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(71) Applicant: **SIEMENS ENERGY, INC.** [US/US]; 4400 Alafaya Trail, Orlando, Florida 32826-2399 (US).

(72) Inventors: **PORTILLO BILBAO, Juan Enrique**; 3766 Safflower Terrace, Oviedo, Florida 32766 (US). **MORRISON, Jay A.**; 2885 Kingfisher Way, Mims, Florida 32754 (US). **SHIPPER, Jonathan E., Jr.**; 529 Silvergate Loop, Lake Mary, Florida 32746 (US). **SMITH, Kyle**; 650 S. Ranger Boulevard, Winter Park, Florida 32792 (US).

WALL, Andrew; 9056 Oak Moss Drive, Orlando, Florida 32832 (US).

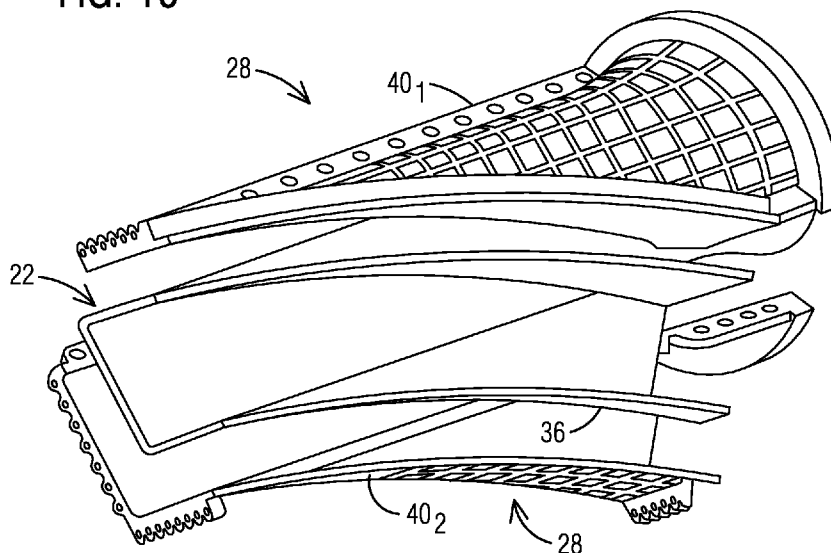
(74) Agent: **MORA, Enrique J.**; Siemens Corporation- Intellectual Property Dept., 3501 Quadrangle Blvd. Ste. 230, Orlando, Florida 32817 (US).

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FIG. 10



(57) Abstract: A transition duct system (10) for delivering hot-temperature gases from a plurality of combustors in a combustion turbine engine is provided. The system includes an exit piece (16) for each combustor. A non-metallic thermally-insulating liner (22), as may be made from a ceramic-based material, such as a ceramic matrix composite (CMC) material or other high-temperature ceramic-based material, e.g., a MAX phase material, may be inwardly disposed onto a splittable or otherwise separable metallic shell support structure (38). Disclosed structural arrangements are effective to securely attach the non-metallic thermally-insulating liner in the presence of substantial flow path pressurization. Cost-effective serviceability of the transition duct systems is realizable since the liner can be readily removed and replaced as needed.

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UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
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TRANSITION DUCT SYSTEM WITH NON-METALLIC THERMALLY-INSULATING
LINERS SUPPORTED WITH SPLITTABLE METALLIC SHELL STRUCTURES FOR
DELIVERING HOT-TEMPERATURE GASSES IN A COMBUSTION TURBINE ENGINE

5 STATEMENT REGARDING FEDERALLY SPONSORED DEVELOPMENT

Development for this invention was supported in part by Contract No. DE-FE0023955, awarded by the United States Department of Energy. Accordingly, the United States Government may have certain rights in this invention.

10 FIELD OF THE INVENTION

Disclosed embodiments relate in general to a combustion turbine engine, such as a gas turbine engine, and, more particularly, to a transition duct system in the combustor section of the engine, and, even more particularly, to a transition duct system with non-metallic thermally-insulating liners supported with splittable metallic shell structures for delivering hot-temperature
15 gasses in the combustion turbine engine.

BACKGROUND OF THE INVENTION

Disclosed embodiments may be suited for a transition duct system configured so that a first stage of stationary airfoils (vanes) in a turbine section of the engine is eliminated, and where
20 the hot working gases exiting the transition duct system are conveyed directly to a row of rotating airfoils (blades) with high tangential velocity. In such cases, the transition duct system accomplishes the task of redirecting the gases, which would otherwise have been accomplished by a first row of turbine vanes. One example of a transition duct system having such a configuration is described in U.S. Patent Nos. 8,276,389. One example of a transition duct
25 system utilizing ceramic thermally-insulating liners is described in U.S. Patent Nos. 9,810,434. Each of such patents is incorporated herein by reference in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in the following description in view of the drawings that
30 show:

FIG. 1 is an upstream view of one non-limiting embodiment of a disclosed transition duct system as may be arranged for delivering hot-temperature gases from a plurality of combustors in a combustion turbine engine to a first row of turbine blades in the combustion turbine engine.

FIG. 2 is a downstream view of the disclosed transition duct system shown in FIG. 1.

5 FIG. 3 is an isometric view of one non-limiting embodiment of a pair of disclosed non-metallic thermally-insulating liners, such as may be made from a ceramic-based material, where each liner may be arranged as a constituent structure of a respective exit piece of the disclosed transition duct system.

10 FIG. 4 is an isometric, exploded view of a disclosed splittable metallic shell support structure, which when assembled is configured to support a respective non-metallic thermally-insulating liner disposed inwardly of the splittable metallic shell support structure.

15 FIG. 5 is an isometric view illustrating a circumferential arrangement of non-metallic thermally-insulating liners that in combination form an annular chamber for delivering the hot-temperature gases. FIG. 5 further illustrates in exploded relationship a disclosed annular spring biasing assembly for radially supporting with respect to a turbine vane carrier structure the circumferential arrangement of non-metallic thermally-insulating liners.

FIG. 6 is a fragmentary, cross-sectional view of one embodiment of a disclosed non-metallic thermally-insulating liner arrangement with a liner segment extending downstream from a cone/exit piece joint into a portion of the exit piece.

20 FIG. 7 is a fragmentary cross-sectional view of another embodiment of the disclosed non-metallic thermally-insulating liner arrangement.

FIG. 8 is an isometric view of a disclosed assembly of a splittable non-metallic thermally-insulating liner that may be arranged as a constituent structure of a respective exit piece of the disclosed transition duct system.

25 FIG. 9 is an isometric view of one sub-assembly of the disclosed assembly shown in FIG. 8.

FIG. 10 is an isometric, exploded view of a disclosed splittable metallic shell support structure and an arcuate connection segment of a disclosed non-metallic thermally-insulating liner.

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DETAILED DESCRIPTION OF THE INVENTION

The present inventors have recognized that certain known transition duct systems tend to consume a substantial amount of cooling air in view of the hot-temperature gases directed by such systems. This can reduce the overall efficiency of the gas turbine engine and can lead to increased generation of NO_x emissions. At least in view of such recognition, the present
5 inventors disclose innovative structural arrangements in a transition duct system that in a reliable and cost-effective manner can be used to securely and reliably attach a non-metallic thermal insulating liner in the presence of a substantial flow path pressurization, as may develop in the high Mach (M) number regions of the system (e.g., approaching approximately 0.8 M).

Without limitation, disclosed non-metallic thermally-insulating liners may be made from
10 a ceramic-based material, such as a ceramic matrix composite (CMC) material or other high-temperature ceramic-based materials, e.g., MAX phase materials. Disclosed structural arrangements are designed to accommodate thermal growth differences such as may develop between the thermal insulating liner and a metallic shell support structure onto which the thermal liner is inwardly disposed. Lastly, disclosed structural arrangements are designed to improve
15 cost-effective installability and serviceability of the transition duct system since disclosed thermal insulating liners can be readily removed and replaced as needed.

In the following detailed description, various specific details are set forth in order to provide a thorough understanding of such embodiments. However, those skilled in the art will understand that embodiments of the present invention may be practiced without these specific
20 details, that the present invention is not limited to the depicted embodiments, and that the present invention may be practiced in a variety of alternative embodiments. In other instances, methods, procedures, and components, which would be well-understood by one skilled in the art have not been described in detail to avoid unnecessary and burdensome explanation.

Furthermore, various operations may be described as multiple discrete steps performed in
25 a manner that is helpful for understanding embodiments of the present invention. However, the order of description should not be construed as to imply that these operations need be performed in the order they are presented, nor that they are even order dependent, unless otherwise indicated. Moreover, repeated usage of the phrase "in one embodiment" does not necessarily refer to the same embodiment, although it may. It is noted that disclosed embodiments need not
30 be construed as mutually exclusive embodiments, since aspects of such disclosed embodiments may be appropriately combined by one skilled in the art depending on the needs of a given

application.

As used herein, the phrases “configured to” or “arranged to” embrace the concept that the feature preceding the phrases “configured to” or “arranged to” is intentionally and specifically designed or made to act or function in a specific way and should not be construed to mean that the feature just has a capability or suitability to act or function in the specified way, unless so indicated.

FIG. 1 is an upstream view of one non-limiting embodiment of a transition duct system 10 for delivering hot-temperature gases from a plurality of combustors in a combustion turbine engine to a first row of turbine blades in the combustion turbine engine. As referred to herein, an upstream view means looking from upstream toward downstream along a longitudinal axis 20 of the gas turbine engine, and a downstream view, as shown in FIG. 2, means the opposite.

As can be appreciated in FIGs. 1 and 2, transition duct system 10 is composed of multiple sets of flow directing structures 12. There is a flow directing structure 12 for each combustor (not shown). Combustion gases from each combustor flow into a respective flow directing structure 12. Each flow directing structure may include a flow-accelerating cone 14 and an exit piece 16. The exit pieces 16 in combination form an annular chamber 18, which is illustrated in FIG. 2.

Each gas flow from a respective exit piece 16 enters annular chamber 18 at respective circumferential locations. Each gas flow originates in its respective combustor can and is directed as a discrete flow to the annular chamber 18. Each exit piece 16 abuts adjacent annular chamber ends at exit piece joints 24. Annular chamber 18 is arranged to extend circumferentially and oriented concentric to longitudinal axis 20 for delivering the gas flow to the first row of blades (not shown), which would be disposed immediately downstream of annular chamber 18.

FIG. 3 is an isometric view of a pair of non-metallic thermally-insulating liners 22, as may be arranged to form structural constituents of circumferentially adjoining exit pieces. In one non-limiting embodiment, each exit piece liner 22 may include a straight path segment 26 (e.g., a path segment not generally curved along its longitudinal direction) for receiving a gas flow from a respective combustor (not shown).

Each straight path segment 26 may form a closed perimeter starting at an inlet end 28 of straight path segment 26. In one non-limiting embodiment, the closed perimeter of the straight path segment of liner 22 changes to an open perimeter 30 that is in fluid communication with a

corresponding portion of annular chamber 18 (FIG. 2) along a common plane between a convergence flow junction (not shown) and an outlet end 34 of straight path segment 26. A closed perimeter refers to a closed contour or outline formed by the sides of a given structure (e.g., the sides of straight path segment 26), whereas an open perimeter refers to an unclosed contour or outline formed by the sides of the given structure. In one non-limiting embodiment, the closed perimeter of straight path segment 26 starting at inlet end 28 may have a circular shape. This circular shape may change to a polygonal shape further downstream from inlet end 28 of straight path segment 26.

Each exit piece liner 22 may further include an arcuate connection segment 36 that forms an open perimeter. Each respective exit piece liner 22 connects at joint 24 to an adjacent exit piece liner at a corresponding end of the arcuate connection segment of the adjacent exit piece liner. In one non-limiting embodiment, thermally-insulating liners 22 may be --but need not each be respectively-- formed as an integral structure for maximum resistance to pressure loads and minimal cooling air leakage paths.

Each ceramic-based liner is disposed inwardly of a respective splittable (e.g., separable), such as a longitudinally-splittable, metallic shell support structure 38, as may be formed by two (or more) appropriately configured shell support panels 40₁ and 40₂, as shown in FIG.4. This splittable or separable arrangement of metallic support structure 38 substantially facilitates handling and accessibility of a respective ceramic-based liner being supported by metallic support structure 38. Shell support panels 40₁ and 40₂ may be mechanically connected to one another by way of bolts through respective rows of bolt holes 42₁ and 42₂ that may be provided in mutually opposed flanges 44₁ and 44₂ that may be respectively constructed along respective longitudinally-extending edges of shell support panels 40₁ and 40₂. As noted above, the circumferential arrangement of all connected exit pieces 16 (FIG. 2) (composed of radially-inwardly non-metallic thermally-insulating exit piece liners 22 (FIG. 3) disposed radially-inwardly with respect to splittable metallic shell support structures 38) in combination define annular chamber 18.

FIG. 5 is an isometric view illustrating a circumferential arrangement 60 of non-metallic thermally-insulating liners 22, structural constituents of the exit pieces that in combination form annular chamber 18 for delivering the hot-temperature gases. FIG. 5 further illustrates in exploded relationship a disclosed annular spring biasing assembly 62 composed of an outer-

diameter annular spring 64 and an inner-diameter annular spring 66 for radially supporting/centering with respect to a turbine vane carrier structure (not shown) the circumferential arrangement of non-metallic thermally-insulating liners 22. Annular springs 64 and 66 also serve to preload thermally-insulating liners 22 against their mechanical supports inside the metallic support structure 38 to ensure positive contact and prevent vibration and wear at these support locations (not shown). It is contemplated that each thermally-insulating liner 22 is appropriately supported against a radially inwardly directed pressure differential. It will be appreciated by one skilled in the art that any of various mechanical attachment techniques may be used to secure thermally-insulating liners 22 within metallic support structure 38, including, but not limited to rails, hooks, pins, bolts, etc.

As may be appreciated in FIG. 6, in one non-limiting embodiment, a disclosed non-metallic thermally-insulating liner arrangement 70 may involve a non-metallic thermally-insulating liner segment 72 extending downstream from a cone/exit piece joint 74 into a portion of exit piece 16. This non-metallic thermally-insulating liner arrangement 70 is effective for reducing the amount of cooling air involved for cooling at least the portion of exit piece 16 over which non-metallic thermally-insulating liner segment 72 extends. In one non-limiting embodiment, a circumferentially extending interface seal 76, such as a ceramic rope seal, may be interposed at a joint 77 between non-metallic thermally-insulating liner segment 72 and a non-metallic thermally-insulating liner 78, such as a conically-shaped non-metallic thermally-insulating liner associated with flow-accelerating cone 14. Circumferentially extending interface seal 76 may be disposed in a pocket 79 defined by respective mutually opposed circumferentially-extending cutouts constructed in non-metallic thermally-insulating liner segment 72 and non-metallic conical thermally-insulating liner 78.

As may be further appreciated in FIG. 6, a liner segment seal 80 may be disposed in a circumferentially-extending pocket 82 defined by a retainer flange 83 disposed at an end of metallic shell support structure 38 and a flange 84 disposed at a corresponding end of non-metallic thermally-insulating liner segment 72. Without limitation, liner segment seal 80 may be an E-seal or a W-seal arranged to accommodate radial growth differential that may develop between mutually opposed surfaces of flanges 83 and 84.

A plurality of axially spaced-apart spring clips 85 or similar spring biasing structures may be circumferentially arranged for centering/supporting non-metallic thermally-insulating

liner segment 72 relative to an inner surface 81 of metallic shell support structure 38. Spring clips 85 may be positioned to define a gap 86 to permit a flow of cooling air (schematically represented by arrows 87) between non-metallic thermally-insulating liner segment 72 and inner surface 81 of metallic shell support structure 38. This embodiment may be viewed as defining a generally non-articulating cone/exit piece joint compared to the embodiment to be described below that may be viewed as an articulating attachment between cone 14 and exit piece 16.

FIG. 7 is a fragmentary cross-sectional view of another embodiment of disclosed non-metallic thermally-insulating liner arrangement 70. The discussion below will focus on structural and/or operational relationships that may be different relative to the embodiment discussed above in the context of FIG. 6. In this embodiment, a flexible metallic attachment 90 is provided for interconnecting flow-accelerating cone 14 and exit piece 16. Without limitation, flexible metallic attachment 90 may comprise a substantially compliant metallic region 92, such as a compliant metallic laminated region and, without trying to restrict to any particular modality of operation, this may be conceptually similar to a leaf-spring arrangement. Compliant metallic region 92 can be arranged in flexible metallic attachment 90 to provide multiple degrees of freedom that, for example, can effectively accommodate combined axial and radial relative motion (schematically represented by twin-headed arrow 94) that in certain applications could develop between flow-accelerating cone 14 and exit piece 16. In this embodiment, leakage air through flexible metallic attachment 90 (schematically represented by arrows 93) may be used for cooling at least a portion of non-metallic conical thermally-insulating liner 78 of flow-accelerating cone 14. It will be appreciated that this cooling arrangement regarding flow-accelerating cone 14 is separate from the cooling arrangement for non-metallic thermally-insulating liner segment 72 in exit piece 16. It will be appreciated that in certain applications, the cooling arrangement of flow-accelerating cone 14 and non-metallic thermally-insulating liner segment 72 could be combined.

FIG. 8 is an isometric view of a disclosed assembly of a splittable (e.g., longitudinally splittable) non-metallic thermally-insulating liner 100 that may be arranged as a constituent structure of a respective exit piece of the disclosed transition duct system. It will be appreciated that this embodiment is conceptually analogous to the longitudinally-splittable arrangement regarding the metallic support structure discussed in the context of FIG. 4.

FIG. 8 illustrates splittable non-metallic thermally-insulating liner 100 as being composed of two complementary non-metallic thermally-insulating panels 100₁ and 100₂. FIG. 9 is an isometric view of panel 100₂. It will be appreciated that splittable non-metallic thermally-insulating liner 100 need not be formed by two non-metallic thermally-insulating panels since the number and shape of these panels may be tailored based on the needs of a given application.

FIG. 10 is an isometric, exploded view of disclosed splittable metallic shell support structure 28, as may be formed by shell support panels 40₁ and 40₂, and arcuate connection segment 36 of disclosed non-metallic thermally-insulating liner 22.

In operation, disclosed embodiments reduce the amount of cooling air that may be needed to cool the transition duct system. This improves the efficiency of the gas turbine engine and can lead to reduced generation of NO_x emissions. Disclosed embodiments are effective to securely attach a thermal insulating liner, such as may comprise a suitable ceramic-based material, such as a ceramic matrix composite (CMC) material or other high-temperature ceramic-based material, e.g., a MAX phase material, in the presence of a substantial flow path pressure, as may develop in the high Mach (M) number regions of the system. Moreover, disclosed embodiments effectively accommodate thermal growth differences that may develop between the thermal insulating liner and a metal outer shell onto which the liner is disposed.

While various embodiments have been shown and described herein, it will be apparent that such embodiments are provided by way of example only. Numerous variations, changes and substitutions may be made without departing from the concepts disclosed herein. Accordingly, it is intended that the concepts disclosed herein be limited only by the scope of the appended claims.

The invention claimed is:

1. Apparatus for delivering hot-temperature gasses from a plurality of combustors in a combustion turbine engine to a first row of turbine blades in the combustion turbine engine, the apparatus comprising:

an exit piece (16) for each combustor, wherein each exit piece comprises an arcuate connection segment (36), wherein each arcuate connection segment forms an open perimeter, wherein each exit piece connects to an adjacent exit piece at the arcuate connection segment of the adjacent exit piece, and the connected exit pieces define an annular chamber (18), the annular chamber arranged to extend circumferentially and oriented concentric to a longitudinal axis (20) of the combustion turbine engine for delivering a gas flow to the first row of turbine blades, the exit piece comprising:

a splittable, metallic shell support structure (38); and

a non-metallic thermally-insulating liner (22) inwardly disposed onto the splittable metallic shell support structure.

2. The apparatus of claim 1, wherein the non-metallic thermally-insulating liner comprises a ceramic-based thermally-insulating liner.

3. The apparatus of claim 2, wherein the ceramic-based thermally-insulating liner comprises a material selected from the group consisting of a ceramic matrix composite (CMC) material and a MAX phase material.

4. The apparatus of claim 1, further comprising a flow-accelerating cone (14) connected by way of a joint (74) formed between the flow-accelerating cone and the exit piece to an inlet end (28) of a straight path segment (26) of the exit piece,

wherein the non-metallic thermally-insulating liner (22) comprises a non-metallic conically-shaped thermally-insulating liner (78) associated with the flow-accelerating cone, and the non-metallic thermally-insulating liner further comprises a non-metallic thermally-insulating liner segment (72) extending downstream from the joint formed between the flow-accelerating cone and the exit piece into a portion of the straight path segment of the exit piece.

5. The apparatus of claim 4, wherein the joint (74) between the flow-accelerating cone (14) and the exit piece (16) comprises a non-articulating joint.

6. The apparatus of claim 5, further comprising a plurality of axially spaced-apart spring clips (85) circumferentially arranged for supporting the non-metallic thermally-insulating liner segment (72) relative to an inner surface (81) of the splittable, metallic shell support structure (38).

7. The apparatus of claim 6, wherein the plurality of axially spaced-apart spring clips (85) is positioned to define a gap (86) to permit a flow of cooling air between the non-metallic thermally-insulating liner segment (72) and the inner surface (81) of splittable, metallic shell support structure (38).

8. The apparatus of claim 4, wherein the joint (74) formed between the flow-accelerating cone and the exit piece comprises a flexible metallic attachment (90) for interconnecting the flow-accelerating cone (14) and the exit piece (16).

9. The apparatus of claim 8, wherein flexible metallic attachment (90) comprises a compliant metallic region arranged to provide multiple degrees of freedom effective to accommodate combined axial and radial relative motion that can develop between flow-accelerating cone 14 and exit piece 16.

10. The apparatus of claim 8, wherein flexible metallic attachment (90) includes a cooling air flow path effective to cool at least a portion of non-metallic conically-shaped thermally-insulating liner (78) associated with the flow-accelerating cone.

11. The apparatus of claim 1, further comprising an annular spring biasing assembly (62) including an outer-diameter annular spring (64) and an inner-diameter annular spring (66) for radially supporting with respect to a turbine vane carrier structure a circumferential arrangement (60) of the non-metallic thermally-insulating liners (22).

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12. The apparatus of claim 1, wherein the splittable metallic shell support structure (38) comprises a longitudinally-splittable metallic shell support structure.

13. The apparatus of claim 12, wherein the longitudinally-splittable metallic shell support structure comprises two shell support panels connected to one another by way of bolts through respective rows of bolt holes (42₁, 42₂) disposed in mutually opposed flanges (44₁, 44₂) respectively constructed along respective longitudinally-extending edges of shell support panels (40₁ and 40₂).

14. The apparatus of claim 1, wherein the non-metallic thermally-insulating liner (22) comprises a splittable, non-metallic thermally-insulating liner (100).

15. The apparatus of claim 14, wherein the non-metallic thermally-insulating liner (22) comprises at least two complementary non-metallic thermally-insulating panels (100₁, 100₂).

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16. The apparatus of claim 4, further comprising a circumferentially-extending interface seal (76) between non-metallic thermally-insulating liner segment (72) and the non-metallic conically-shaped thermally-insulating liner (78).

17. The apparatus of claim 16, wherein the circumferentially-extending interface seal (76) is disposed in a pocket (79) defined by respective mutually opposed circumferentially-extending cutouts constructed in non-metallic thermally-insulating liner segment (72) and non-metallic conically-shaped thermally-insulating liner (78).

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18. The apparatus of claim 4, further comprising a circumferentially-extending liner segment seal (80) disposed in a circumferentially-extending pocket 82 defined by a retainer flange (83) disposed at an end of the metallic shell support structure (38) and a flange (84) disposed at a corresponding end of the non-metallic thermally-insulating liner segment (72).

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19. The apparatus of claim 18, wherein the circumferentially-extending liner segment seal (80) comprises an E-seal or an Ω -seal arranged to accommodate radial growth differential that can develop between mutually opposed surfaces of flanges (83, 84).

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FIG. 1

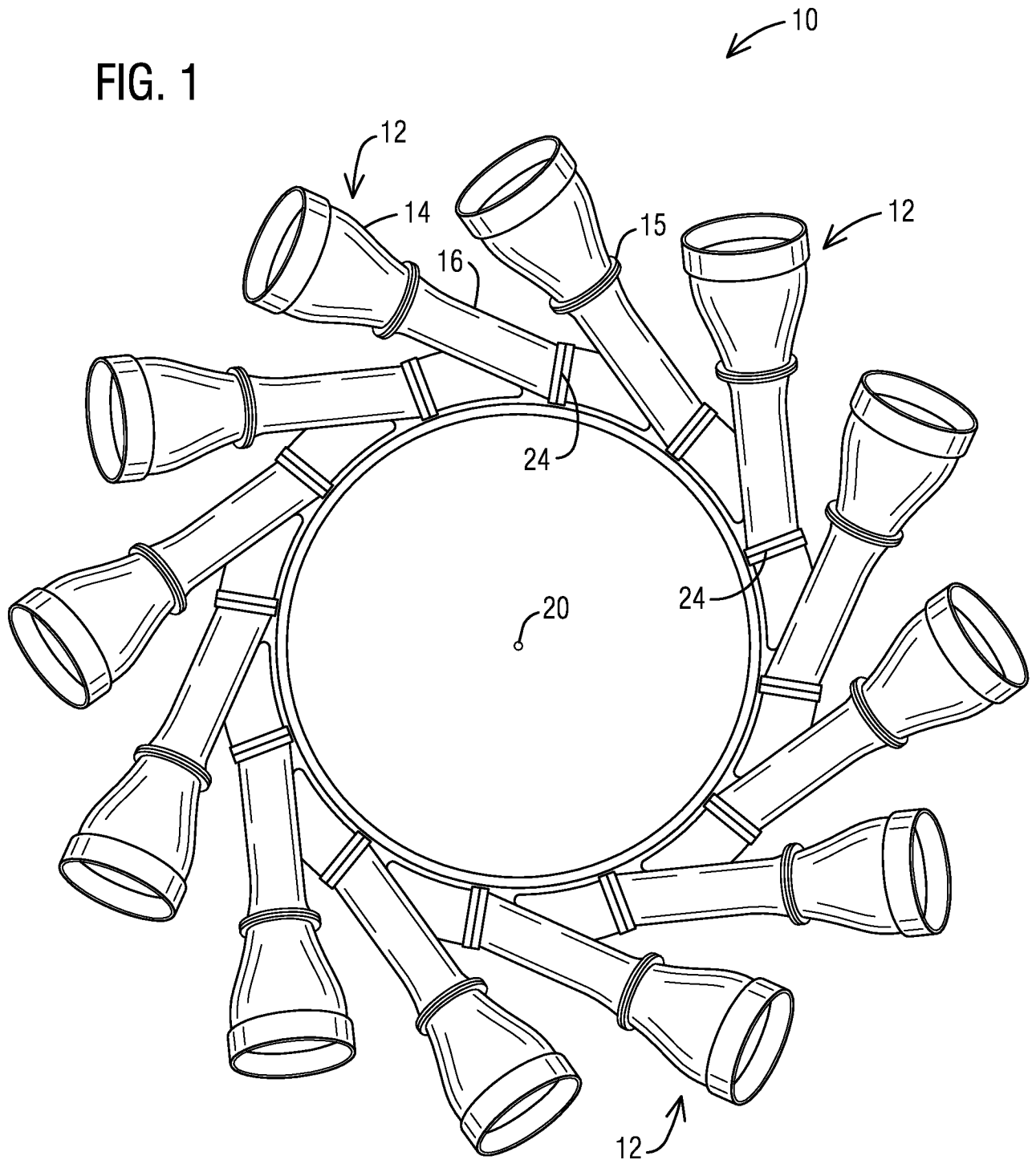
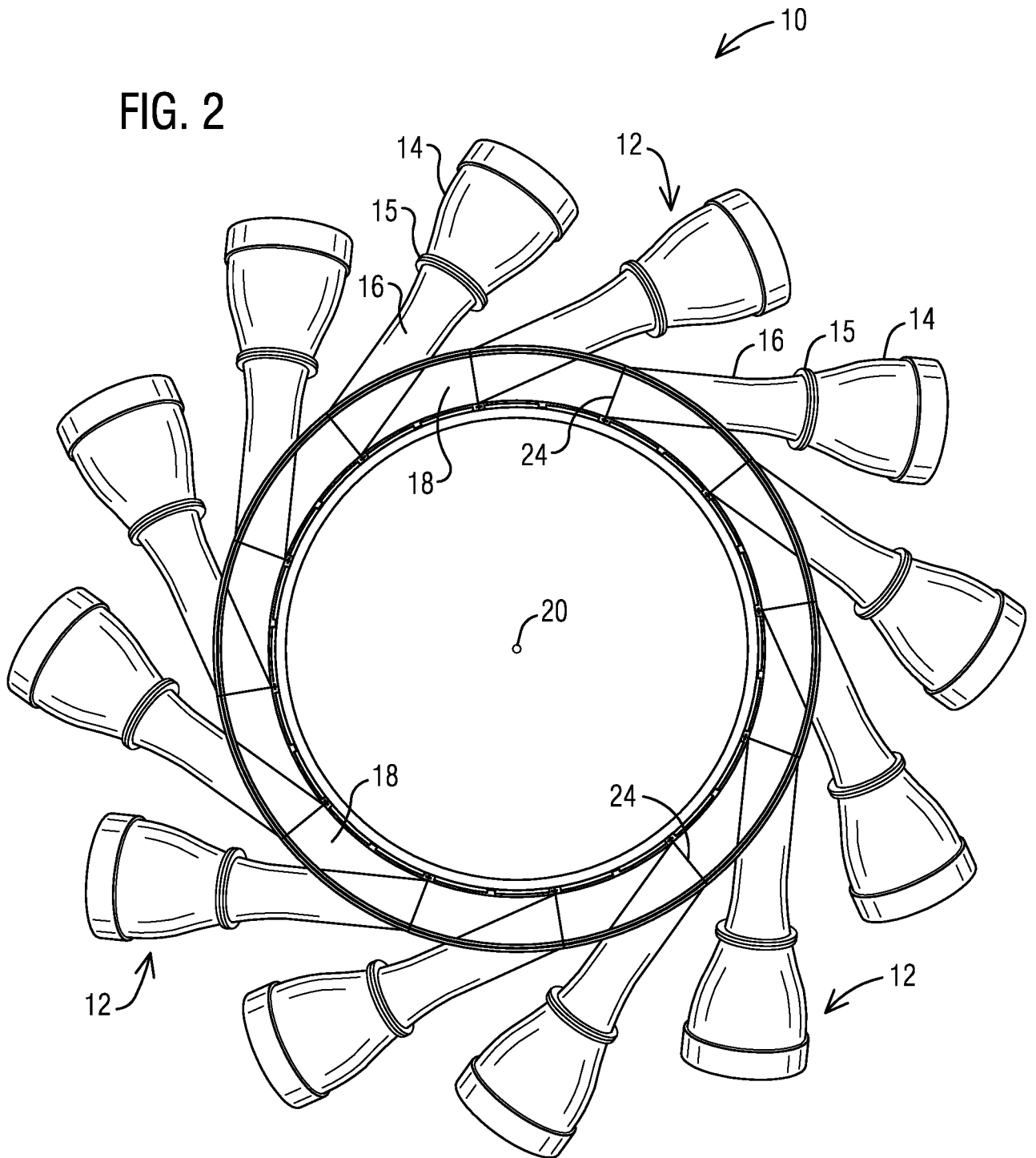


FIG. 2



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FIG. 3

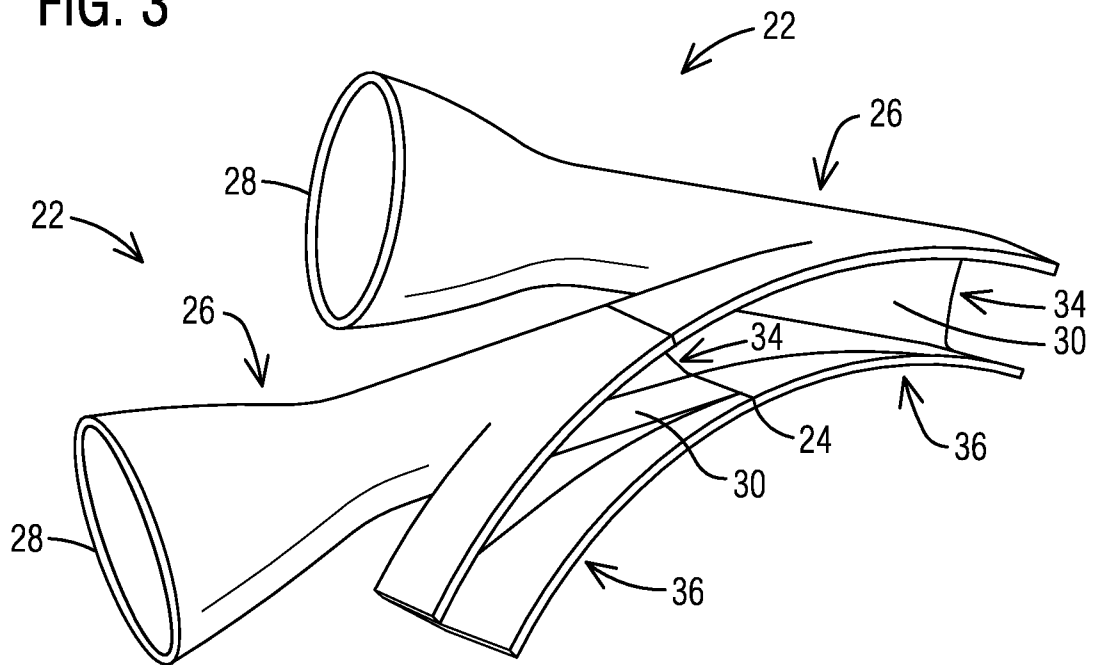
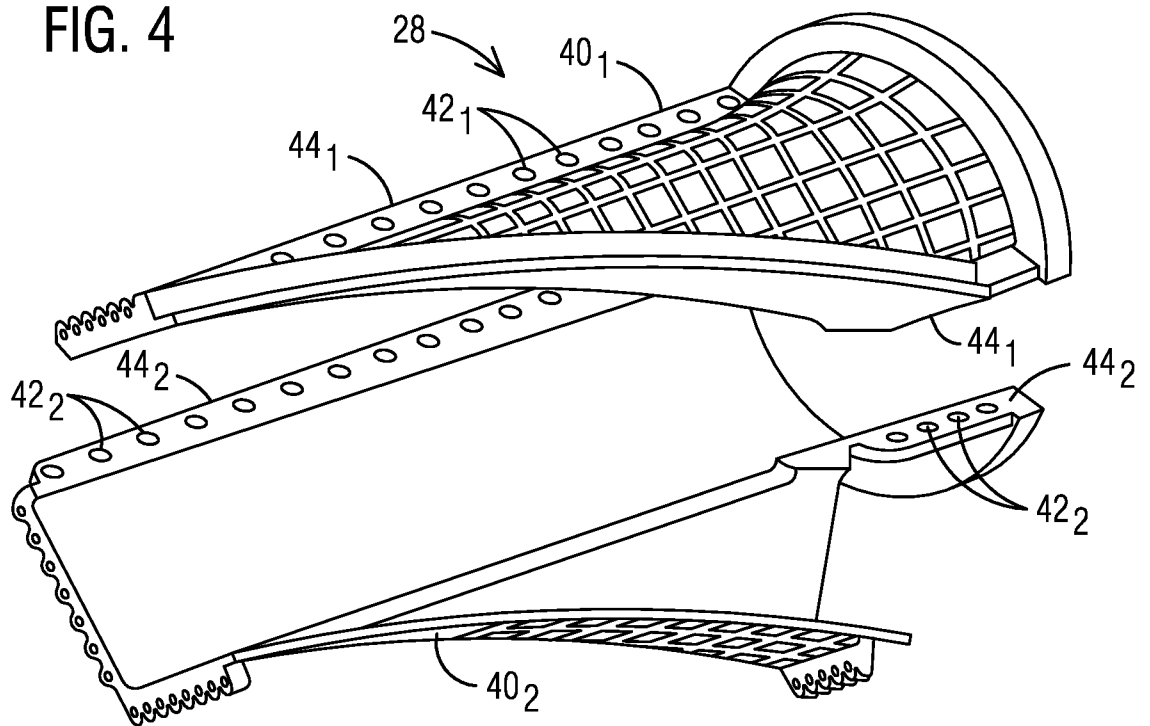


FIG. 4



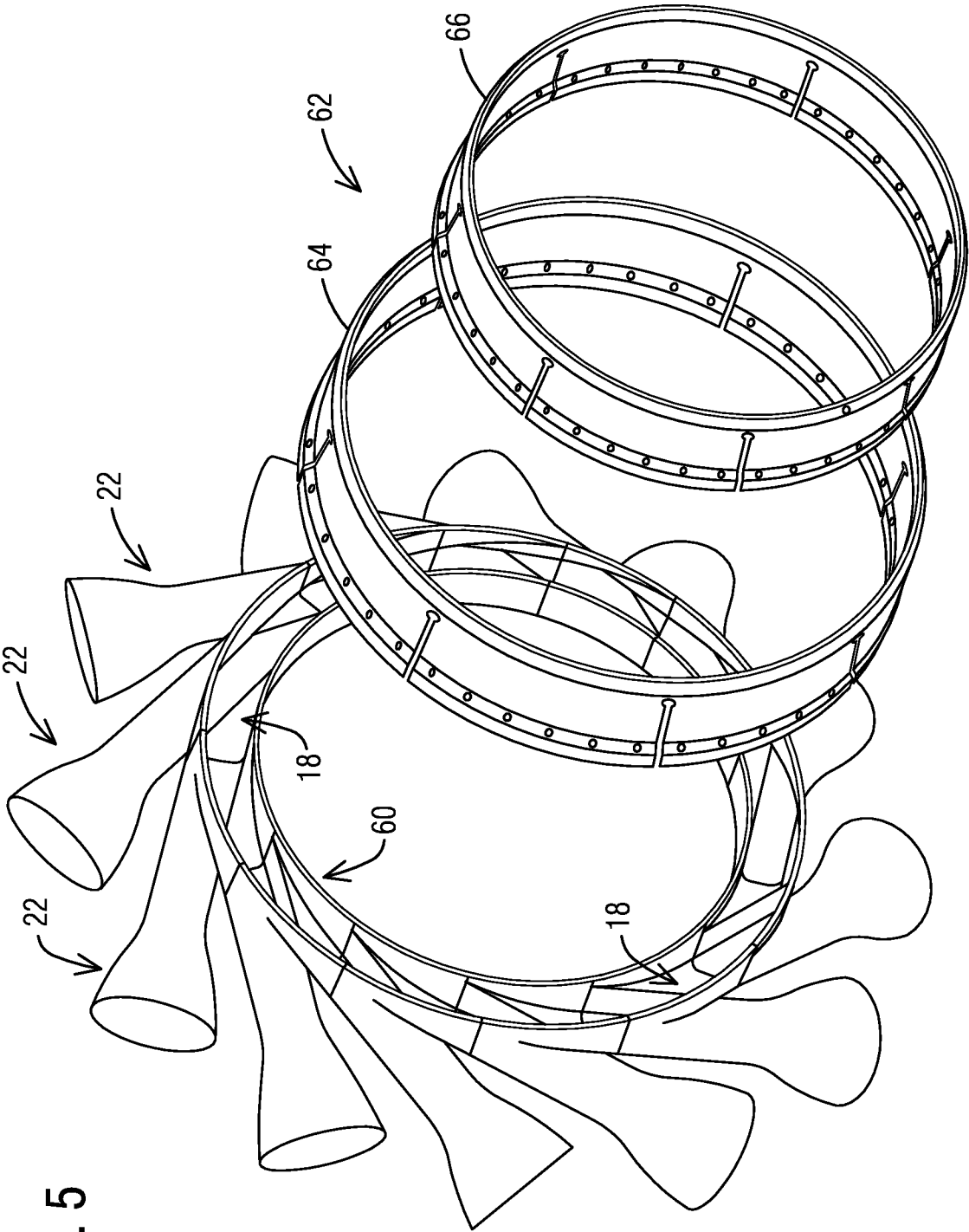


FIG. 5

FIG. 6

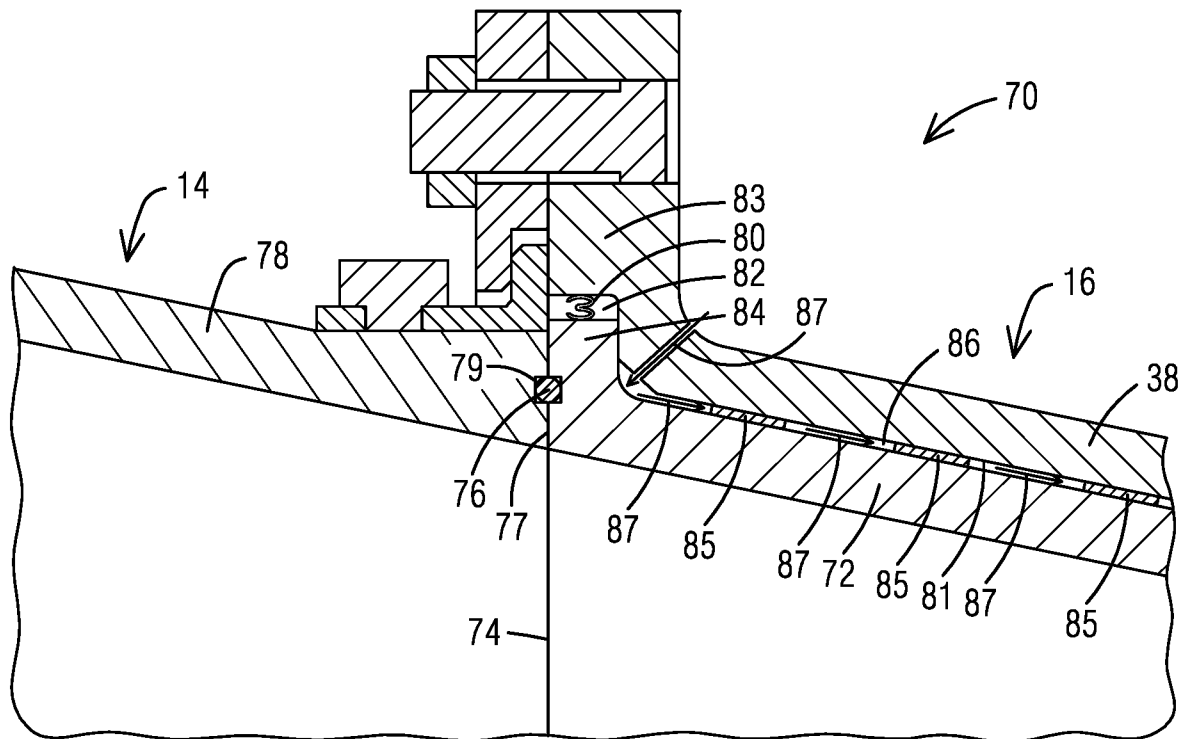


FIG. 7

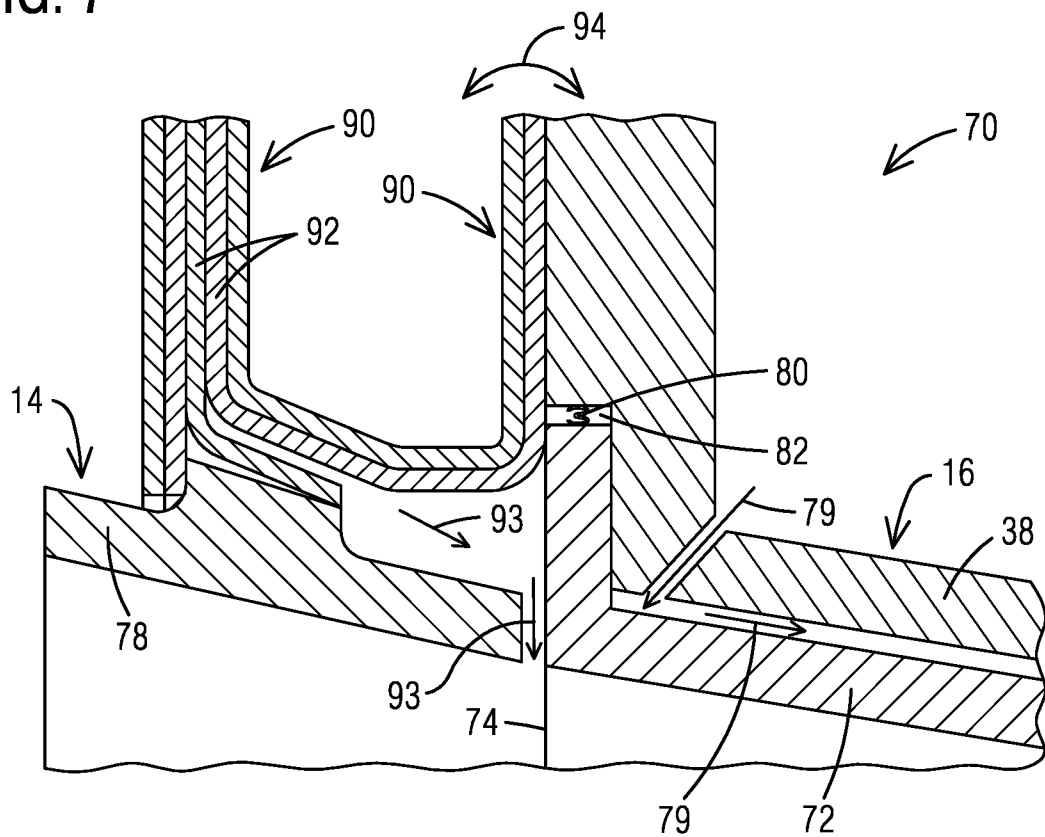


FIG. 8

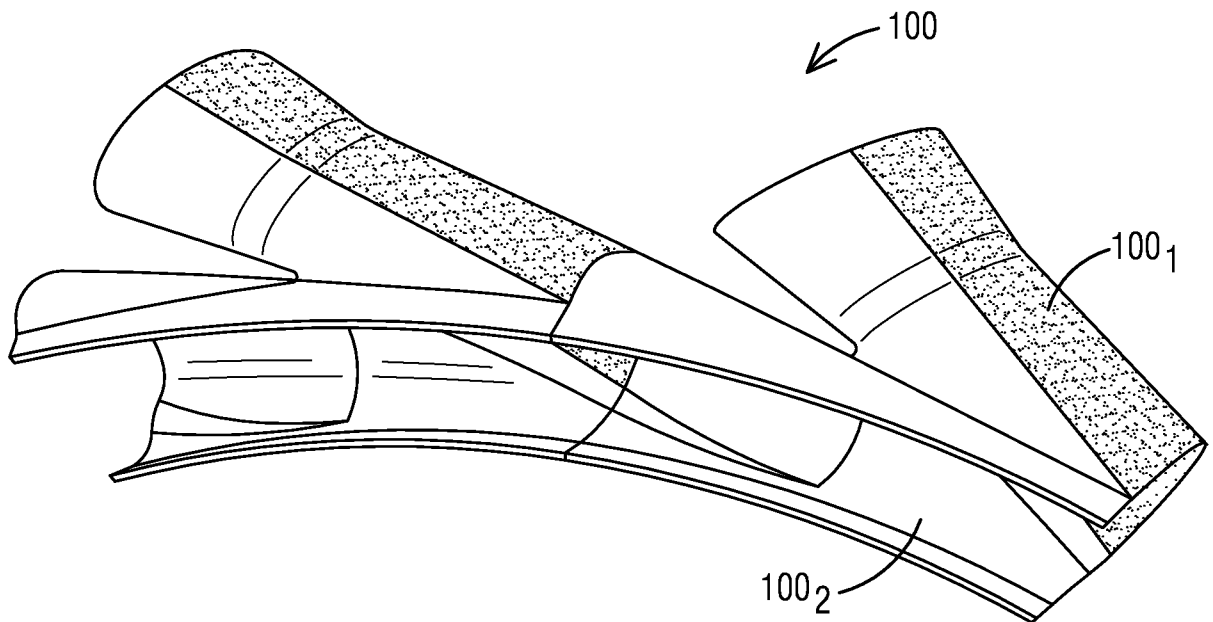


FIG. 9

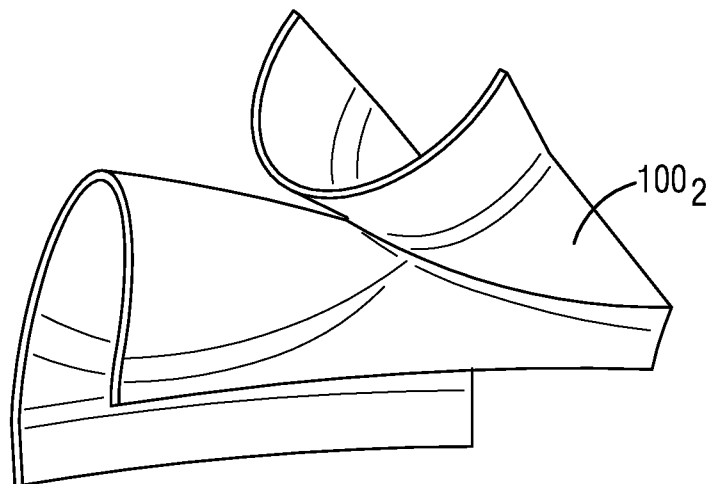
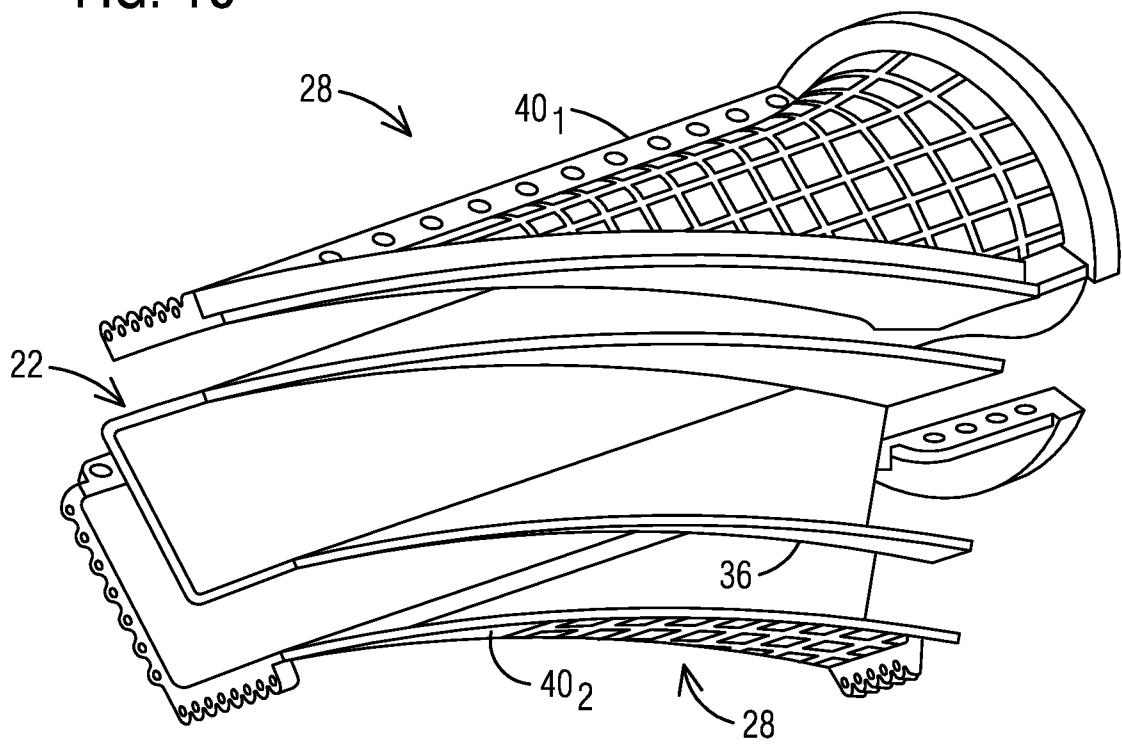


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/057231

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D9/02 F01D5/28
ADD.

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)
F01D

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 9 650 904 B1 (WIEBE DAVID J [US]) 16 May 2017 (2017-05-16)	1-4,14
Y	the whole document	5-13, 15-19
Y	----- US 2018/017259 A1 (SCHIAVO ANTHONY L [US]) 18 January 2018 (2018-01-18) paragraphs [0024] - [0036]; figures 4-7,11	5-10
Y	----- US 2012/121408 A1 (LEE CHING-PANG [US] ET AL) 17 May 2012 (2012-05-17) paragraphs [0032] - [0035], [0038], [0045]; figures 2,7,8	11-13,15
Y	----- EP 2 775 102 A2 (GEN ELECTRIC [US]) 10 September 2014 (2014-09-10) paragraphs [0011] - [0013], [0019] - [0021]; figures 1-14	16-19
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Chatziapostolou, A

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