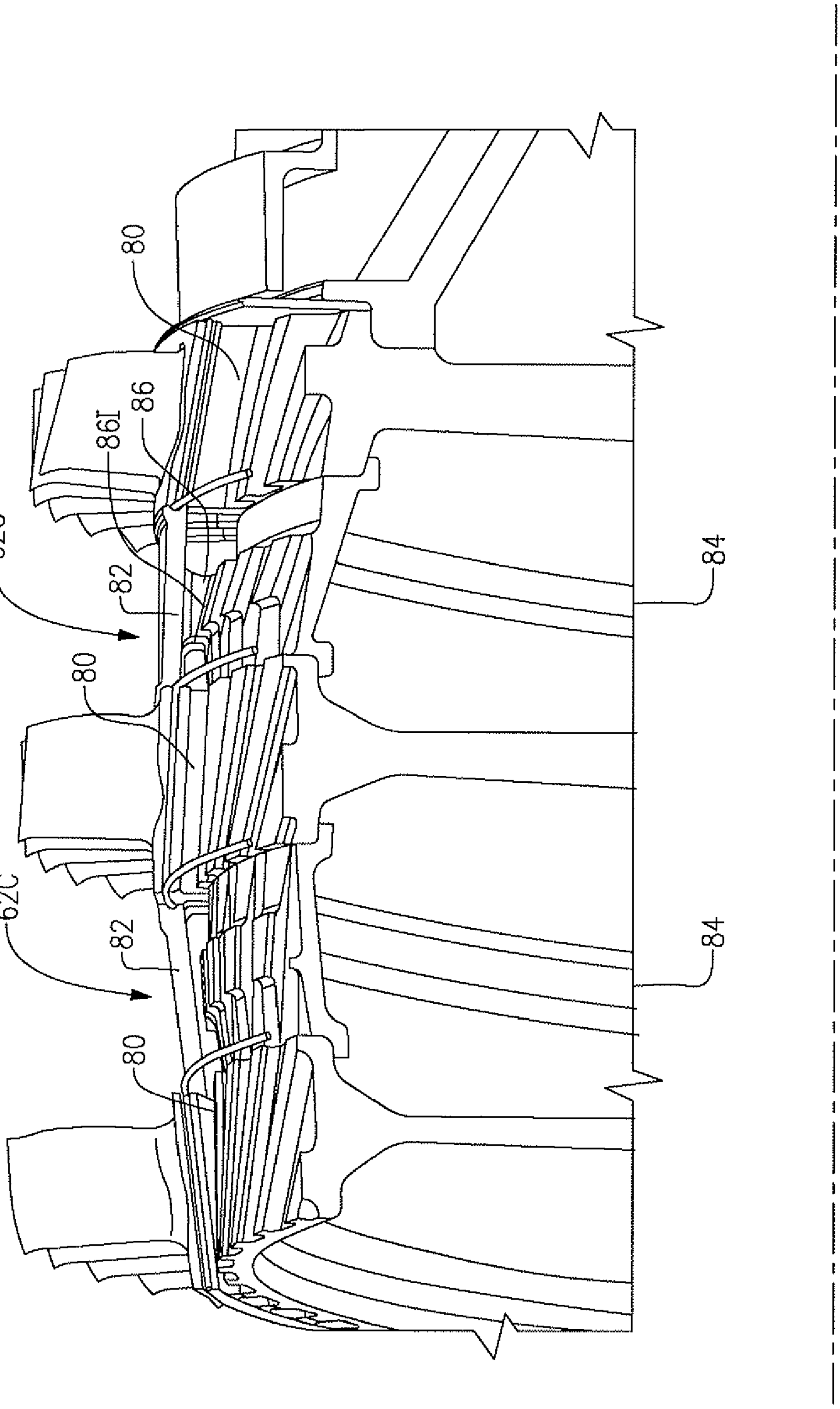


FIG.6

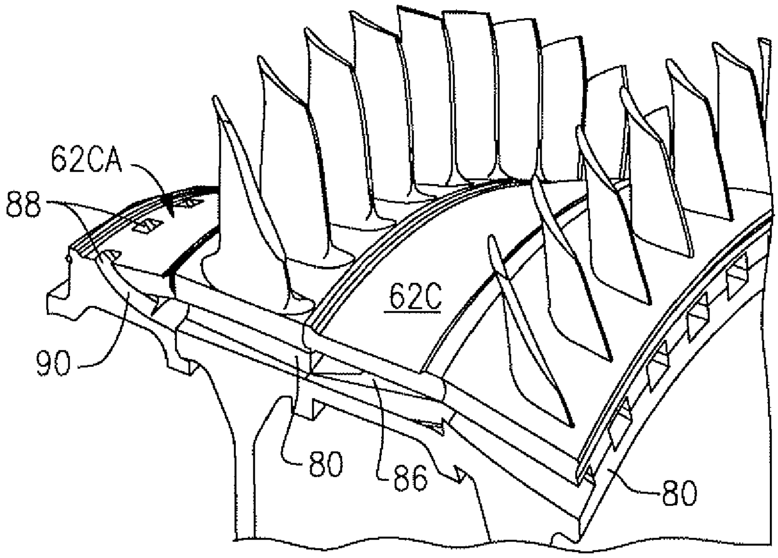


FIG.7

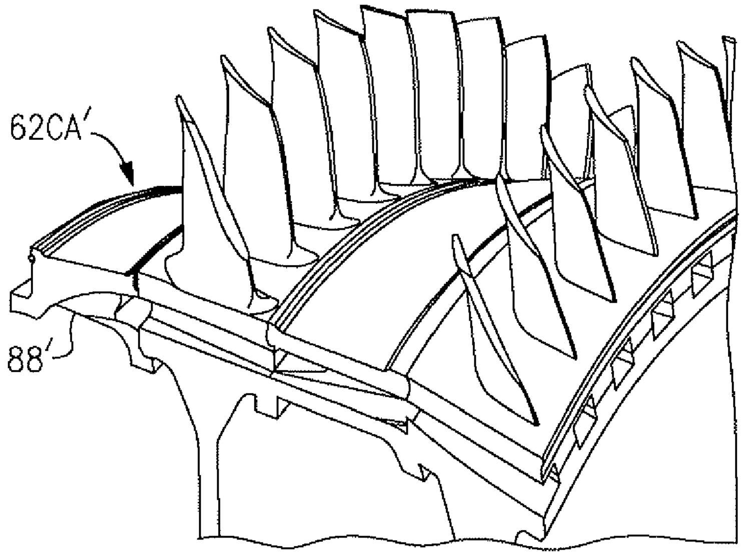


FIG.8

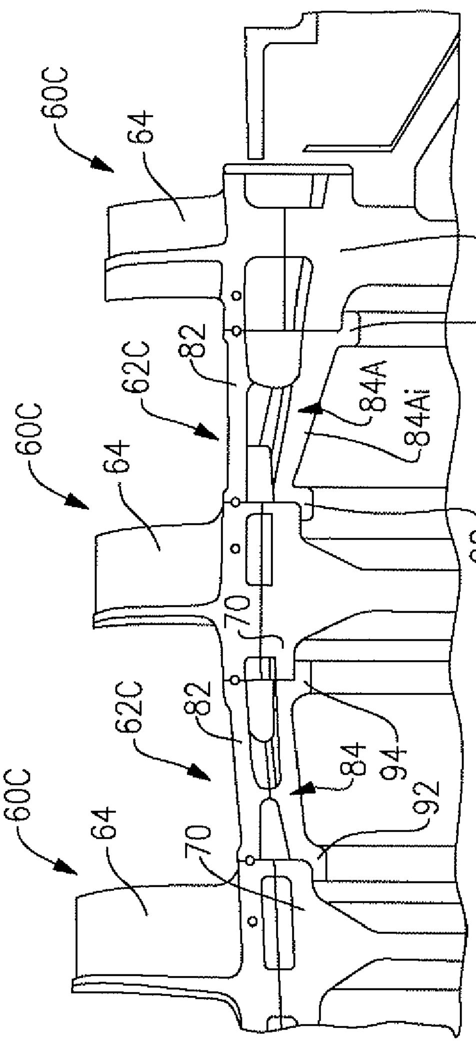


FIG.9

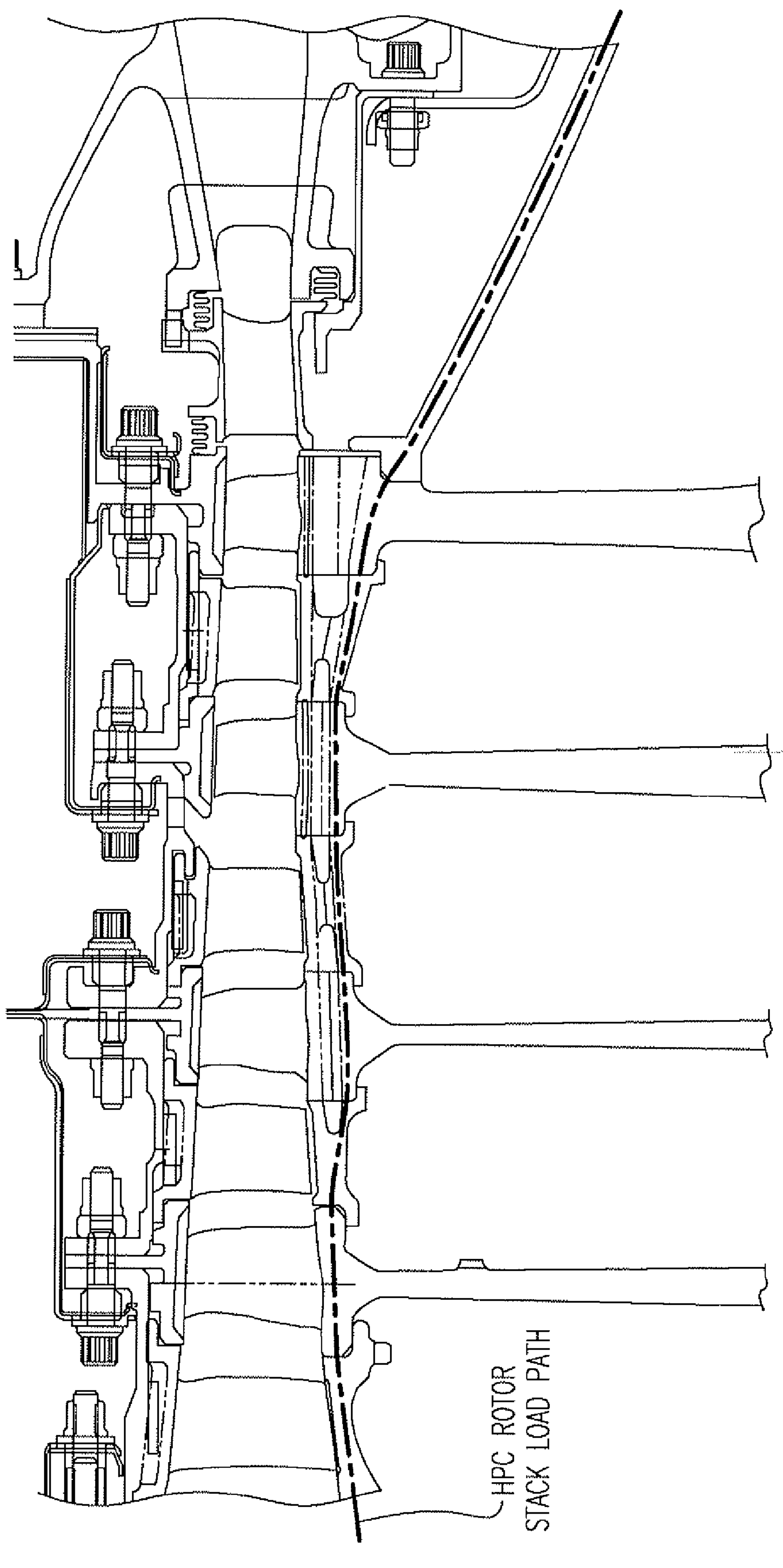


FIG.10

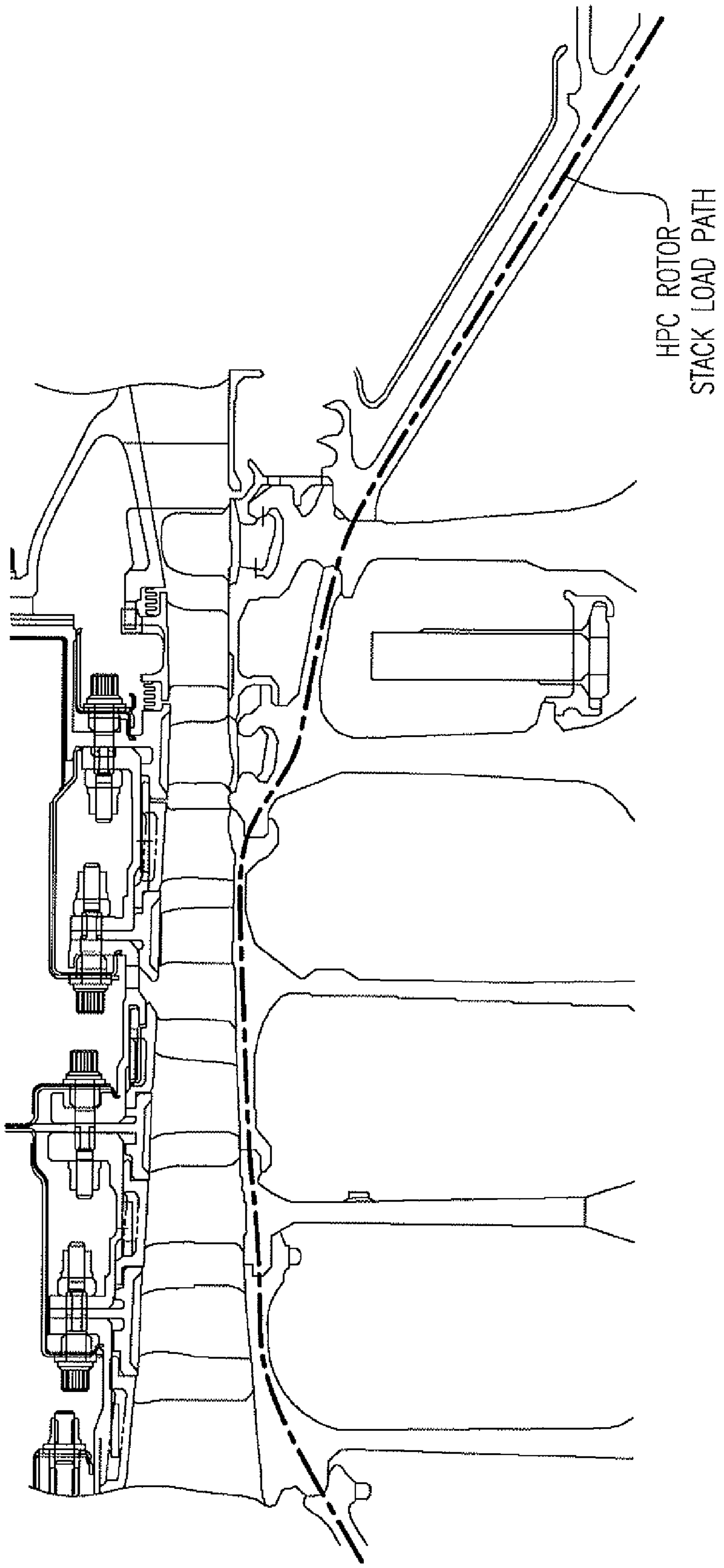


FIG.11
Related Art

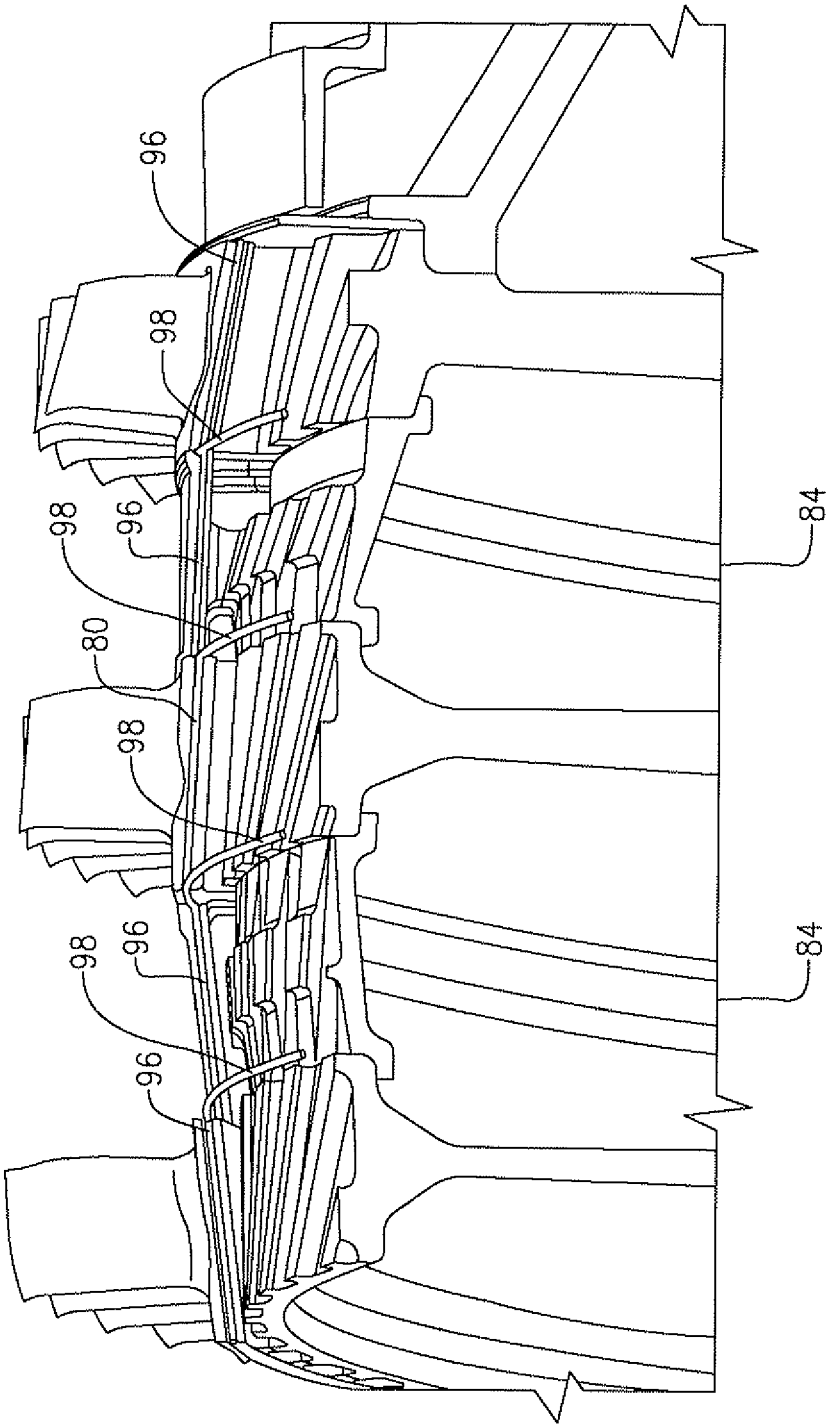


FIG.12

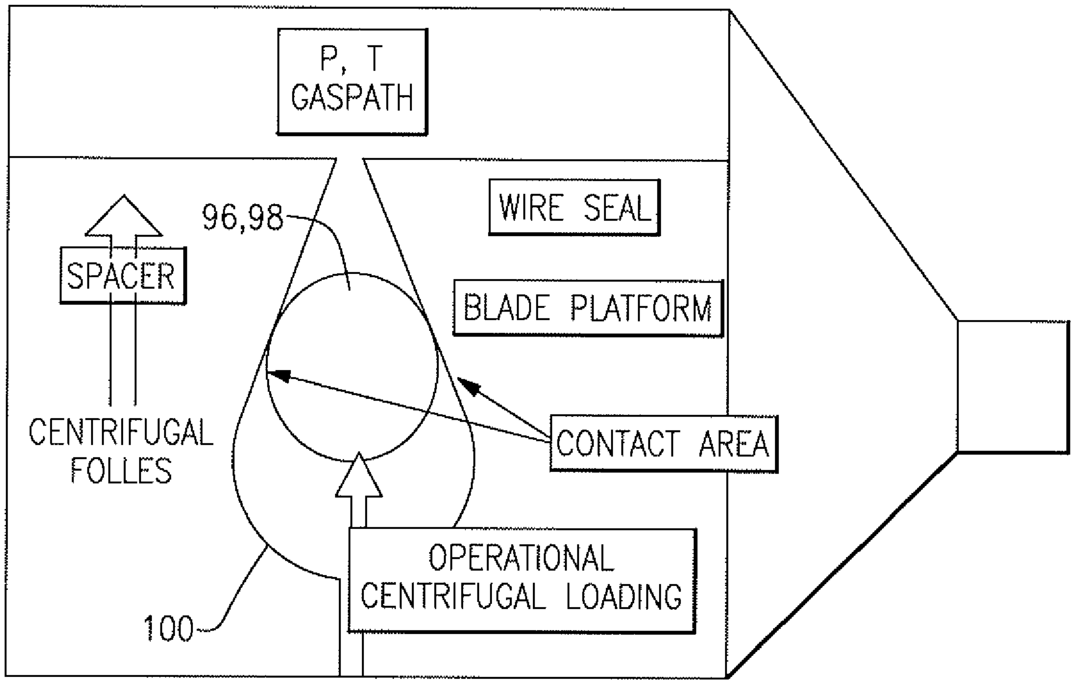

P, T
GASPATH
WIRE SEAL
96,98
SPACER
BLADE PLATFORM
CENTRIFUGAL
FOLLES
CONTACT AREA
OPERATIONAL
CENTRIFUGAL LOADING
100

FIG.13

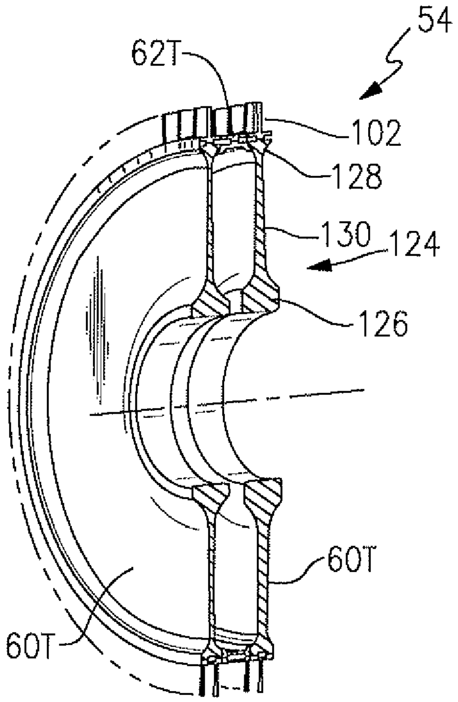
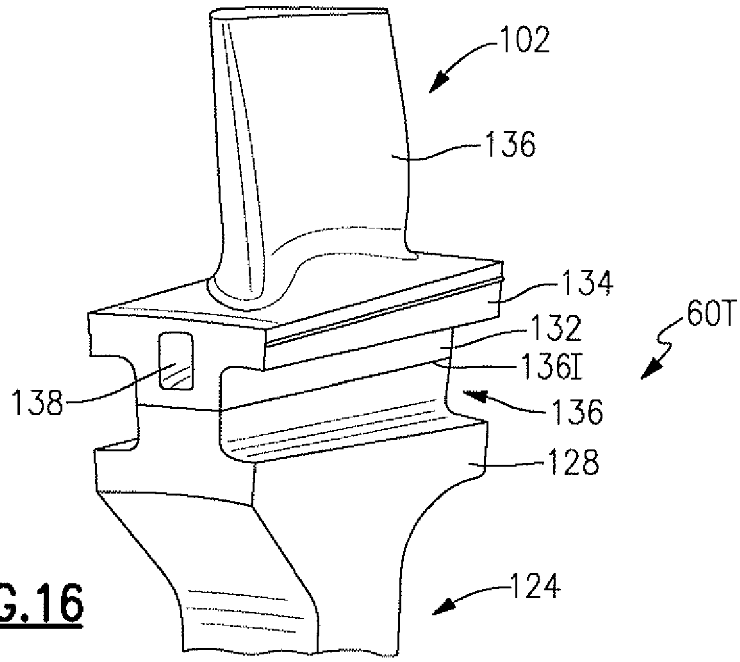

54
62T
102
128
130
124
126
60T
60T

FIG.14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136I
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FIG.16

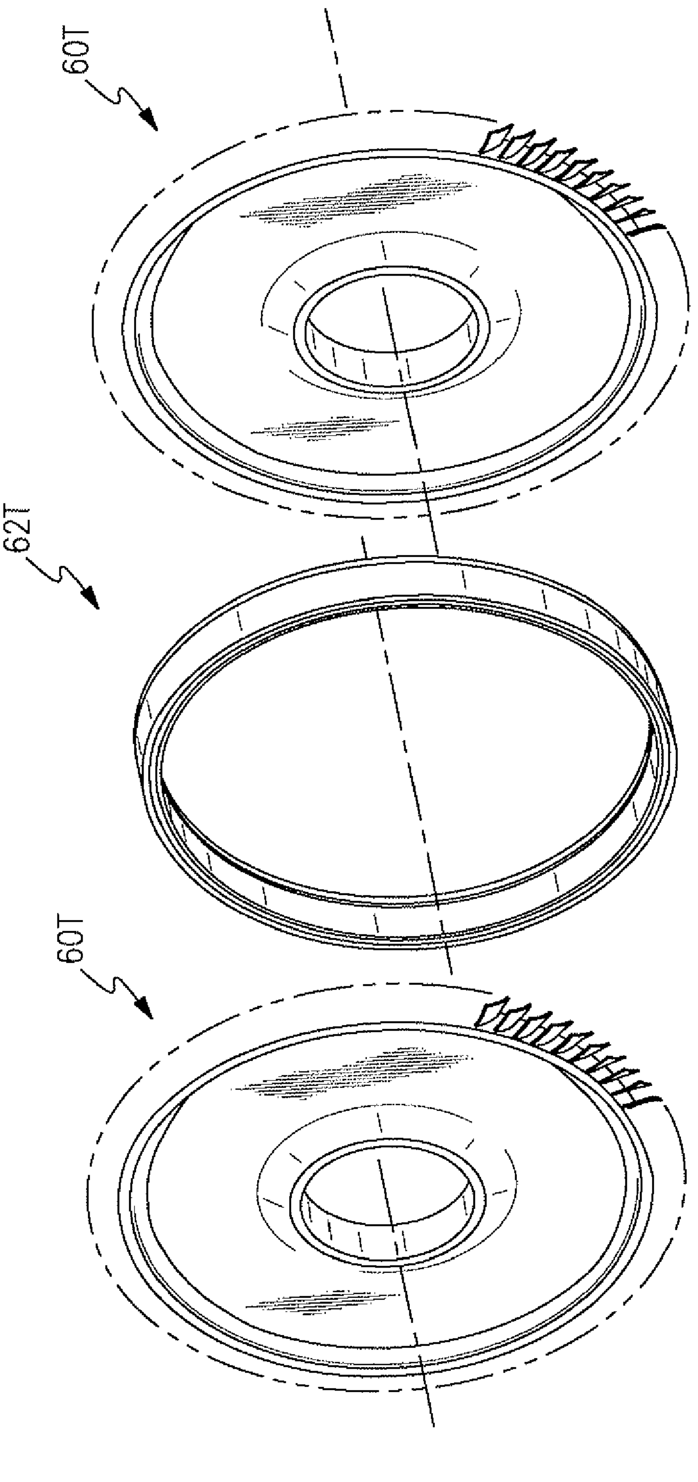

FIG.15