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(54) Method and apparatus for reducing axial compressor blade tip flow

(57) A turbine machine (T1) of the type having a high pressure compressor positioned in a casing is provided with a plurality of rotating compressor blades (10-14) with at least one air channel (10C-14C) formed in the blades (10-14) for air flow communication from the base to the

tip for extracting and pressurizing air from an inner area proximate the disk (20) and conveying the extracted and pressurized air into an area between the blade tip and casing (C1) for blocking air flow across the tips of the blades (10-14).

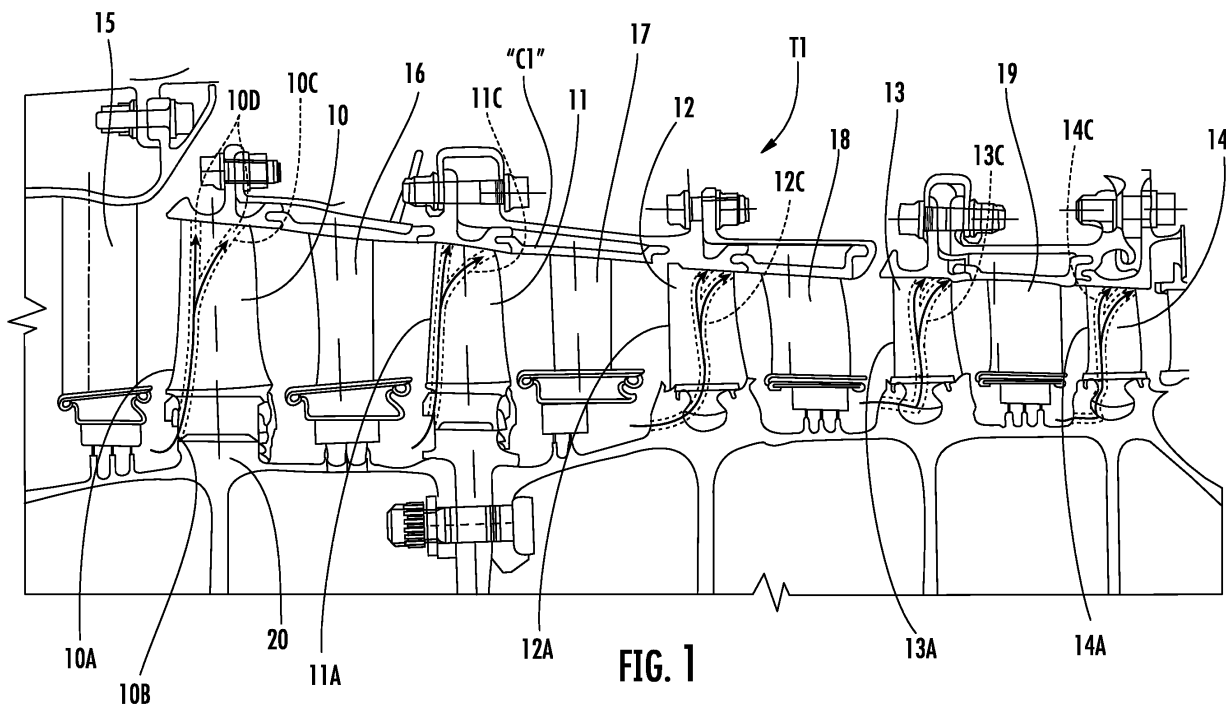


FIG. 1

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Description

[0001] This invention relates to a method and apparatus for reducing axial compressor tip flow in airfoils, such as blades and vanes. Blade tip flow in the compressor area of a turbine engine results in loss of compressor efficiency and stall margin. In addition, flow recirculation in seal cavities along the inner flow path between the vanes and blades also degrades compressor performance. One prior art solution for reducing tip flow is to reduce the blade tip clearance. This is done by a variety of means, including control of the casing and vane interface using mechanical and/or thermal methods. These methods can cause tip rubbing, excess wear and loss of engine efficiency.

[0002] According to one aspect of the invention, a method of reducing air flow between a tip of a turbine airfoil rotating in a closely-spaced apart casing is provided, and comprises the step of providing in the airfoil a radially-extending channel having an inlet opening proximate a base of the airfoil and an exit opening on the airfoil tip. Air is extracted and pressurized from a region proximate the base of the airfoil, introduced into the channel and conveyed through the channel to the airfoil tip. The air exits the channel through the exit openings in the airfoil tip into an area between the airfoil tip and casing under sufficient pressure to resist axial air flow from a pressure side to a suction side of the airfoil.

[0003] Another aspect of the invention provides a method of reducing air flow between a tip of a turbine airfoil rotating in a closely-spaced apart casing, comprising the steps of providing a first radially-extending channel having an inlet opening proximate a base of the airfoil on a leading edge side thereof, and an exit opening on the airfoil tip, and providing a second radially-extending channel having an inlet opening proximate the base of the airfoil on a trailing edge side thereof, and an exit opening on the airfoil tip. The air is extracted from a region proximate the base of the airfoil into the channel and pumped through the channel to the airfoil tip. The air exits the channel through the exit openings in the airfoil tip into an area between the airfoil tip and casing under sufficient pressure to resist axial air flow from a pressure side to a suction side of the airfoil.

[0004] In another aspect of the invention a turbine machine compressor airfoil is provided, comprising a airfoil base, a airfoil tip, and an air flow channel extending radially from an air inlet opening in the airfoil proximate the airfoil base to an exit opening in the airfoil tip for providing a air blockage against an axial flow of air from the pressure side of the airfoil to the suction side of the airfoil to thereby reduce compressor airfoil tip flow.

[0005] Various aspects and embodiments of the invention are described below in conjunction with the following drawings, in which:

Figure 1 is a fragmentary cross-section of an axial flow compressor section of a turbine engine illustrating

ing one embodiment of the invention;

Figure 2 is an enlarged fragmentary cross-section of a portion of the compressor shown in Figure 1;

Figure 3 is a fragmentary cross-section of the compressor section of a turbine engine illustrating another embodiment of the invention;

Figure 4 is an enlarged fragmentary cross-section of a portion of the compressor shown in Figure 3;

Figure 5 is a fragmentary cross-section of the compressor section of a turbine engine illustrating yet another embodiment of the invention; and

Figure 6 is an enlarged fragmentary cross-section of a portion of the compressor shown in Figure 5.

[0006] Referring now specifically to the drawings, a partial section of the axial compressor section of a turbine engine T1 illustrating a method and apparatus for controlling axial compressor blade tip flow according to the present invention is illustrated in Figure 1. The turbine engine "T1" includes compressor blades 10-14 and intermediately-positioned stator vanes 15-19 in a casing C1. The compressor blades 10-14 include respective leading edges 10A-14A.

[0007] As is shown in Figure 2, blade 10 is shown in enlarged detail for clarity, and is also exemplary of blades 11-14. Air is extracted and pressurized from the area of the leading edge side 10A of the blade 10 through holes 10B in a disk 20. The holes 10B communicate with a channel 10C that extends radially outwardly through the blade 10 to the tip where it exits through holes 10D. Note that the channel 10C may branch out before exiting the tip of the blade 10. The size of the channel 10C and the location and number of the branches is determined empirically based on blade size, shape and volume, and engine performance, rating, tip clearance and similar factors. Note in the drawings that the tip clearance is sufficiently small in relation to the scale of the drawings that actual representation of the tip clearance cannot be shown.

[0008] Referring now to Figure 3, a turbine engine "T2" includes compressor blades 30-34 and intermediately-positioned stator vanes 35-39 in a casing C2. The compressor blades 30-34 include respective trailing edges 30A-34A.

[0009] In Figure 4, blade 31 is shown in enlarged detail for clarity, and is exemplary of blades 30 and 32-34. Air is extracted from the area of the trailing edge side 31A of the blade 31 through holes 31B in the disk rim 40. The holes 31B communicate with a channel 31C that extends radially outwardly through the blade 31 to the tip where it preferably branches before exiting through holes 31D.

[0010] Referring now to Figure 5, a turbine engine "T3" includes compressor blades 50-54 and intermediately-

positioned stator vanes 55-59 in a casing C3. The compressor blades 50-54 include respective leading edges 50A-54A and respective trailing edges 50B-54B.

[0011] Figure 6 illustrates a blade 52 that is shown in enlarged detail for clarity, and is exemplary of blades 51 and 52-54. Air is extracted from both the areas of the leading edge side 52A and trailing edge side 52B of blade 52 through holes 52C and 52D in the disk rim 60. The holes 52C and 52D communicate with channels 52E and 52F, respectively, that extend radially outwardly through the blade 52 to the tip, where they preferably branch before exiting through holes 52G.

[0012] In each of the embodiments described above, the air discharged at the blade tip reduces or prevents blade tip flow by aerodynamically blocking air flow in the region of the tip clearance between the blade tip and the casing. Air from the inner flow path is brought to the tip clearance, as described above, to form this air block. The pressure of the extracted air increases due to the compressor rotor pumping and, when exiting the blade at the tip, resists air flow across the blade tip from the pressure side to the suction side.

[0013] The methods described above can be applied to both low pressure compressors (boosters) and high pressure compressors. There is no chargeable flow loss when these methods are utilized. Furthermore, by reducing air flow by aerodynamic air blockage rather than by a tight running clearance between the blade tips and the casing, a larger assembly clearance between the blade tips and the casing can be established and maintained. Blade tip rubs are thus reduced, as is recirculation in the inner flow path between the vane and the blade. The extracted air is continuously pumped from the inner flow path to the blade tip, thus providing a continuous air blockage to the blade tip at all times during engine operation.

[0014] The methods described in this application also have application in blisk (blade integrated disk), skewed or circumferential dovetailed blades.

[0015] A method and apparatus for controlling axial compressor blade tip flow is described above. Various details of the invention may be changed without departing from its scope. Furthermore, the foregoing description of the preferred embodiment of the invention and the best mode for practicing the invention are provided for the purpose of illustration only and not for the purpose of limitation--the invention being defined by the claims.

Parts List

[0016]

T1	turbine machine
T2	turbine machine
T3	turbine machine
C1	casing

(continued)

C3	casing
10	blades
10A	leading edge
10B	inlet openings
10C	channel
10D	exit openings
11	blades
11C	channel
12	blades
12C	channel
13	blades
13C	channel
14	blades
14C	channel
15	stationary vanes
16	stationary vanes
17	stationary vanes
18	stationary vanes
19	stationary vanes
20	disk
31	blade
31A	trailing edge
31B	inlet opening
31C	channel
31D	exit opening
50	blade
50A	leading edge
50B	trailing edge
50C	inlet opening
50D	inlet opening
50F	channel
52	blade
52A	leading edge
52B	trailing edge
52C	inlet opening
52D	inlet opening

(continued)

52E	first channel
52F	second channel
52G	exit holes

Claims

1. A turbine machine (T1) of the type having a high pressure compressor positioned in a casing (C1), a plurality of rotating compressor blades (10-14) having respective blade tips, respective blade bases affixed to a central disk (20), and a plurality of stationary vanes (15-19) positioned between respective ones of the blades (10-14), comprising at least one air channel (10C, 11C, 12C, 13C, 14C) formed in respective ones of the blades (10-14) for air flow communication from the base to the tip for extracting and pressurizing air from an inner area proximate the disk (20) and conveying the extracted and pressurized air through the channel (10C, 11C, 12C, 13C, 14C) into an area between the blade tip and casing (C1) for blocking air flow from a tip of the blades (10-14). 5
2. A turbine machine (T1) according to claim 1, wherein the channel (10C) exits the blade tip through a respective plurality of exit holes (10D). 10
3. A turbine machine (T1) according to claim 1 or claim 2, wherein the channel (10C) includes an air inlet (10B) opening in on leading edge (10A) of the blade (10). 15
4. A turbine machine (T2) according to any preceding claim, wherein the channel (31 C) includes an air inlet opening (31B) on a trailing edge (31A) side of the blade (31). 20
5. A turbine machine (T3) according to any preceding claim, wherein the channel (50F) includes an air inlet opening (50C) in on a leading edge (50A) side and an air inlet opening (50D) on a trailing edge (50B) side of the blade (50). 25
6. A turbine machine (T3) according to any preceding claim, and including a first channel (52E) having an air inlet opening (52C) on a leading edge (52A) side of the blade (52) and a second channel (52F) having an air inlet opening (52D) on a trailing edge (52B) side of the blade (52). 30
7. A turbine machine (T1) according to any preceding claim, wherein the channel (50F) includes a plurality of exit holes (52G) in the blade tip. 35
8. A method of reducing air flow between a tip of a turbine airfoil (10) rotating in a closely-spaced apart casing (C1), comprising the steps of: 40
 - (a) providing in the airfoil (10) a radially-extending channel (10C) having an inlet opening (10B) proximate a base of the airfoil (10) and an exit opening (10D) on the airfoil tip;
 - (b) extracting and pressurizing air from a region proximate the base of the airfoil (10) into the channel (10C);
 - (c) conveying the air through the channel (10C) to the airfoil tip; and
 - (d) discharging the air through the exit openings (10D) in the airfoil tip into an area between the airfoil tip and casing (C1) under sufficient pressure to resist axial air flow across the tip of the airfoil (10). 45
9. A method according to claim 8, wherein the step of providing a radially-extending channel (10C) having an inlet opening (10B) proximate a base of the airfoil (10) and an exit opening (10D) on the airfoil tip includes the step of forming the inlet opening (10B) on a leading edge (10A) side of the airfoil (10). 50
10. A method according to claim 8 or claim 9, wherein the step of providing a radially-extending channel (31C) having an inlet opening (31B) proximate a base of the airfoil (31) and an exit opening (31D) on the airfoil tip includes the step of forming the inlet opening (31B) on a trailing edge (31A) side of the blade (31). 55

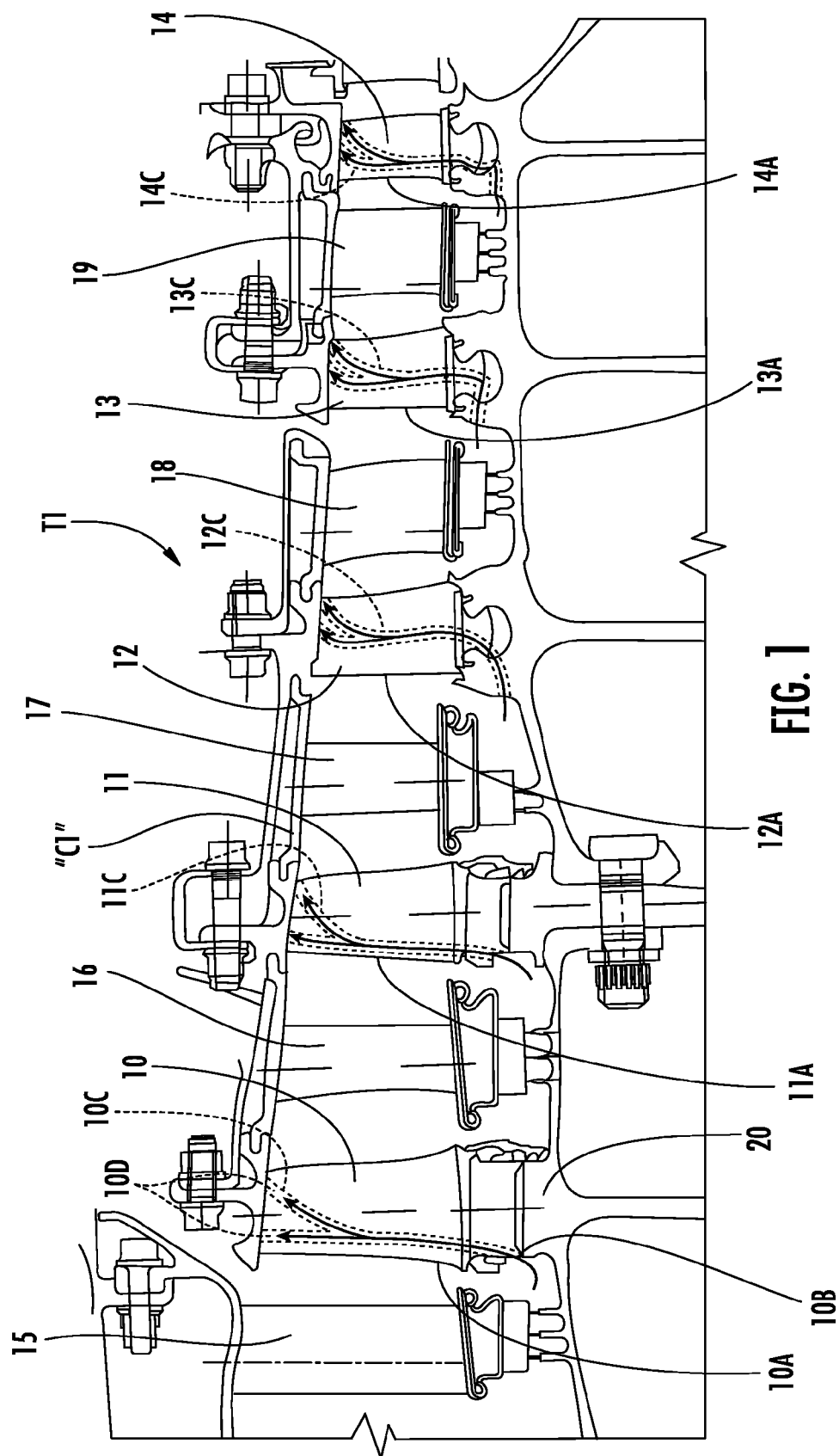
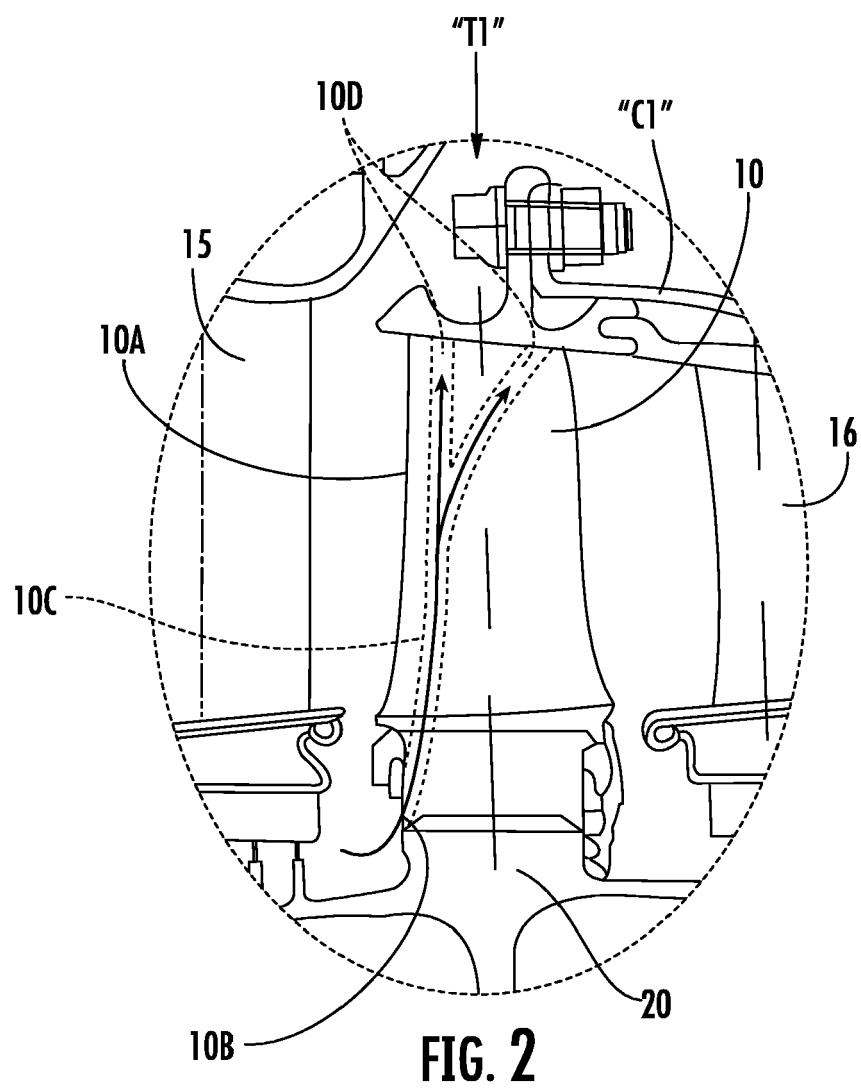
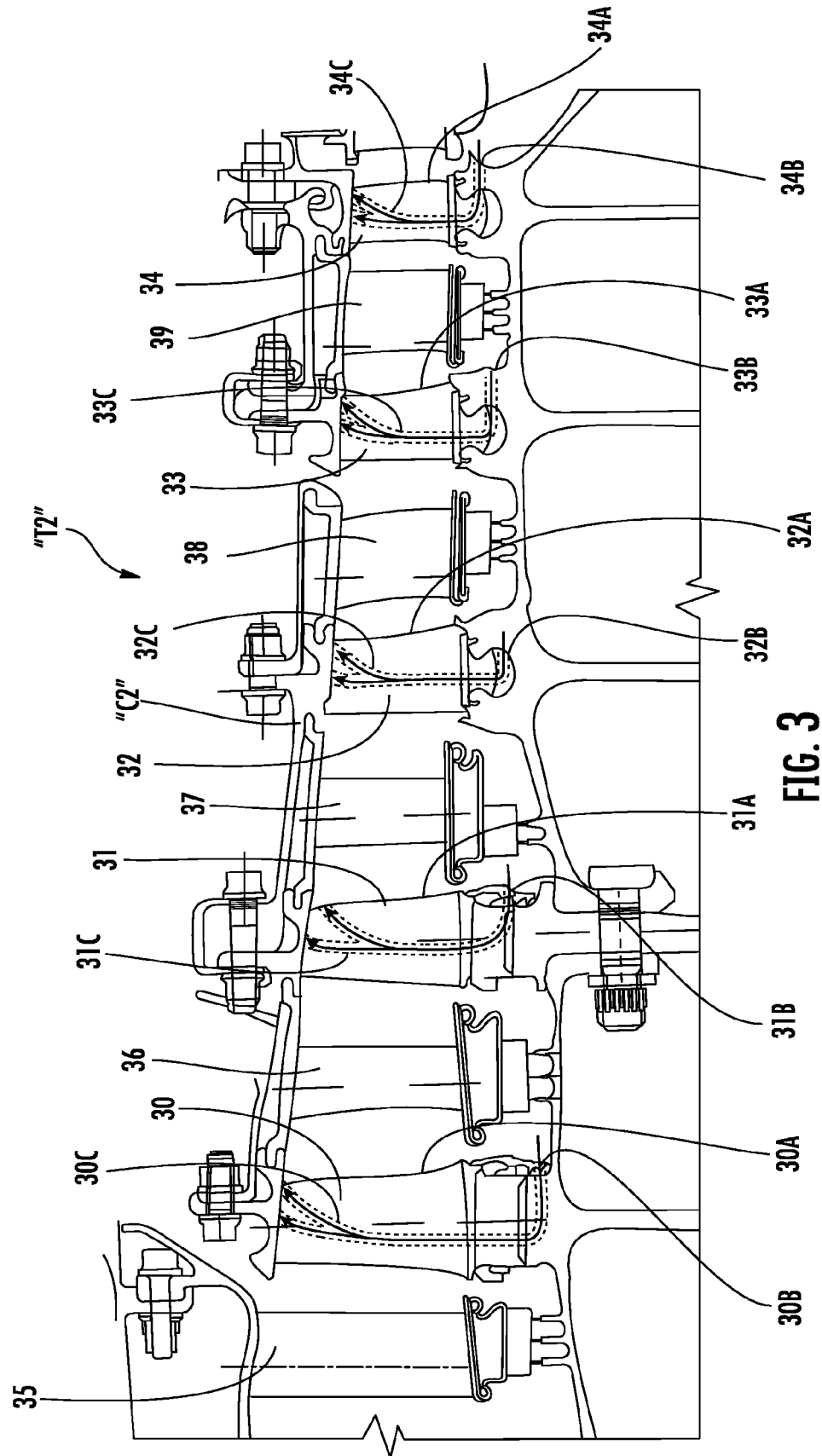


FIG. 1





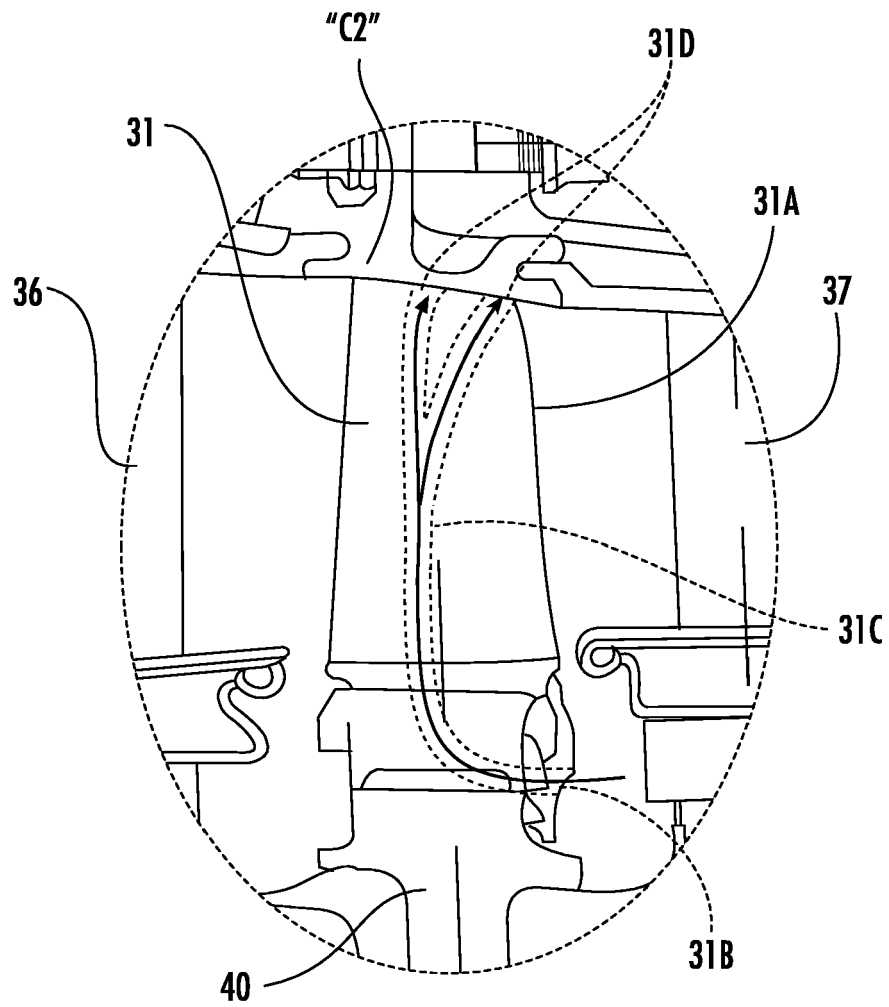
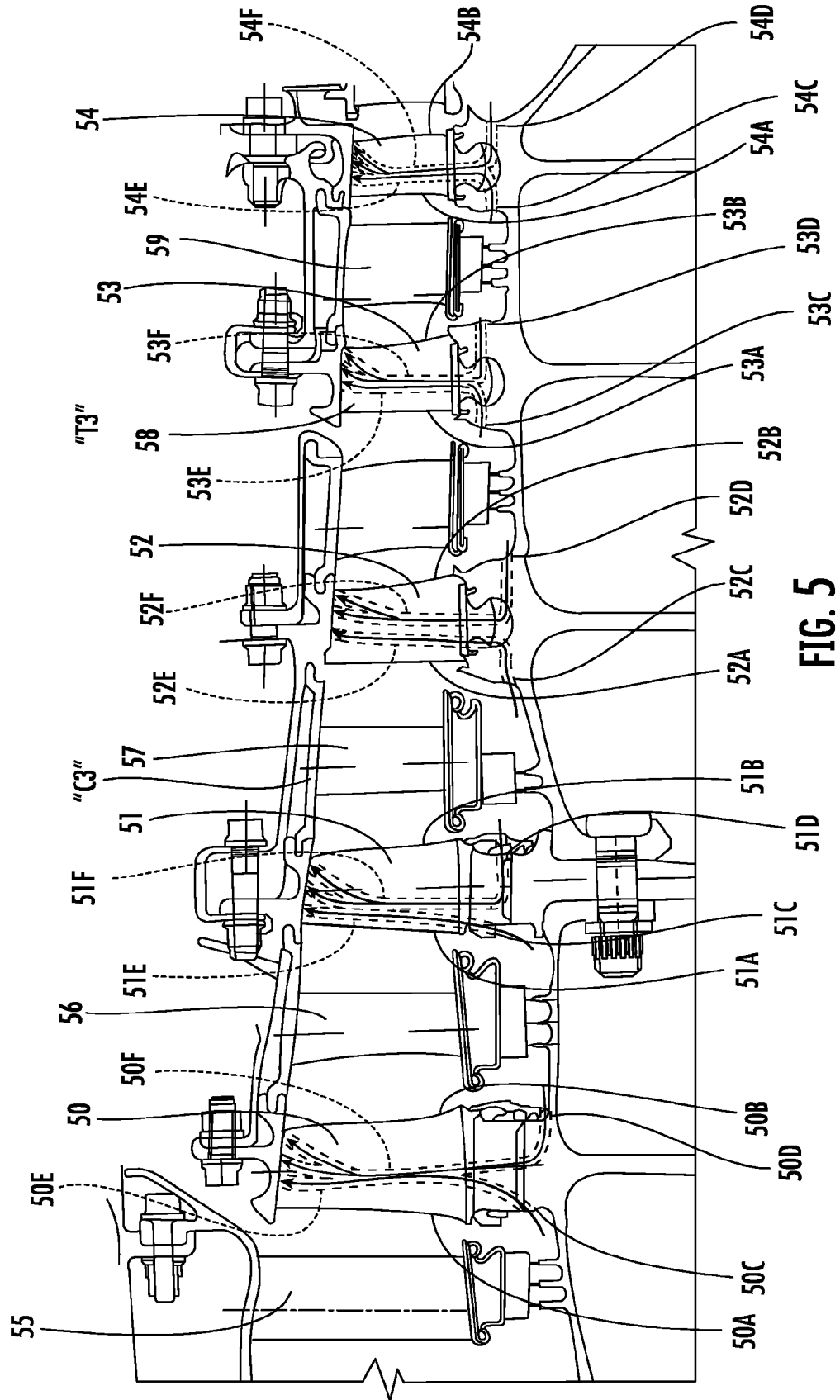


FIG. 4



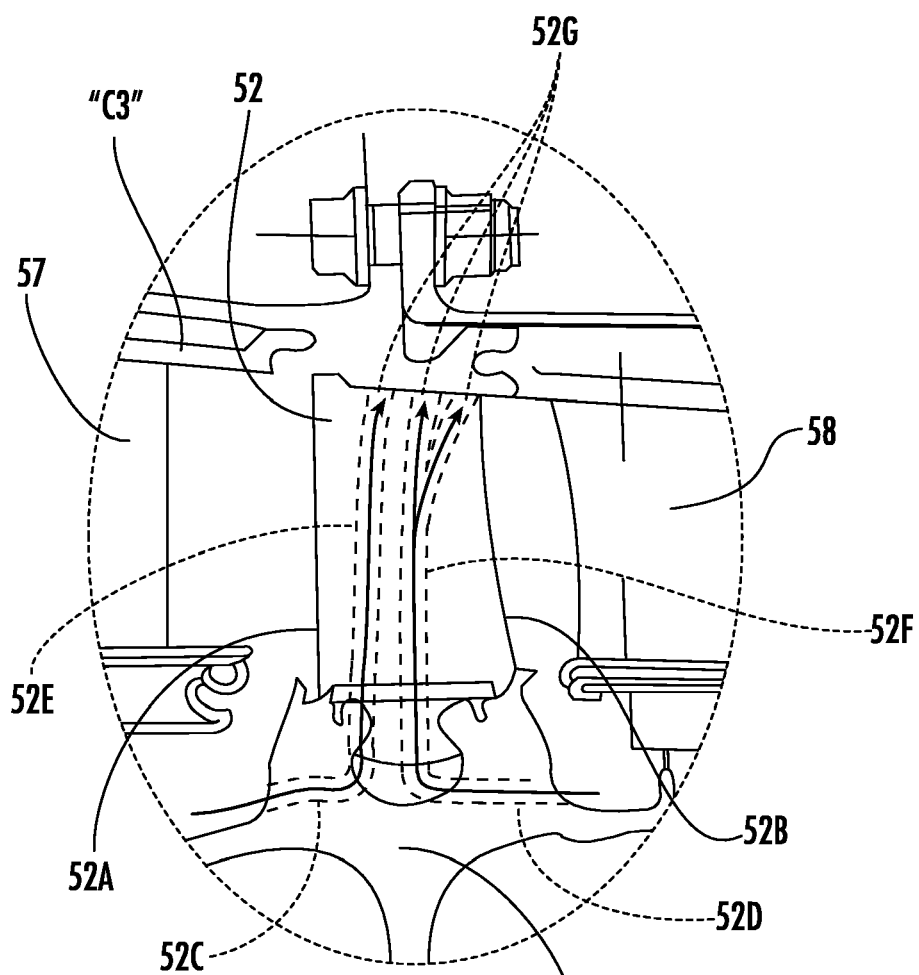


FIG. 6