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- (54) Title: CRENELATED TURBINE NOZZLE

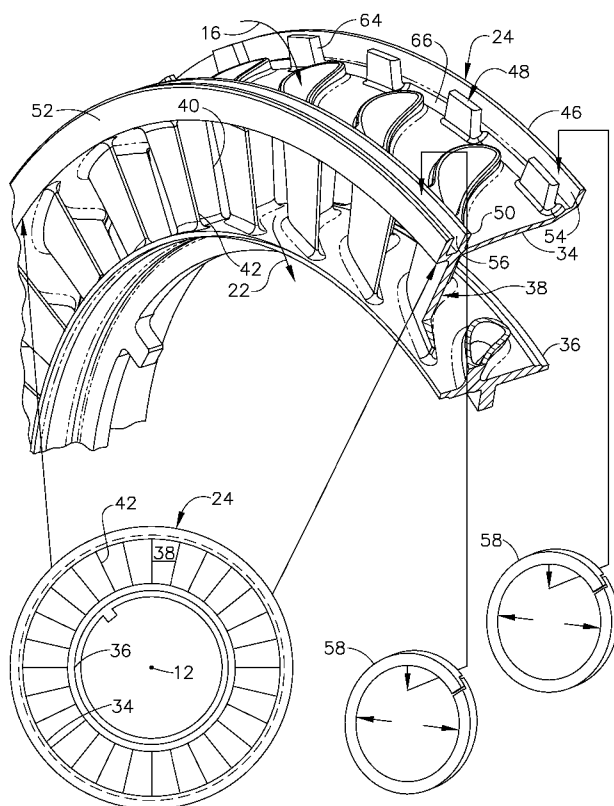


FIG. 3

- (57) Abstract: A turbine nozzle (24) includes a row of vanes (38) extending radially between annular outer and inner bands (34, 36). The outer band (34) includes a pair of radial flanges (46-52) defining an annular seal groove (54, 56) therebetween. One of the flanges (46-52) is crenelated to improve nozzle life.



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CRELATED TURBINE NOZZLE

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to gas turbine engines, and, more specifically, to turbine nozzles therein.

[0002] In a gas turbine engine, air is pressurized in a compressor and mixed with fuel in a combustor for generating hot combustion gases. The combustion gases are discharged from the combustor through a first stage turbine nozzle that channels the combustion gases into a row of turbine rotor blades which extract energy therefrom for powering the compressor.

[0003] The high pressure turbine (HPT) may have one or more turbine stages and is typically followed by a multistage low pressure turbine (LPT) that extracts additional energy from the combustion gases for powering an upstream fan in the typical turbofan aircraft engine configuration.

[0004] Since the first stage turbine nozzle first receives the high temperature combustion gases from the combustor it is subject to an extremely hostile operating environment that affects the useful life thereof. The nozzle components are typically formed from

circumferential continuity of the annular outer and inner bands which integrally support

the corresponding turbine nozzle vanes therebetween.

[0009] Fully annular or unsegmented nozzle bands have increased strength and rigidity but correspondingly restrain expansion and contraction of the rigid nozzle vanes extending radially therebetween. Accordingly, significant thermal stresses are generated at the radial ends of the vanes where they integrally join their corresponding outer and inner bands.

[0010] Thermal restraint as well as structural rigidity are correspondingly reduced by circumferentially segmenting the nozzle bands, which correspondingly increases the complexity of the design by requiring suitable spline seals between the segmented bands.

[0011] A nozzle having a row of vane singlets has maximum segmentation of the bands with a single vane being integrally mounted to correspondingly short outer and inner band segments.

[0012] A nozzle having vane doublets includes two vanes integrally mounted in common band segments with correspondingly fewer segments around the perimeter.

[0013] And nozzle triplets are also known in which three vanes are integrally grouped to corresponding band segments for further reducing the segmentation of the bands.

[0014] However, as the number of vanes in each band segment increases, the significant problem of thermal restraint of the individual vanes also increases, with an associated increase in thermal stress where the vanes meet the integral bands.

turbine nozzle is used without any circumferential segmentation of its outer and inner

bands for reducing the structural complexity thereof, but at the expense of nozzle life.

[0019] The inner band includes a middle mounting flange, with the outer band including two pairs of circumferentially continuous flanges defining forward and aft annular grooves. Expansion seals in the form of split piston rings are trapped in the grooves and extend radially outwardly in sealing abutment with corresponding annular seal lands.

[0020] In this way, the unitary turbine nozzle is fixedly mounted in the engine from its inner band, with the outer band being allowed to freely expand and contract radially while the ring seals seal the pressurized gases.

[0021] However, operating experience has shown that this type of turbine nozzle has a finite useful life substantially less than that typically found for segmented turbine nozzles. And, in a present development program, it is desired to substantially increase the useful life of this type of nozzle for reducing maintenance outages and operating costs.

[0022] Accordingly, it is desired to provide a unitary turbine nozzle having reduced thermal stress for increasing useful life.

BRIEF DESCRIPTION OF THE INVENTION

[0023] A turbine nozzle includes a row of vanes extending radially between annular

[0028] Figure 4 is an enlarged axial sectional view of the outer band portion of the

turbine nozzle illustrated in Figures 2 and 3 in accordance with one embodiment.

[0029] Figure 5 is a forward-facing schematic view of a portion of the outer band illustrated in Figure 4 and taken along line 5-5.

[0030] Figure 6 is an enlarged axial sectional view of the outer band, like Figure 4 illustrating another embodiment thereof.

[0031] Figure 7 is a forward-facing schematic view of a portion of the outer band illustrated in Figure 6 and taken along line 7-7.

[0032] Figure 8 is an enlarged axial sectional view of the outer band, like Figure 4 illustrating another embodiment thereof.

[0033] Figure 9 is a forward-facing schematic view of a portion of the outer band illustrated in Figure 8 and taken along line 9-9.

[0034] Figure 10 is an enlarged axial sectional view of the outer band, like Figure 4 illustrating another embodiment thereof.

[0035] Figure 11 is a forward-facing schematic view of a portion of the outer band illustrated in Figure 10 and taken along line 11-11.

DETAILED DESCRIPTION OF THE INVENTION

through an annular first stage turbine nozzle 24 which is axisymmetrical about the

centerline axis 12.

[0040] The turbine nozzle 24 discharges the combustion gases into a row of first stage turbine rotor blades 26 extending radially outwardly from a supporting rotor disk. The turbine nozzle 24 and rotor blades 26 define a single stage high pressure turbine (HPT).

[0041] The combustion gases as discharged from the turbine blades 26 in the axial downstream direction into a corresponding low pressure turbine (LPT) 28 which may have three corresponding stages for example. Each stage of the LPT 28 includes a corresponding stator nozzle followed in turn by a row of low pressure turbine rotor blades.

[0042] During operation, energy is extracted from the combustion gases 22 by the HPT blades 26 with their supporting disk being joined by a first drive shaft 30 to the centrifugal compressor 18 for providing energy thereto. Further energy is extracted from the combustion gases in the LPT 28 whose rotors are joined by a second drive shaft 32 disposed coaxially through the first drive shaft and extending axially forward to drive the upstream fan 14.

[0043] The exemplary engine illustrated in Figure 1 typically has a relatively small size and power output, with the centrifugal form of the compressor 18 having sufficient capacity for pressurizing the volume of air required for the intended power output. This type of small engine is in contrast with the substantially larger high bypass turbofan

circumference of the nozzle. The nozzle may be formed in any suitable manner to effect

the unitary or one-piece assembly thereof.

[0047] For example, the outer and inner bands 34,36 may be separately manufactured or cast as complete rings. The individual nozzle vanes 38 may be separately cast. And the bands and vanes may be formed of suitable superalloy metal for withstanding the high temperature environment of the engine, with the vanes being suitably brazed to the corresponding bands in a conventional manner.

[0048] The vanes 38 themselves are preferably hollow with thin metal walls having the typical crescent or airfoil configuration with a leading edge 40 at the upstream or forward end of the nozzle and bands, and corresponding axially opposite trailing edges 42 at the aft end of the nozzle and bands.

[0049] In the exemplary embodiment illustrated in Figure 3, each of the hollow vanes 38 extends radially through a corresponding aperture in the outer band 34 for receiving therethrough during operation compressor discharge air for internally cooling the vanes.

[0050] The vanes may have any conventional cooling configuration including one or more impingement baffles in the central chamber thereof for internally cooling each vane, with the vanes typically having various rows of film cooling holes disposed through the sidewalls thereof for discharging the spent cooling air for film cooling the external surfaces of the vanes.

[0054] The third and fourth flanges 50,52 of the aft flange pair extend radially outwardly

from the aft end of the outer band to define an aft annular seal groove 56.

[0055] As best illustrated in Figure 4, the first flange 46, the second flange 48, the third flange 50, and the fourth flange 52 are arranged in downstream numerical sequence between the forward and aft ends of the outer band 34 corresponding with the leading and trailing edges 40,42 of the vanes 38. The forward flange pair 46,48 and the annular groove 54 therebetween are disposed at the forward end of the outer band 34 cantilevered upstream from and terminating closely adjacent to the vane leading edges 40.

[0056] In contrast, the aft pair of flanges 50,52 and the corresponding groove 56 therebetween, are disposed at the aft end of the outer band directly above the solid trailing edge portion of the vanes 38. It is noted that each vane 38 as illustrated in Figure 3 first increases in width in the downstream direction from its leading edge and then decreases in width as it tapers to the relatively thin trailing edge. The internal cooling chamber or plenum of the hollow vane terminates upstream from the thin trailing edge to ensure suitable width for receiving the impingement baffle or other cooling features desired therein.

[0057] The two annular seal grooves 54,56 illustrated in Figure 4 face or open radially outwardly and correspondingly receive structurally similar or identical first and second expansion seal rings 58.

[0061] Similarly, the turbine casing commences around the aft end of the outer band 34

with an annular aft land 62 disposed concentrically around the corresponding aft two flanges 50,52 and against which the aft expansion ring 58 provides another abutting contact seal.

[0062] During operation, the pressurized compressor discharge air 16 is channeled around the combustor and is distributed into an open plenum surrounding the outer band of the nozzle for flow through the outer band into the corresponding nozzle vanes 38.

[0063] As better illustrated in Figure 4, the pressurized compressor air 16 pressurizes the supply plenum between the outer band 34 and the two sealing lands 60,62 and also acts against the forward and aft seal rings 58.

[0064] These two seal rings 58 provide effective contact seals between their radially outer perimeter surfaces and the corresponding inner surfaces of the two lands 60,62 to prevent or minimize leakage of the pressurized air into the combustion gas flowpath.

[0065] Furthermore, the forward ring 58 is pressurized forward against the aft surface of the first flange 46 to provide a lateral abutting contact seal therewith. Similarly, the aft seal ring 58 is pressurized aft against the forward surface of the fourth flange 52 to provide another laterally adjoining contact seal therebetween.

[0066] The two expansion rings 58 typically include a single split in the circumferential continuity thereof with a suitable lateral lap joint therebetween, and initially oversized in

[0069] However, the four sealing flanges 46-52 provide substantial structural rigidity to

the thin outer band 34 in their circumferentially continuous configuration required for suitably trapping the two rings 48 with minimal side clearance to permit differential radial thermal expansion and contraction between the nozzle and the sealing lands 60,62.

[0070] Nevertheless, this basic nozzle design has enjoyed suitably long life in commercial service, but it is desired to increase the useful service life of the nozzle which in turn requires substantial improvements in the design.

[0071] However, the unitary turbine nozzle 24 is a highly complex and three-dimensional assembly of a multitude of hollow nozzle vanes integrally joined to the unitary outer and inner bands. Accordingly, the mechanical and thermal loads and stresses experienced by the nozzle are quite complex and inter-related.

[0072] In particular, the individual vanes 38 are rigidly joined at their radially outer and inner ends to the corresponding bands, and provide distributed radial loadpaths between the two bands during operation. The outer ends of the vanes are rigidly joined to the inner surface of the outer band 34, and necessarily cooperate with the four sealing flanges extending radially outwardly from the outer surface of the bands.

[0073] The forward pair of flanges 46,48 are cantilevered axially forward from the leading edges of the vanes. Whereas, the aft flanges 50,52 are disposed directly above the solid portion of the vane trailing edges.

example, the crenelated flange 48 preferably includes a common row of rectangular tabs or

solid merlons 64 spaced circumferentially apart from each other by corresponding rectangular spaces or crenels 66.

[0078] As best shown in Figure 5, the merlons 64 are relatively tall and match the radial height of the cooperating first flange 46 and therefore begin in height at the outer surface of the outer band 34 and terminate in height at the same outer diameter as the first flange 46.

[0079] Correspondingly, the cooperating crenels 66 are also tall or full height and extend circumferentially along the outer surface of the band between adjacent merlons 64 over the full height of the merlons in the second flange 48.

[0080] The four flanges 46-52 may enjoy the benefit of their original designs and have minimum radial height and axial thickness as required for duly supporting the corresponding expansion rings 58 in accordance with their original design.

[0081] The preferential modification of the second flange 48 to introduce the crenel spaces 66 for interrupting the circumferential continuity of the flange locally reduces the structural rigidity of the outer band near the junctions of the vane leading edges and the band for substantially reducing local stresses thereat for increasing nozzle life.

[0082] As indicated above, each vane effects a locally rigid radial loadpath having locally high stresses with its juncture with the outer band, particularly near the leading and

crenels 66 bridging the vane leading edge between merlons.

[0087] The structural rigidity between the thin outer band and each vane around its leading edge is therefore substantially reduced which correspondingly reduces the local stresses thereat during operation, which in turn leads to increased nozzle life.

[0088] In the exemplary embodiment illustrated in Figure 3, the nozzle includes a full complement of twenty eight vanes 38 spaced apart circumferentially around the perimeter thereof, with the number of merlons 64 preferably matching in quantity, twenty eight, the number of vanes in the nozzle in a one-to-one arrangement.

[0089] This configuration suitably isolates the individual merlons 64 away from the leading edge junctures of the vanes and outer band while also maintaining the retention capability of the second flange 48 for preferentially trapping the forward expansion ring 58. And, since the expansion ring 58 has the split lap joint in its perimeter, the close spacing of adjacent merlons 64 ensures effective lateral or axial retention of the split-ring 58 without unacceptable separation of the lap joint itself due to lateral bending.

[0090] Each merlon 64 is preferably rectangular in configuration as disclosed above and has a radial height matching that of the cooperating first flange 46. Otherwise, the circumferential width and axial thickness of each merlon 64 may be suitably designed for minimizing added rigidity of the outer band while maintaining the retention function of the segmented second flange 48 by its merlons 64.

particular their leading and trailing edges 40,42. The vane leading and trailing edges 40,42

effect corresponding local stress concentrations at their juncture with the outer bands.

[0094] Note in particular that although the fourth flange 52 at the vane trailing edges may be crenelated for locally reducing stresses, such crenelation interferes with the original sealing design of the aft expansion ring 58. Any circumferential interruptions in the aft flange 52 create local sites where the pressurized compressor air may leak, which leakage must be controlled for proper operation of the turbine nozzle.

[0095] Figures 6 and 7 illustrate a suitable form of the crenelated fourth flange 52 for resolving this sealing problem. In particular, the crenelated aft flange 52 includes an annular ridge or base 68 which is circumferentially continuous around the full 360 degree circumference of the outer band, which base 68 extends radially outwardly from the outer surface thereof.

[0096] In this configuration, the rectangular merlons 64 are relatively short and extend radially outwardly in integral width from the supporting base 68, with the correspondingly short crenels 66 extending circumferentially between the adjacent short merlons and above or along the top surface of the annular base 68.

[0097] In this configuration, the aft flange 52 is crenelated in part and provides a circumferentially scalloped retaining flange that retains full surface coverage along the bottom of the aft groove 56, while interrupting the circumferential continuity and rigidity

contact seal with the outer surface of the outer band in the aft groove, with the inner aft

surface of the ring 70 also providing a contact seal along the forward face of the annular base 68. The inward contraction force is represented in Figure 7 by the diametric arrows.

[0101] Figure 7 illustrates schematically the radially outward or outbound residual loads in the expansion ring 58 for providing outward seating thereof with the corresponding lands 60,62. Correspondingly, the radially inward or inbound residual loads in the contraction ring 70 are also illustrated schematically to ensure inward seating thereof in the aft groove 56.

[0102] Accordingly, the aft flange 52 may be crenelated in part for reducing structural rigidity of the outer band around the vane trailing edges, with the secondary contraction ring 70 being introduced into the aft groove 56 for cooperating with the expansion ring 58 to collectively effect suitable sealing during operation.

[0103] The relative dimensions of the expansion ring 58 and cooperating contraction ring 70 in the common aft groove 56 may be selected as desired for withstanding the operating environment of the nozzle. The contraction ring 70 is illustrated as being thinner than the expansion ring 58 but may have the same or similar thickness suitably accommodated by increasing the width of the aft groove 56 if desired.

[0104] Both the forward and aft grooves 54,56 are sized in axial width to be a few mils

of this flange is to retain the aft expansion ring 58 without any requirement for sealing. As

indicated above, sealing in the aft groove 66 occurs both at the radial perimeter of the expansion ring 58 and its axially aft surface, and not its axially forward surface which is typically spaced from the third flange 50.

[0108] Whereas the crenelated fourth flange 52 reduces structural rigidity around the outer band over the vane trailing edges, crenelation of the third flange 50 also reduces structural rigidity thereof in combination with the aft flange 52.

[0109] Note that in Figure 8 both flanges 50,52 are located directly atop the solid portion of the thin trailing edges 42 of the row of vanes and thusly provide corresponding loadpaths therebetween. Analysis suggests that the use of the crenelated third flange 50 by itself with the remaining three flanges being circumferentially continuous will undesirably increase the local stresses in the junction between the vane trailing edges and the outer band and correspondingly reduce nozzle life.

[0110] Accordingly, the various sealing flanges 46-52 surrounding the nozzle outer band 34 may be crenelated only preferentially, depending upon their relative axial location in the turbine nozzle and relative to the underlying location of the nozzle vanes. Corresponding stress analysis for specific nozzle designs may therefore be used to determine which of the several radial flanges may be effectively crenelated for decreasing, and not undesirably increasing, local stresses for increasing useful life of the nozzle.

outwardly from that base 68, with the corresponding short crenels 66 extending

circumferentially between adjacent short merlons and along or atop the supporting annular base 68.

[0117] Correspondingly, the forward groove 54 includes both the first expansion ring 58 and a laterally abutting contraction ring 70. The contraction ring 70 in the forward groove 54 is disposed axially between the forward ring 58 and the first flange 46, with the forward ring 58 laterally abutting the aft face of the forward contraction ring 70, with the forward face of the contraction ring laterally abutting the crenelated first flange 46.

[0118] Whereas the aft contraction ring 70 in the aft groove 56 provides an aft seal for the aft expansion ring 58, the forward contraction ring 70 in the forward groove 54 provides a forward seal with the forward expansion ring 58 to suitably contain the pressurized air 16 surrounding the nozzle outer band.

[0119] Accordingly, Figures 10 and 11 illustrate a collective embodiment in which all four sealing flanges 46-52 are suitably crenelated for locally reducing the circumferential stiffness and rigidity of the outer band for in turn locally reducing stresses near the leading and trailing edges of the vanes. The forward groove 54 retains the first expansion ring 58 laterally trapped between the two crenelated forward and aft flanges 46,48 in the forward flange pair.

[0120] The aft groove 56 includes a second expansion ring 58 laterally retained between

edges of adjacent vanes.

[0126] Figure 11 illustrates that the corresponding merlons 64 of the aft two flanges 50,52 may also be isolated from the trailing edges of the adjacent vanes and preferably equidistantly therebetween. In this configuration, the aft merlons 64 of the aft two flanges 50,52 may be aligned with each other but circumferentially offset from the corresponding forward merlons 64 of the forward two flanges 46,48 which themselves may be axially aligned together.

[0127] In all of the embodiments disclosed above, crenelation of one or more of the sealing flanges not only reduces structural rigidity and stiffness of the outer band, but also reduces weight of the turbine nozzle which further improves the overall efficiency of the engine. The introduction of the secondary contraction ring 70 is offset in weight by the corresponding crenelation of the associated flanges.

[0128] The crenelated turbine nozzle disclosed above is effective for reducing otherwise locally high stresses where the vanes join the outer band for correspondingly increasing the useful life of the nozzle with relatively few modifications of the original nozzle design with the preferential elimination of flange material.

[0129] While there have been described herein what are considered to be preferred and exemplary embodiments of the present invention, other modifications of the invention shall be apparent to those skilled in the art from the teachings herein, and it is, therefore,

CLAIMS

1. A turbine nozzle (24) comprising:
 - an outer band (34) integrally joined to a row of nozzle vanes (38) extending radially inwardly therefrom, and including forward and aft pairs of flanges (46-52) extending radially outwardly; and
 - one of said flanges (46-52) being crenelated circumferentially therearound with a row of merlons (64) spaced circumferentially apart by corresponding crenels (66).
2. A nozzle according to claim 1 wherein:
 - said vanes (38) have axially opposite leading and trailing edges (40,42);
 - said flanges are arranged in a first, second, third, and fourth flange sequence between forward and aft ends of said outer band (34) corresponding with said leading and trailing edges (38,40) of said vanes (38); and
 - said second flange (48) is crenelated adjacent said leading edge (40).
3. A nozzle according to claim 2 wherein said merlons (64) in said second flange (48) are spaced circumferentially between corresponding pairs of said vanes (38).

a first expansion seal ring (58) disposed in a forward groove (54) between said first and second flanges (46,48);

a second expansion seal ring (58) disposed in an aft groove (56) between said third and fourth flanges (50,52); and

a contraction seal ring (70) disposed also in said aft groove (56) axially between said second ring (58) and said crenelated fourth flange (52).

7. A nozzle according to claim 5 wherein said third flange (50) is also crenelated.

8. A nozzle according to claim 5 wherein said first flange (46) is also crenelated.

9. A nozzle according to claim 5 wherein:

said third flange (50) is also crenelated with merlons (64) beginning at said outer surface of said outer band (34) and corresponding crenels (66) extending circumferentially therebetween along said outer surface; and

said first flange (46) is also crenelated and includes an annular base (68) extending radially outwardly from said outer band (34) with merlons (64) extending radially outwardly from said base (68) and corresponding crenels (66) extending circumferentially therebetween along said base (68).

and spaced axially apart to define an annular seal groove (54,56); and

one of said flanges (46-52) being crenelated.

12. A nozzle according to claim 11 wherein said crenelated flange (46-52) comprises a row of merlons (64) spaced circumferentially apart by corresponding crenels (66).

13. A nozzle according to claim 12 wherein said merlons (64) begin at the outer surface of said outer band (34), and said crenels (66) extend circumferentially along said outer surface between adjacent merlons (64).

14. A nozzle according to claim 12 wherein said crenelated flange (46-52) further comprises an annular base (68) extending radially outwardly from said outer band (34), and said merlons (64) extend radially outwardly from said base (68) with said crenels (66) extending circumferentially therebetween and above said base (68).

15. A nozzle according to claim 12 wherein said merlons (64) match in quantity said row of vanes (38).

16. A nozzle according to claim 12 wherein said merlons (64) are spaced circumferentially between corresponding pairs of said vanes (38).

a contraction seal ring (70) disposed in said seal groove (56) laterally abutting said expansion ring (58) and radially inwardly abutting said outer band (34); and

said contraction ring (70) laterally abuts said crenelated flange (52,46).

21. A nozzle according to claim 12 further comprising:

a forward pair of first and second ones of said flanges (46,48) extending radially outwardly from said outer band (34) at a forward end thereof to define a forward annular seal groove (54);

an aft pair of third and fourth ones of said flanges (50,52) extending radially outwardly from said outer band (34) at an aft end thereof to define an aft annular seal groove (56); and

one of said four flanges (46-52) is crenelated.

22. A nozzle according to claim 21 wherein:

said vanes (38) have axially opposite leading and trailing edges (40,42) corresponding with said forward and aft ends of said outer band (34), and said first, second, third, and fourth flanges (46-52) are arranged in downstream sequence between; and

said second flange (48) is crenelated.

from said outer band (34), and said merions (64) in said fourth flange extend radially outwardly from said base (68) with said crenels (66) extending circumferentially

therebetween and above said base (68).

27. A nozzle according to claim 22 wherein said first flange (46) is also crenelated.

28. A nozzle according to claim 27 wherein said forward groove (54) includes both an expansion ring (58) and a laterally abutting contraction ring (70) in turn laterally abutting said crenelated first flange (46).

29. A nozzle according to claim 28 wherein:

said merlons (64) in said second flange (48) begin at the outer surface of said outer band (34), and said crenels (66) extend circumferentially along said outer surface between adjacent merlons (64); and

said first flange (46) includes an annular base (68) extending radially outwardly from said outboard (34), and said merlons (64) in said first flange (46) extends radially outwardly from said base (68) with said crenels (66) extends circumferentially therebetween and above said base (68).

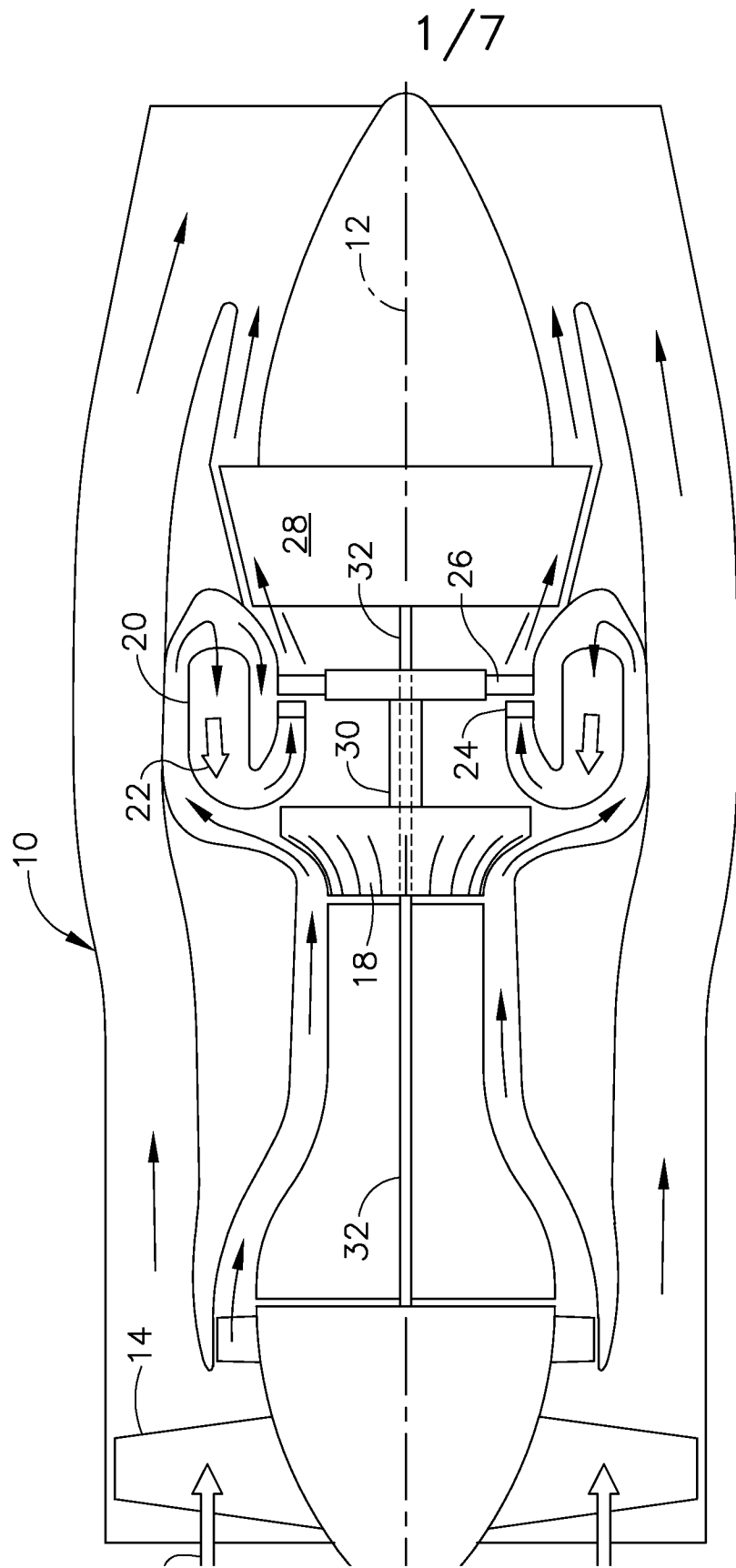


FIG. 1

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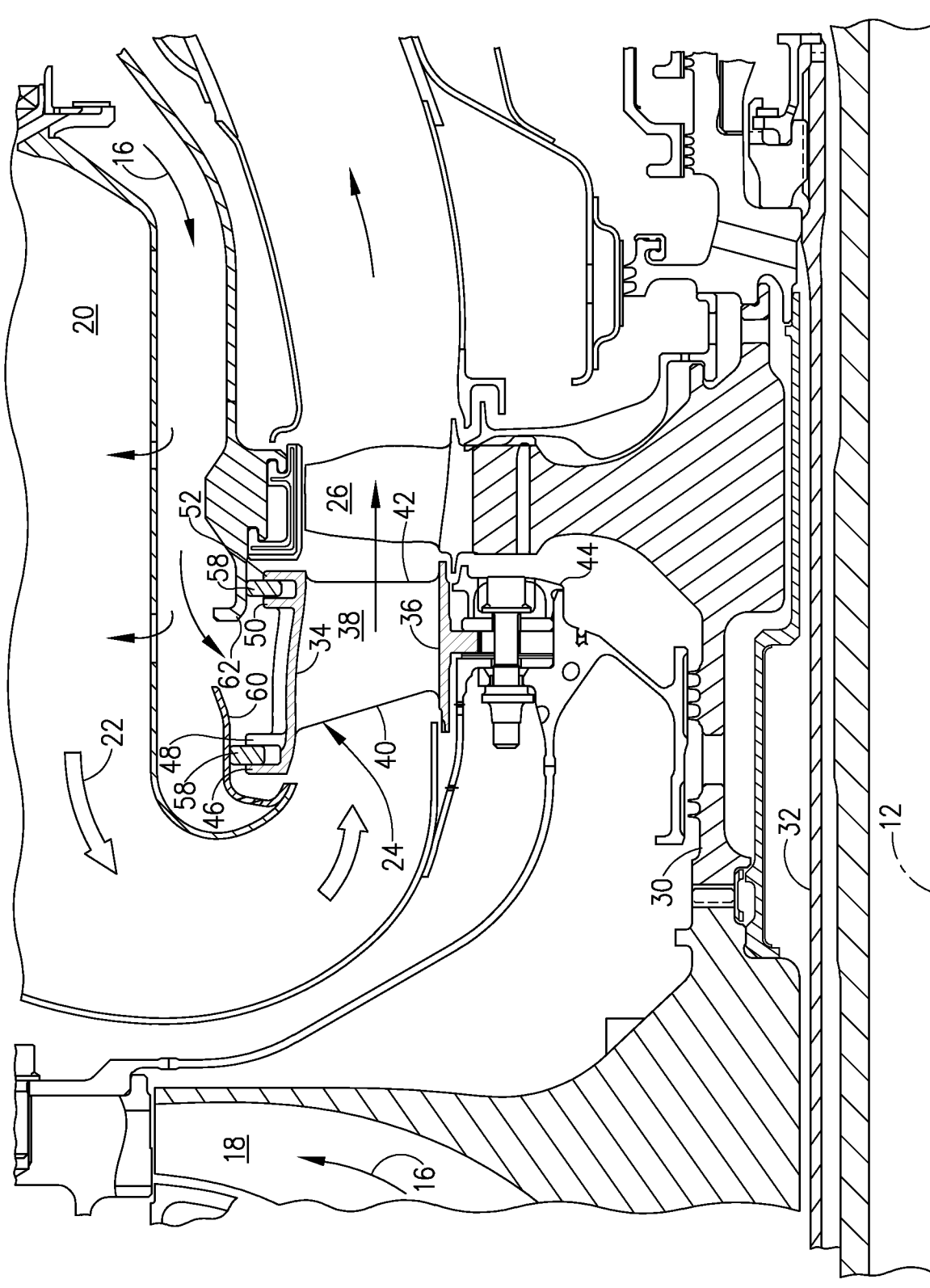


FIG. 2

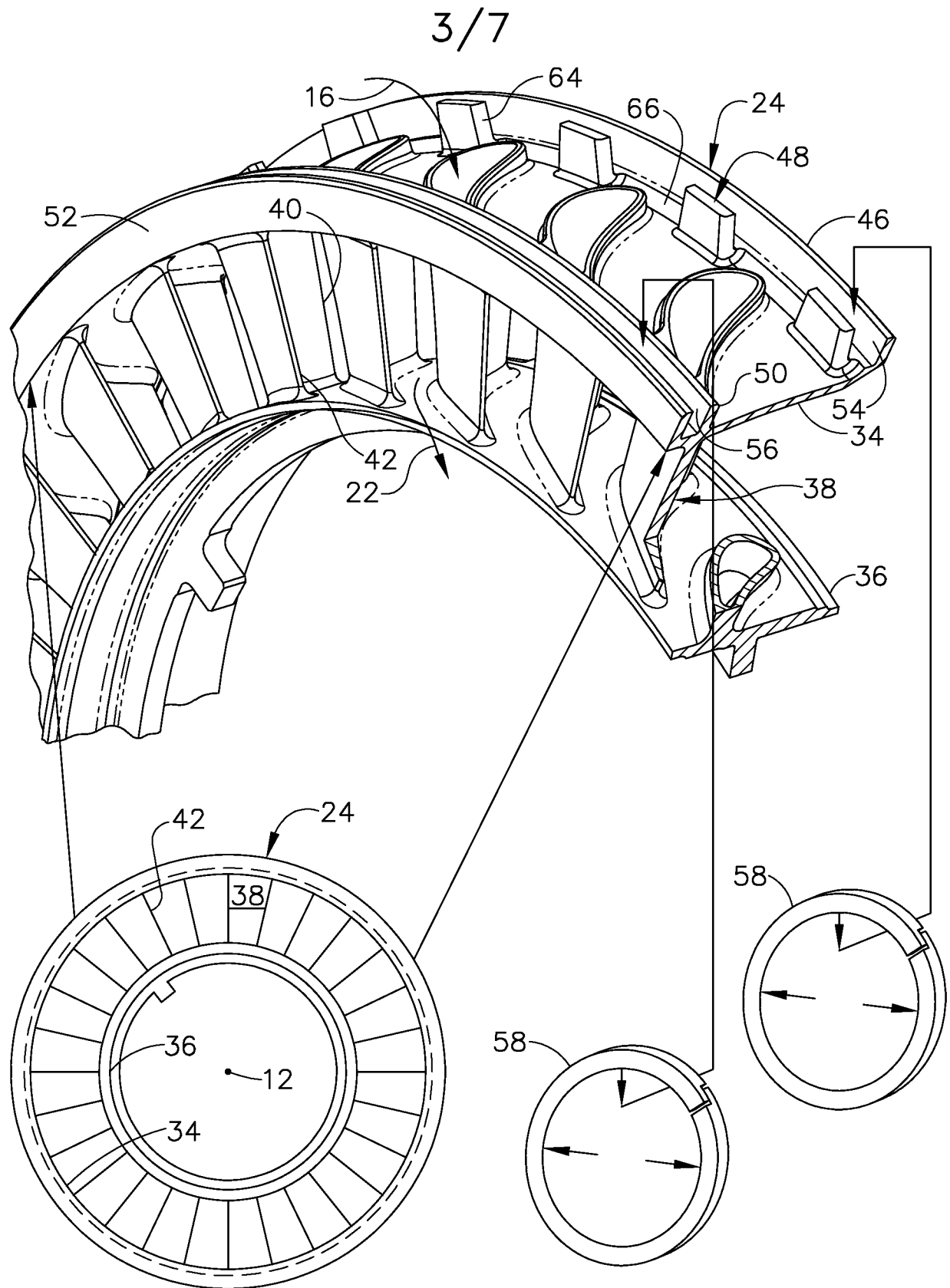


FIG. 3

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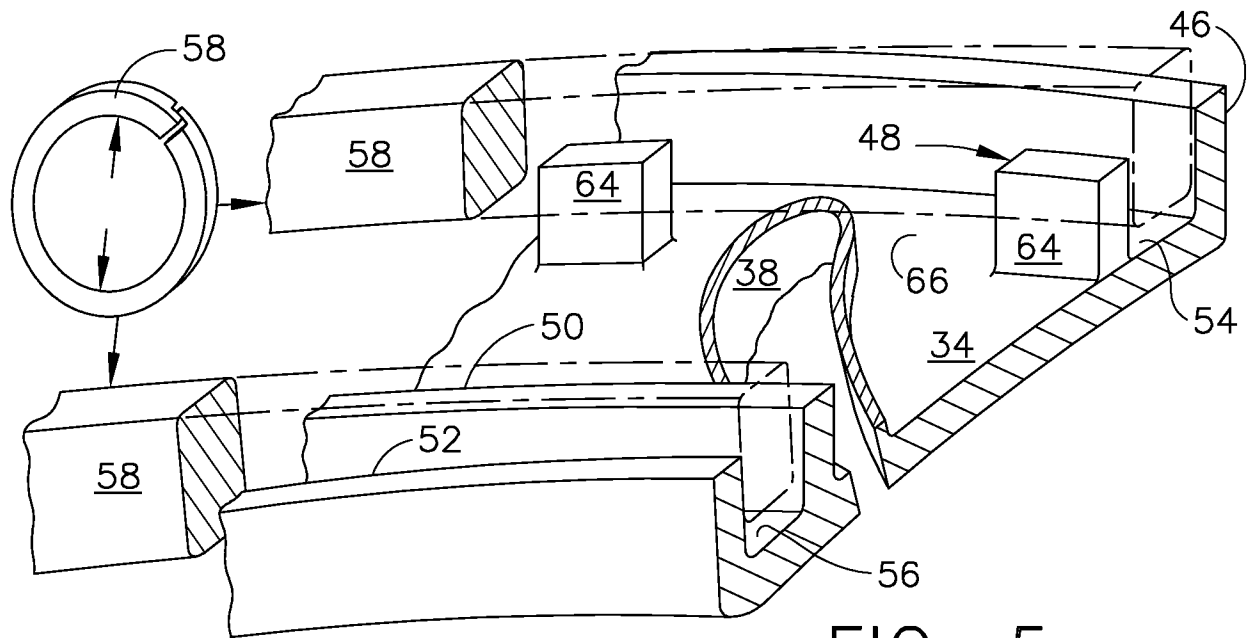


FIG. 5

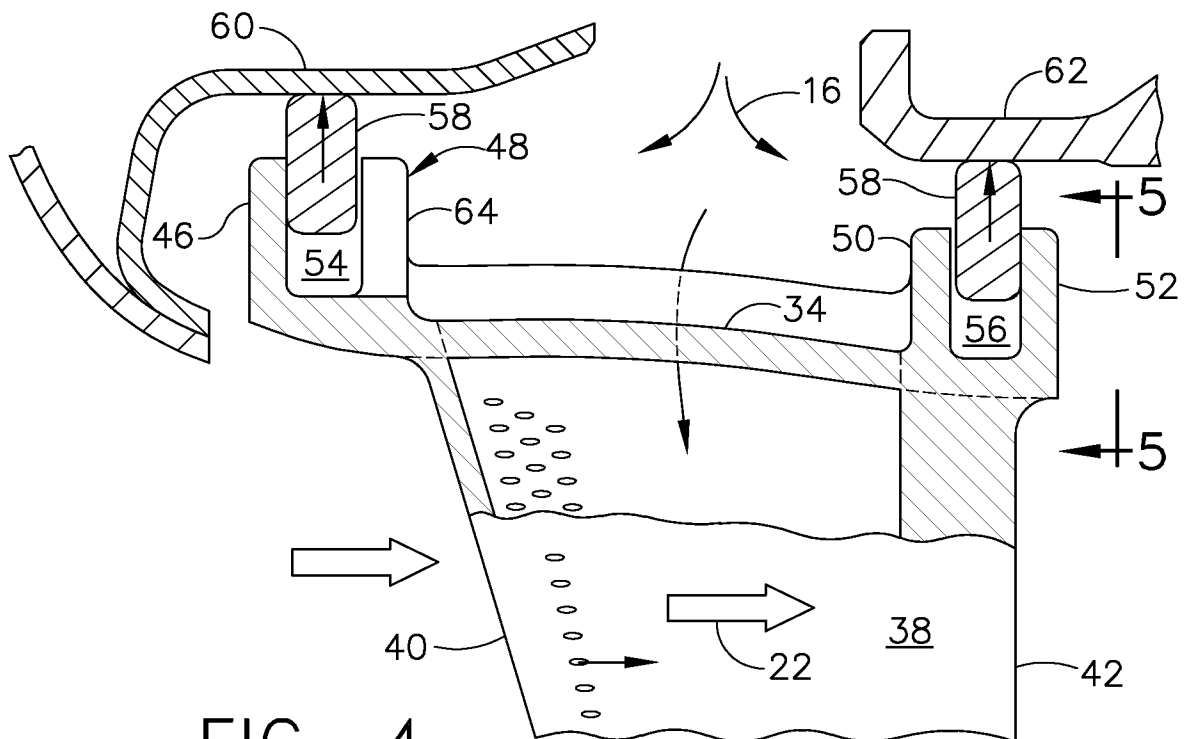


FIG. 4

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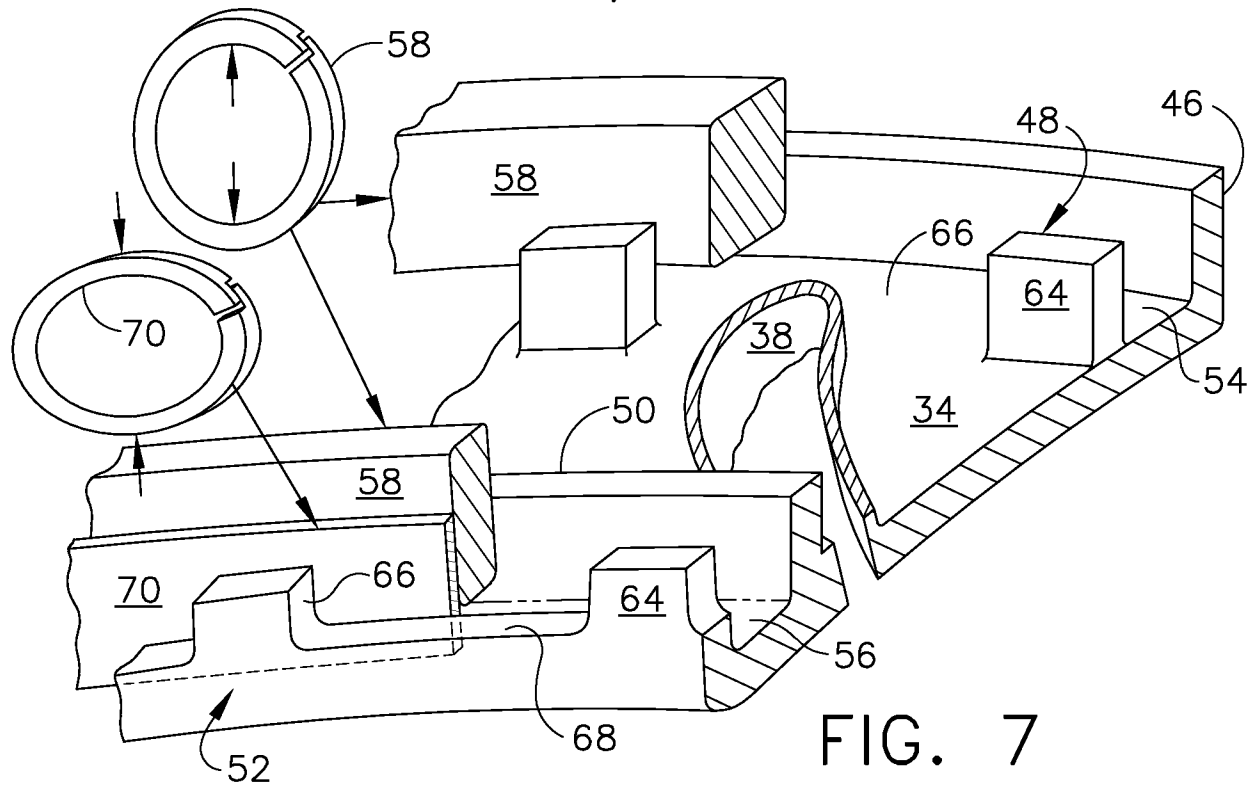


FIG. 7

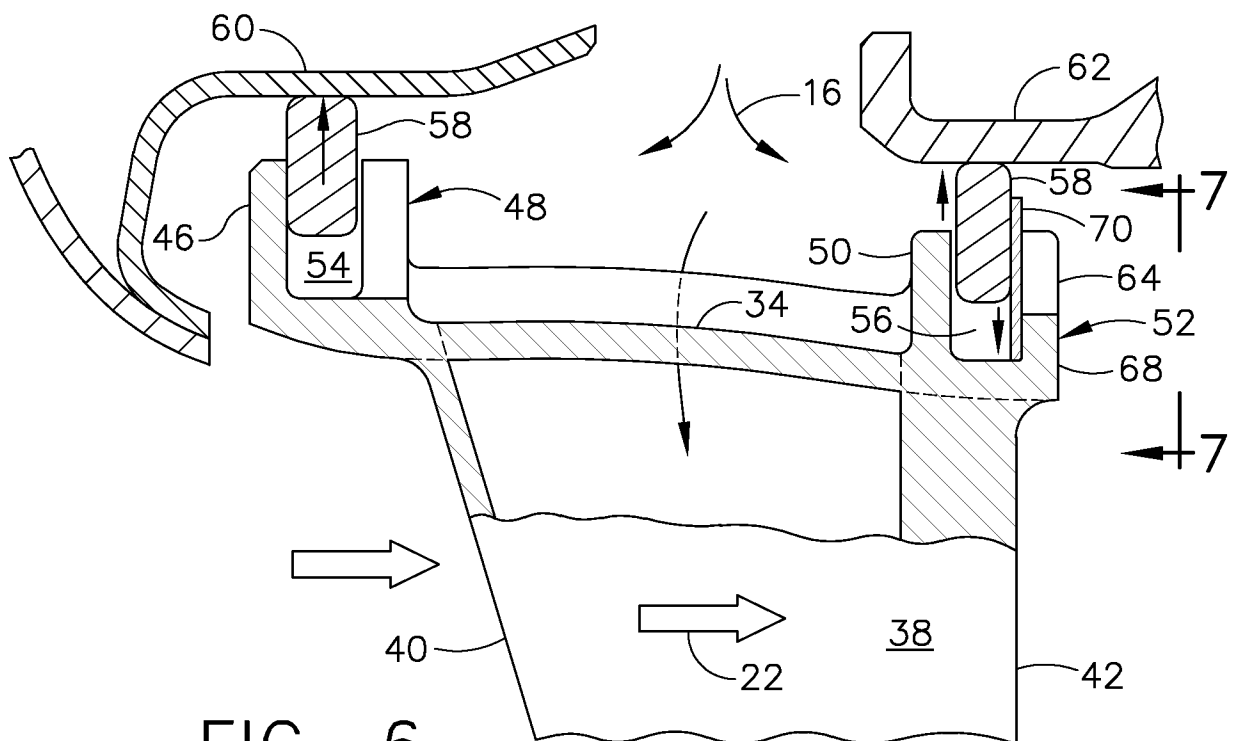


FIG. 6

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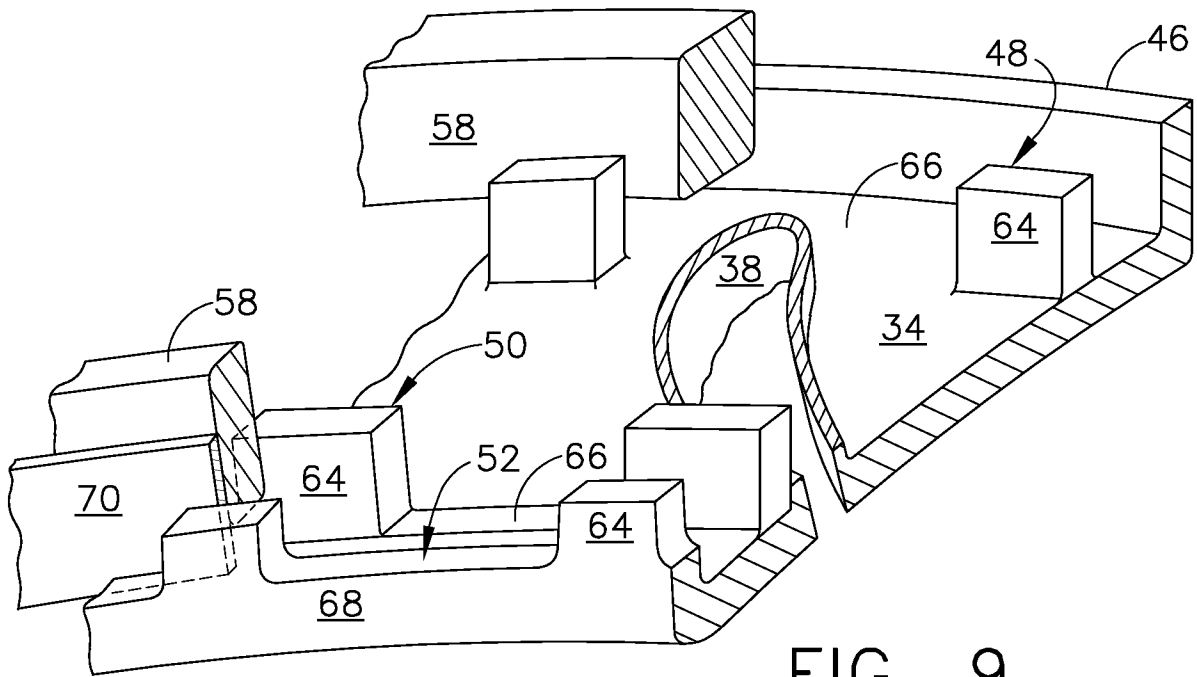


FIG. 9

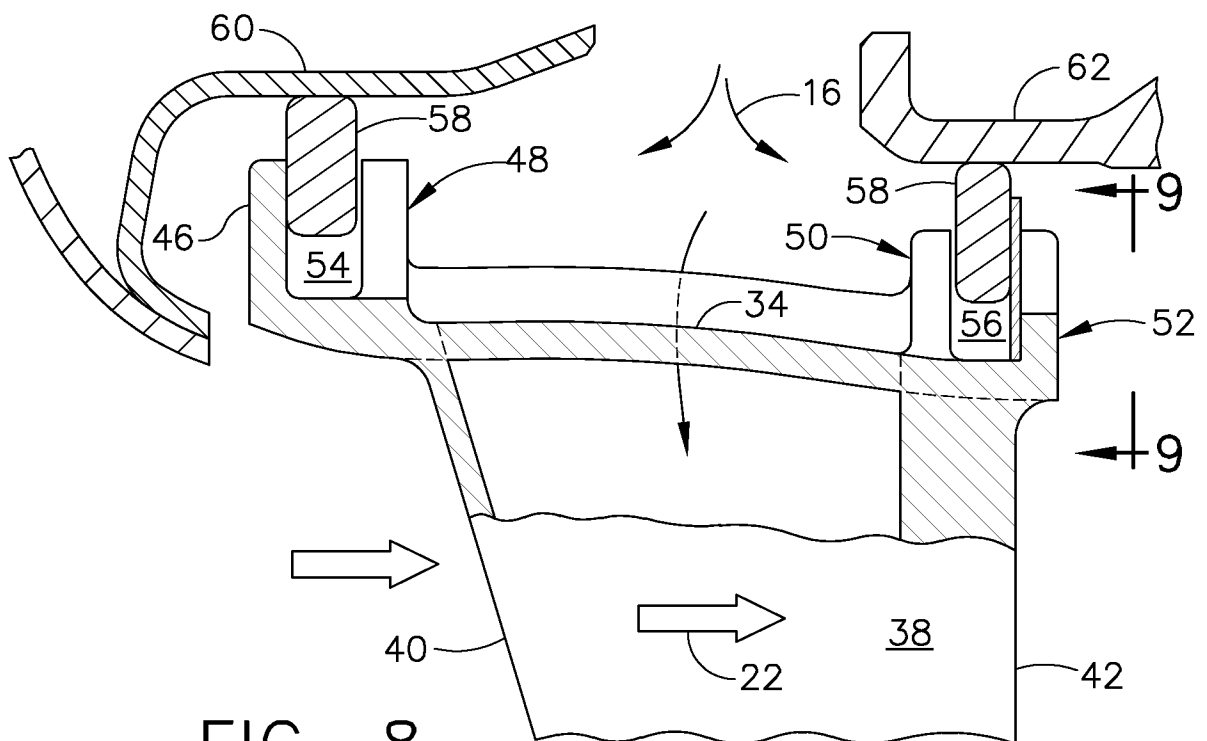


FIG. 8

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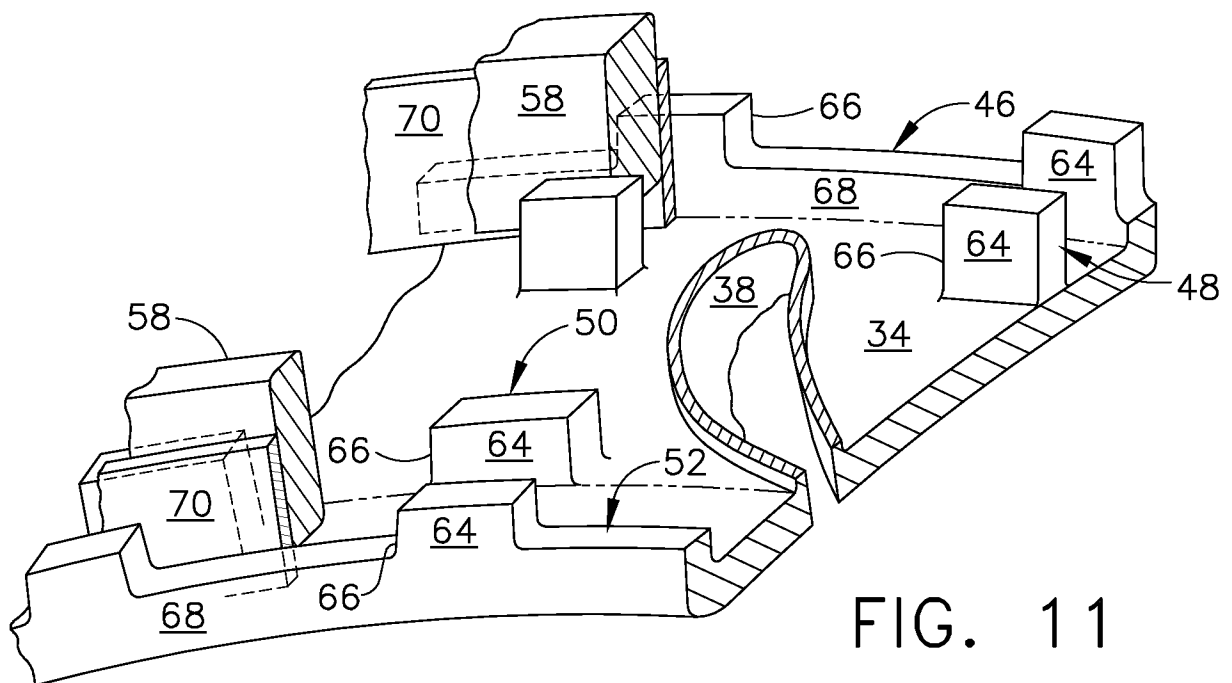


FIG. 11

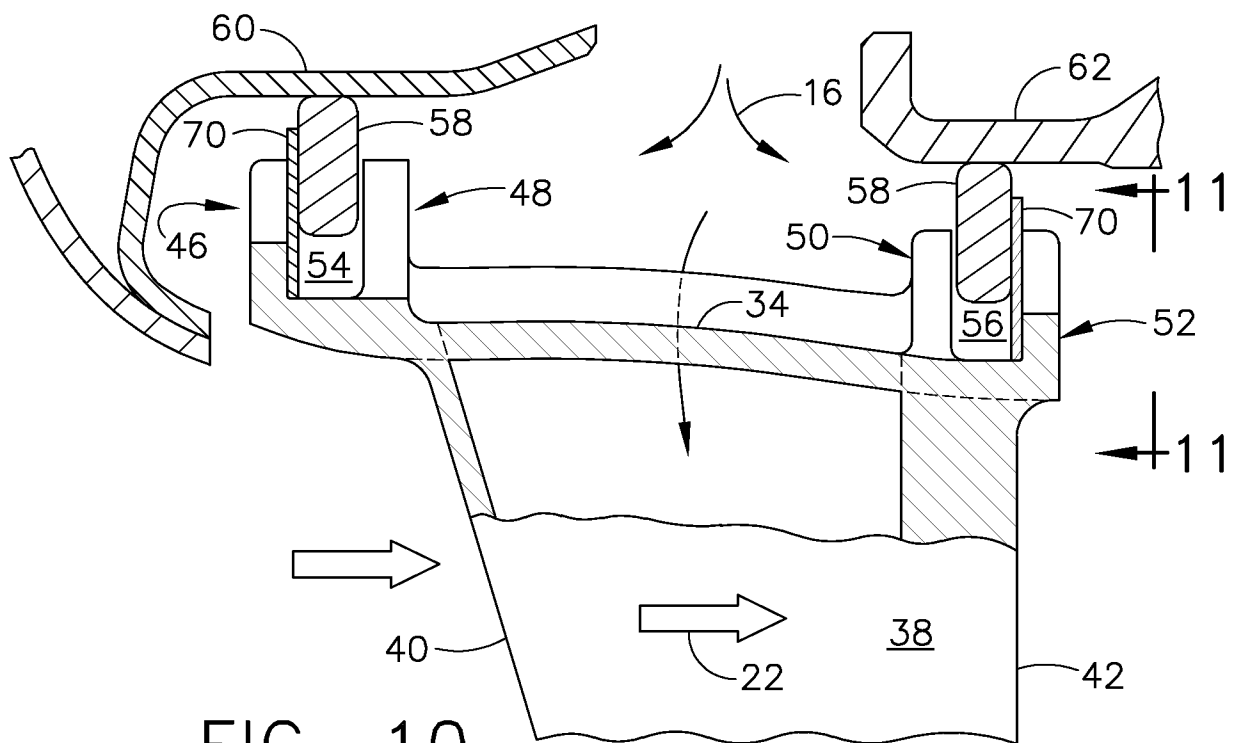


FIG. 10