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(54) GAS TURBINE ENGINE DUCTING ARRANGEMENT HAVING DISCRETE INSERT

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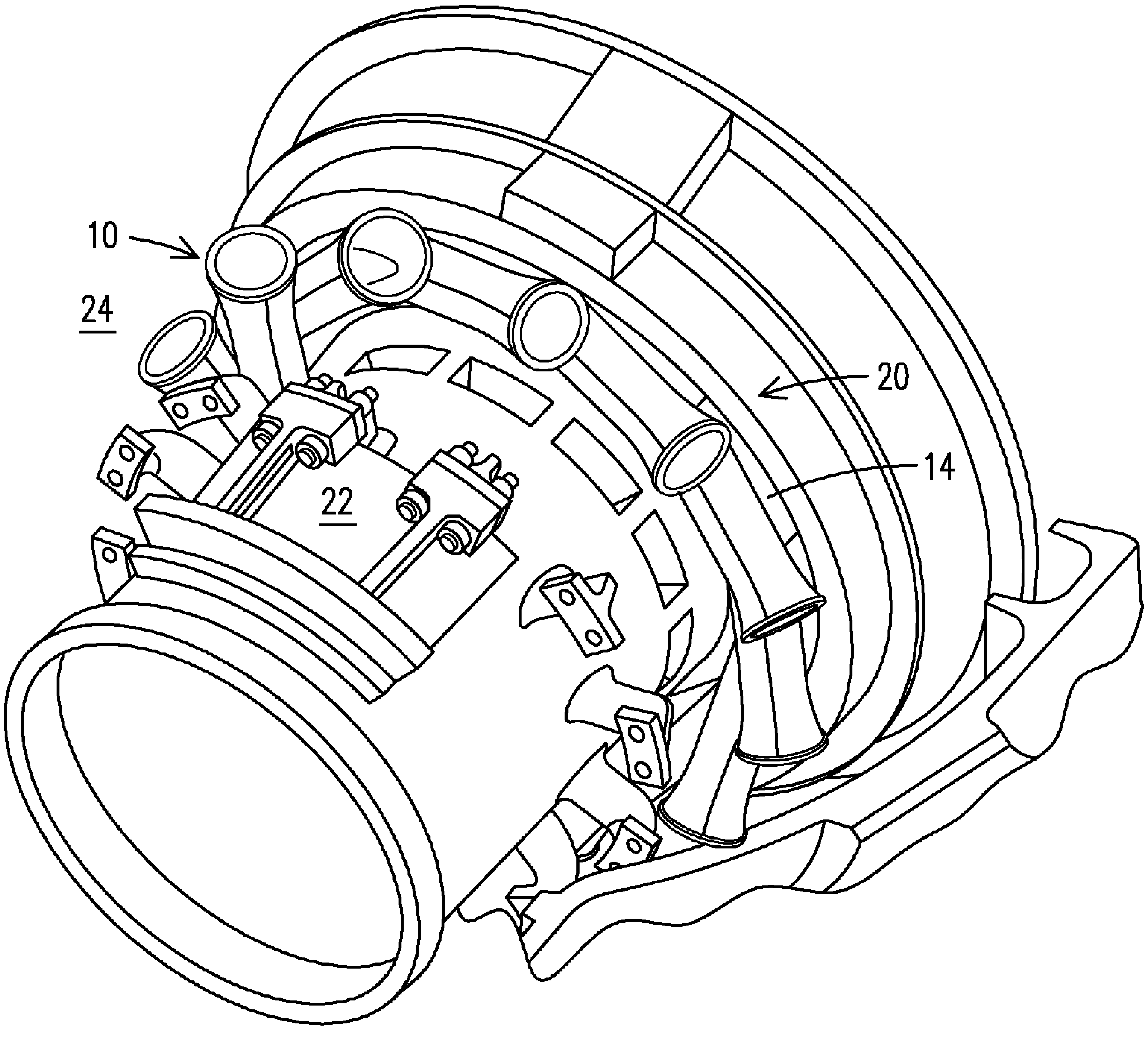
(57) ABSTRACT

A ducting arrangement (**10**), including: a plurality of discrete ducts (**18**), each defining a flow path and configured to receive a flow of combustion gases from a respective combustor can, where the plurality of discrete ducts merge to form a common duct structure; and a throat insert (**50**) configured to define at least part of a junction of one of the discrete ducts and the common duct structure.



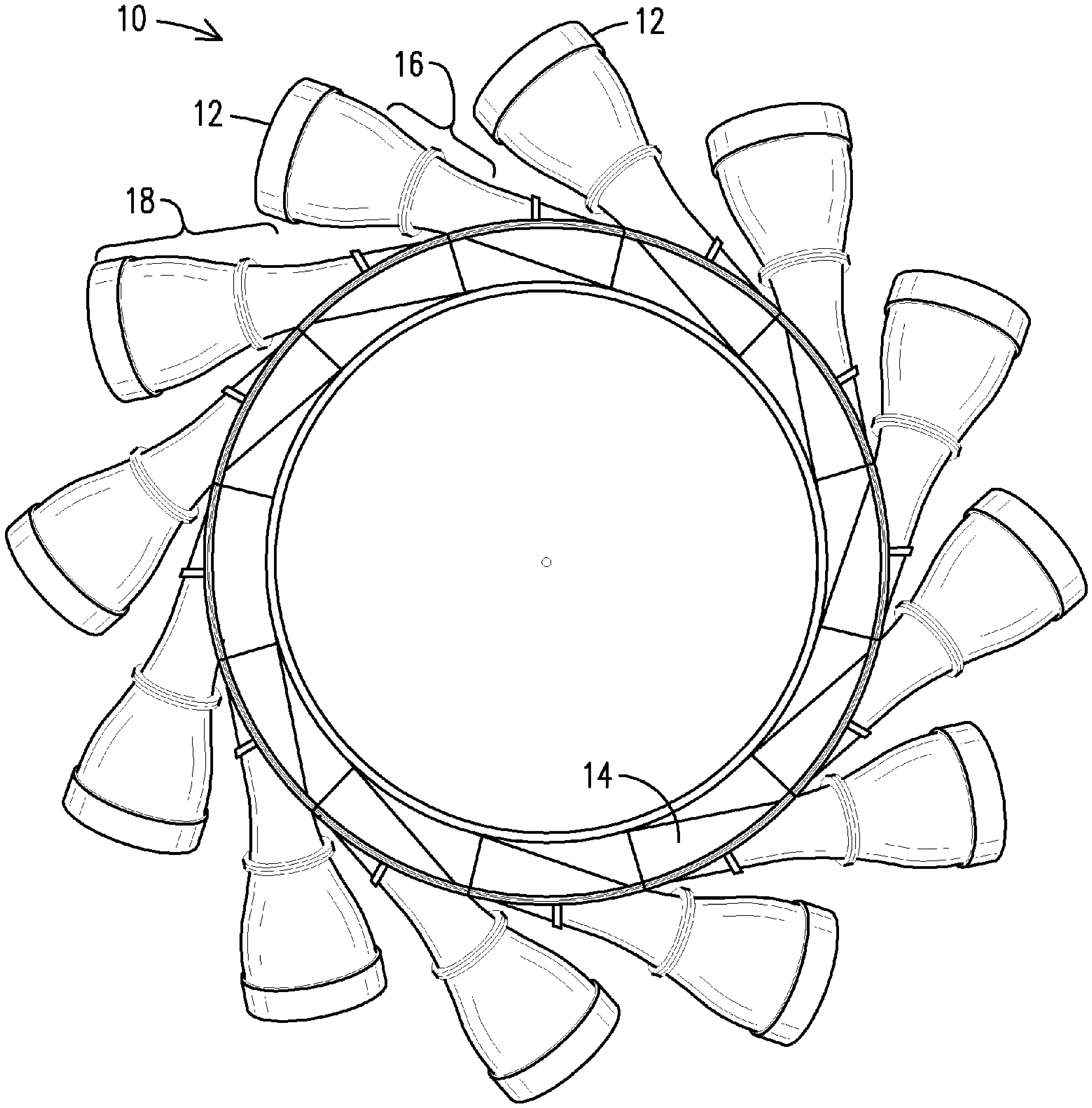


FIG. 1

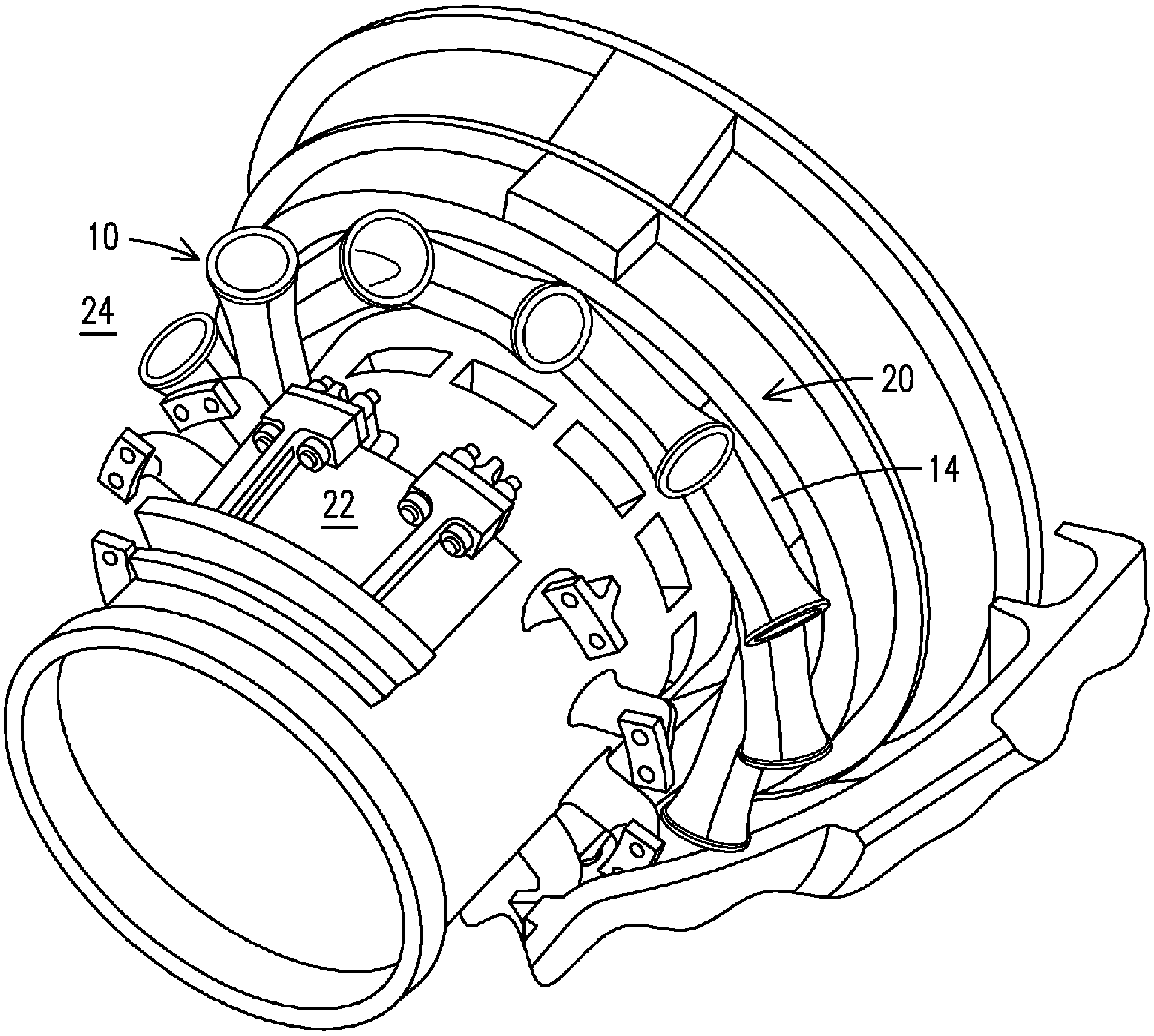


FIG. 2

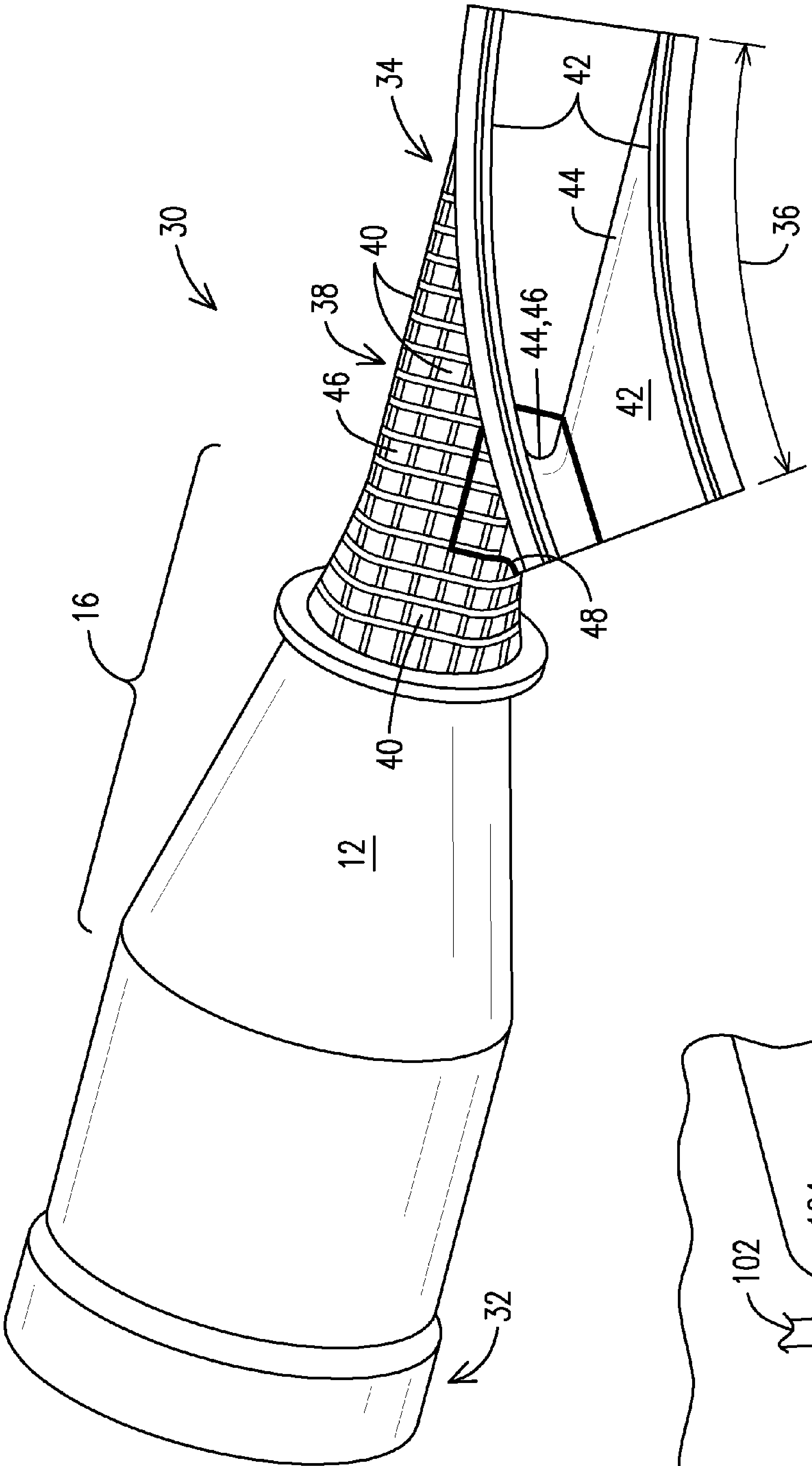


FIG. 3

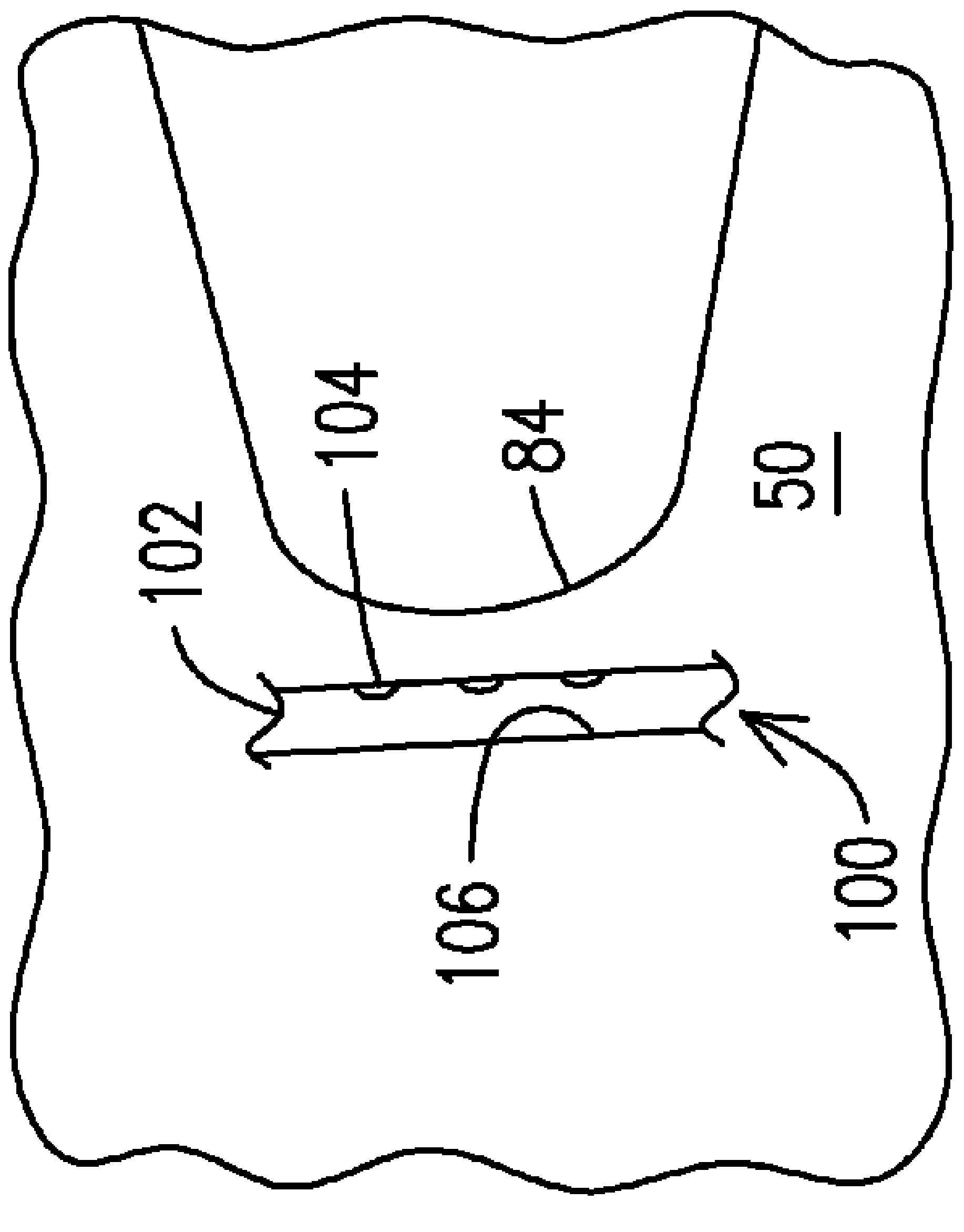


FIG. 8

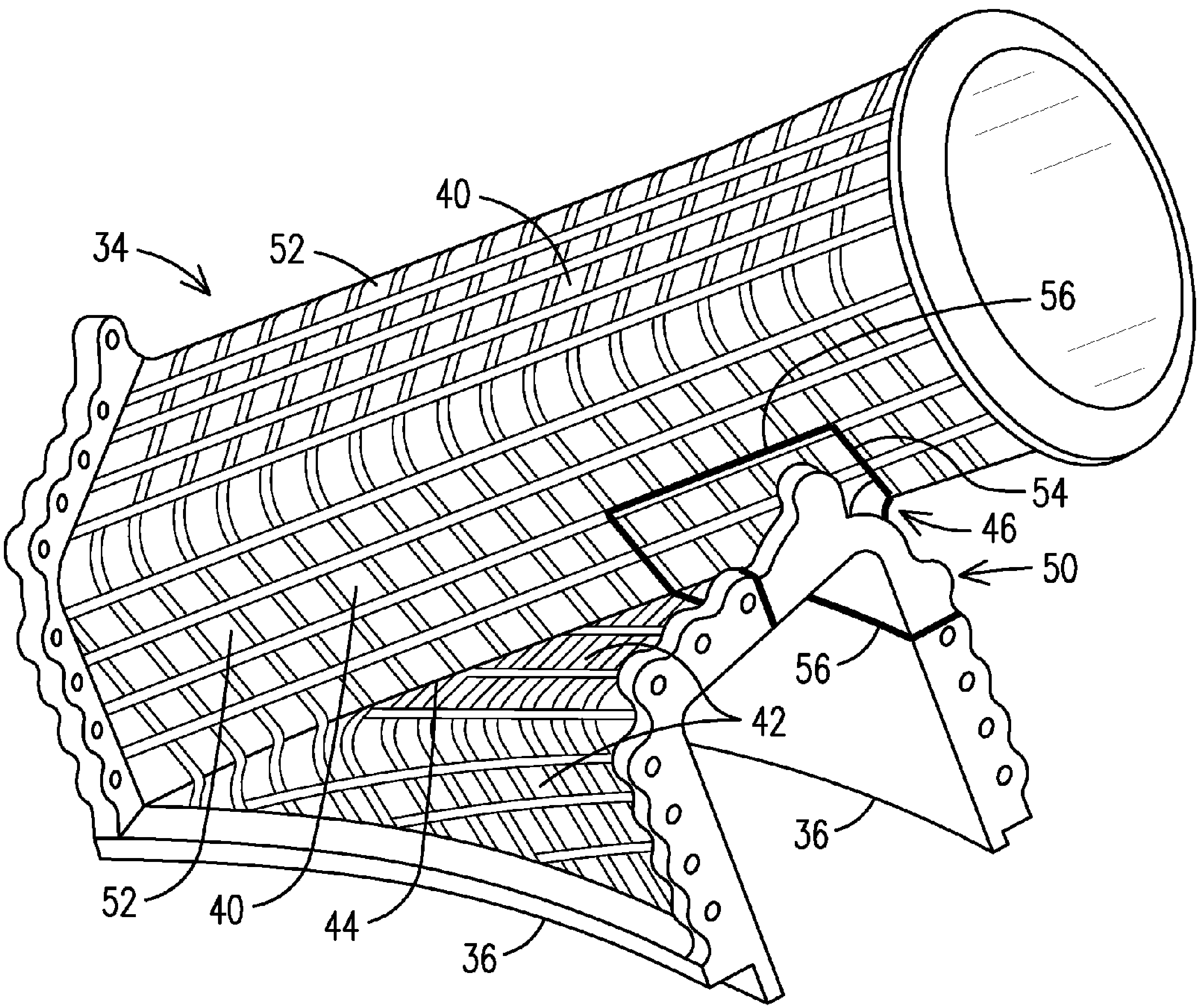


FIG. 4

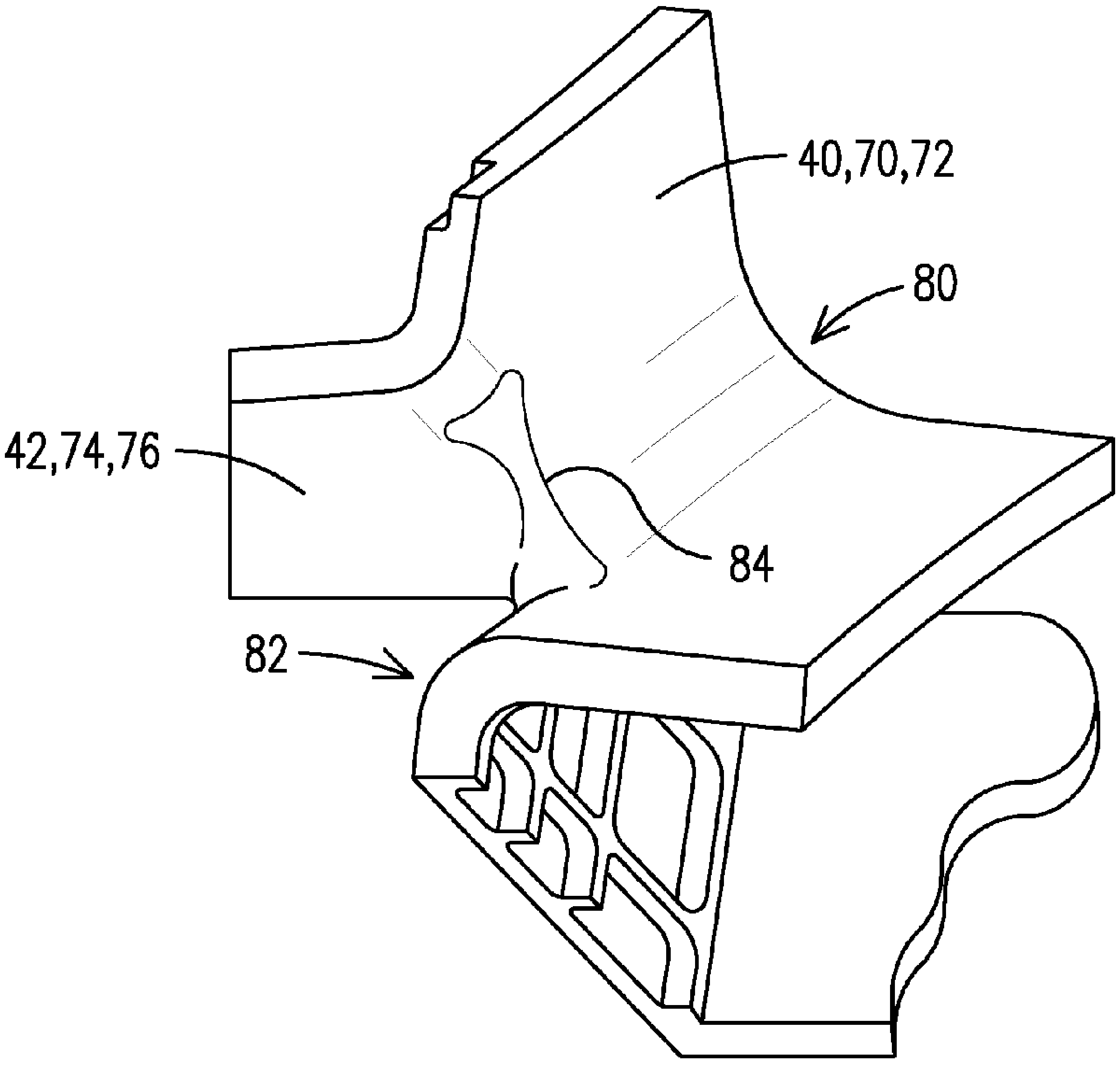


FIG. 7

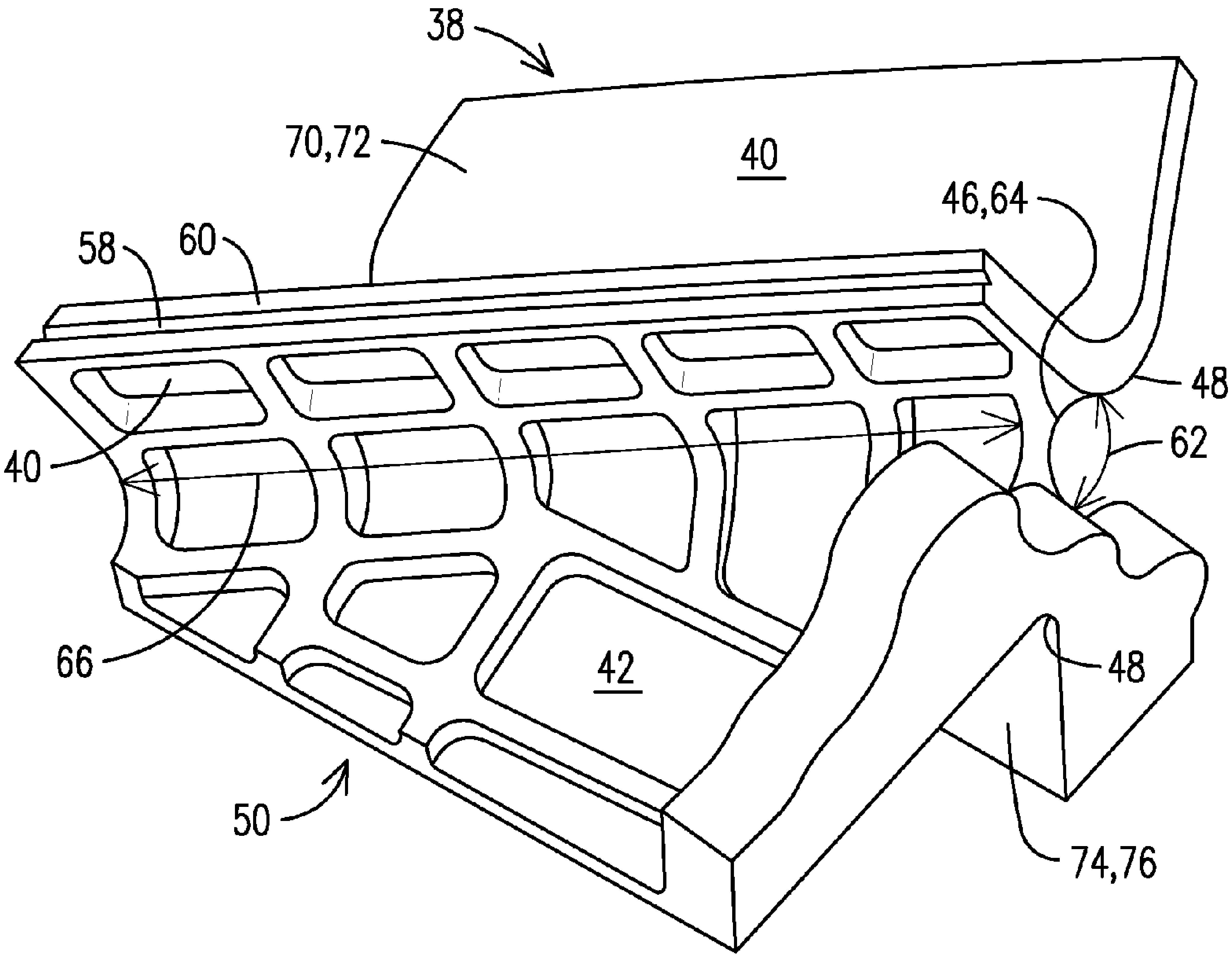

38
70,72
40
46,64
58
60
48
62
40
66
48
42
50
74,76

FIG. 5

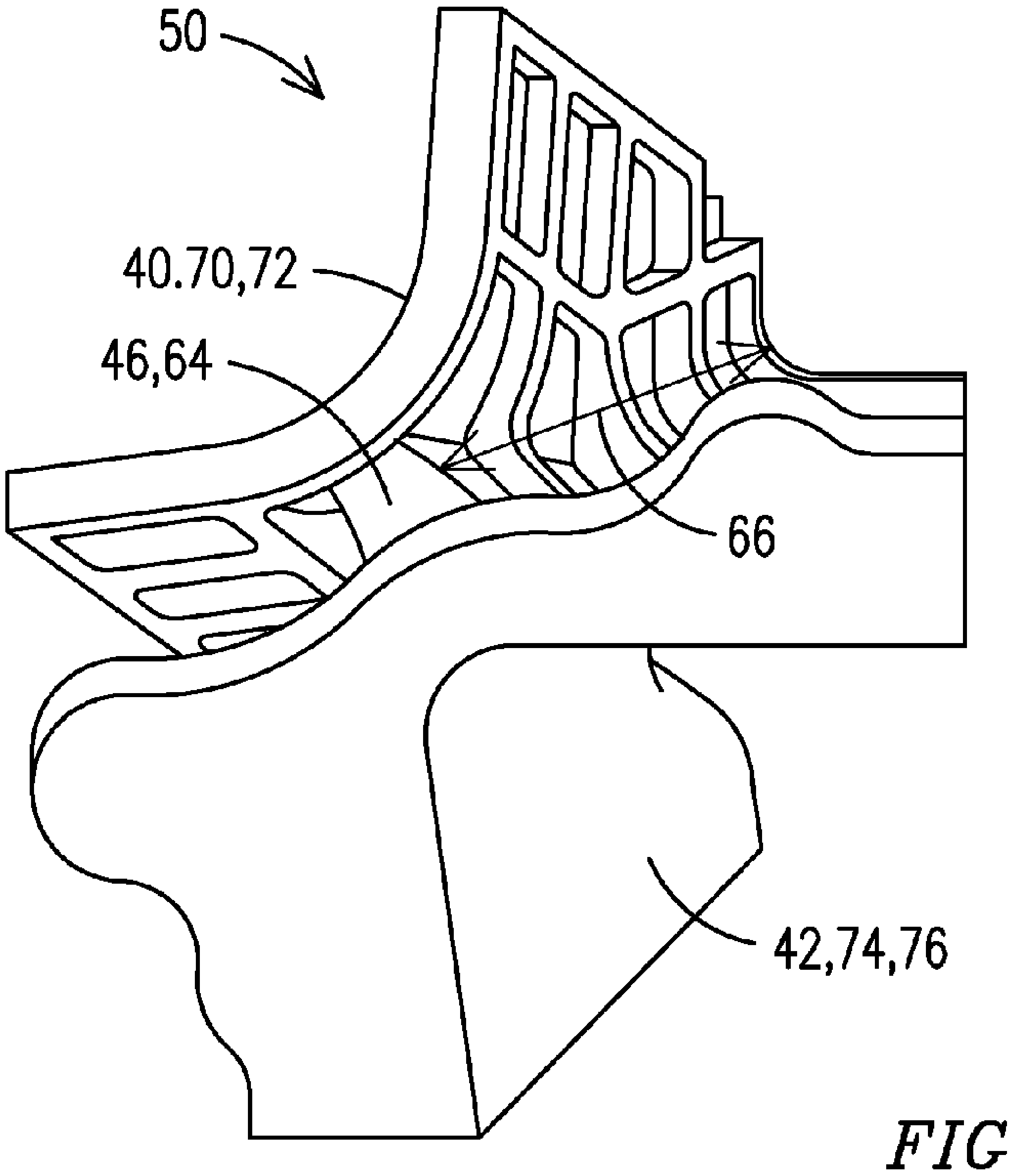

50
40.70,72
46,64
66
42,74,76

FIG. 6

GAS TURBINE ENGINE DUCTING ARRANGEMENT HAVING DISCRETE INSERT

STATEMENT REGARDING FEDERALLY SPONSORED DEVELOPMENT

[0001] Development for this invention was supported in part by Contract No. DE-FC26-05NT42644, awarded by the United States Department of Energy. Accordingly, the United States Government may have certain rights in this invention.

FIELD OF THE INVENTION

[0002] The present invention relates to a combustion gas duct that includes a discrete insert having a different mechanical property than a remainder of the duct. The combustion gas duct may be formed by bi-casting duct material around the insert.

BACKGROUND OF THE INVENTION

[0003] Conventional can-annular gas turbine engines include a plurality of individual combustor cans, where each can is secured to a respective transition duct that directs combustion gases from the combustor can, and through inlet guide vanes to a respective portion of a turbine inlet annulus. Each flow of combustion gas remains discrete from the combustor until exiting the respective transition duct. In contrast, in certain emerging gas turbine engines that use can combustors, the cans are repositioned such that combustion gas flows exiting the cans is already properly oriented for delivery onto the first row of turbine blades. An example of this may be seen in US Patent Application Publication Number 2011/0203282 to Charron et al., published Aug. 25, 2011, which is incorporated by reference in its entirety herein. The array of transition ducts are replaced with a duct arrangement that receives the discrete combustion gas flows, accelerates them to a speed appropriate for delivery onto the first row of turbine blades, and directs them into a common annular chamber where the combustion gas flows are no longer segregated from each other. The annular chamber exhausts directly into the turbine inlet. The proper orientation and speed created by the arrangement eliminates the need for a first row of inlet guide vanes present in the conventional arrangements

[0004] In conventional gas turbine engine combustor arrangements, since the compressed air flows are not accelerated in the transition ducts there is a relatively small static pressure difference between compressed air in the plenum surrounding the transition duct and a static pressure of the combustion gas flows within the transition. Consequently, there is a relatively small force pressing inward on the exterior surface of the transition ducts.

[0005] In contrast, in the emerging technology ducting arrangement the combustion gas flows are traveling at significantly greater speeds. This results in significantly greater pressure differences (up to six atmospheres) and resulting forces acting on the exterior surface of the ducting arrangement. The annular chamber experiences the greatest of these forces because the combustion gas flows are fully accelerated within the annular chamber. These forces act to deform the ducting arrangement and hence there is room in the art for improvements that resist this deformation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The invention is explained in the following description in view of the drawings that show:

[0007] FIG. **1** is a schematic representation of an exemplary embodiment of the ducting arrangement that may use the insert described herein.

[0008] FIG. **2** is a schematic representation of the combustion arrangement of FIG. **1** positioned within a combustion section of a gas turbine engine.

[0009] FIG. **3** shows a single ducting arrangement subcomponent of the ducting arrangement of FIG. **1**.

[0010] FIG. **4** is an exemplary embodiment of the downstream end of the ducting arrangement subcomponent of FIG. **3** showing an exemplary embodiment of the insert.

[0011] FIGS. **5-7** show various angles of the insert of FIG. **4**.

[0012] FIG. **8** shows a close-up in the junction indicated in FIG. **3** and shows an exemplary embodiment of a cooling channel formed in the junction.

DETAILED DESCRIPTION OF THE INVENTION

[0013] The present inventors have recognized at least one form of deformation that may occur when using one exemplary embodiment of a ducting arrangement and have identified a region of the ducting arrangement likely to experience substantial mechanical stresses as a result of this deformation. The inventors have further recognized that this region of relatively great mechanical stress is also a region of relatively great thermal stress which compounds the problem.

[0014] To accommodate this localized region of high mechanical and thermal stresses, and thereby extend the service life of the ducting arrangement, the inventors have proposed an innovative arrangement that lowers the mechanical stresses in the area. This, in turn, permits the use of an insert having a material that is better suited thermally for the local region, and this reduces an amount of cooling air that is required for the local region which, in turn, increases engine efficiency. Reducing the stresses at this location permits the use of an insert material that may possess a different mechanical property, for example a lower yield strength, when compared to a material of the ducting arrangement immediately surrounding the insert. The inventors have also proposed to thermally decouple the insert from the material of the ducting arrangement immediately surrounding the insert. This will reduce thermal growth mismatch and associated stresses, further extending the service life of the component.

[0015] These goals may be accomplished in one exemplary embodiment by bi-casting ducting material around the insert. Bi-casting securely locks the insert in place but does so without a metallurgical bond. This can partially or fully structurally and/or thermally decouple the insert from the remainder of the ducting arrangement. This, in turn, permits the selection of a material for the insert that is tailored to withstand the relatively harsh conditions present in the region, (greater high-temperature stability) while allowing the selection of different material sufficient to withstand the relatively less harsh conditions in the remainder of the ducting arrangement. This is particularly beneficial in terms of cost since it allows for the use of the more expensive material of the insert only where conditions require it, while less expensive material can be used elsewhere.

[0016] FIG. **1** is a schematic representation of an exemplary embodiment of a ducting arrangement **10** that may be used with properly oriented can combustors (not shown), viewed looking from aft to fore. The ducting arrangement **10** receives combustion gases and guides them toward an inlet annulus (not shown) of a turbine (not shown). The ducting arrangement **10** may include a plurality of cones **12**, each configured to receive a discrete flow of combustion gases emanating from a respective can combustor. Each cone **12** may deliver the respective flow of combustion gases to an annular chamber **14** into which all combustion gas flows flow. An accelerating configuration **16** may be present to accelerate a combustion flow from a speed at which it travels when entering the cone **12** to a speed appropriate for delivery onto a first row of turbine blades (not shown), which could approach 0.8 mach and above. In this exemplary embodiment each cone **12** forms part of a respective discrete duct **18**, where each discrete duct **18** ends where the annular chamber **14** is first encountered. The portion of the ducting arrangement from this point downstream is the common duct structure which, in this exemplary embodiment, includes the annular chamber **14**.

[0017] FIG. **2** shows the ducting arrangement **10** (without the cones **12** for clarify) positioned within a turbine vane carrier **20** of a gas turbine engine. Compressed air exits a compressor exit diffuser **22** and enters a plenum **24** surrounding the ducting arrangement **10**. The compressed air is moving relatively slowly in the plenum **24** as it moves toward an inlet (not shown) to the combustor cans (not shown). Once the compressed air is mixed with fuel and combusted in the can it is received by the ducting arrangement **10** and accelerated to a relatively fast speed approaching mach 0.8 and above via the accelerating configuration **16** partly visible in FIG. **2**. Partially visible within the turbine vane carrier **20** is the annular chamber **14** which experiences the bulk of the pressure induced forces. The cone ends of the ducting arrangement **10** are essentially fixed axially by the can combustors and associated structure. Consequently, the pressure of the compressed air in the plenum **24** not only presses on all exterior surfaces of the ducting arrangement **10**, it also tends to push the annular chamber **14** aft into the turbine inlet annulus. The result is a cantilever-like “prying” of the discrete flow ducts portion of the ducting arrangement **10** from the annular chamber **14**.

[0018] FIG. **3** shows one exemplary embodiment of the ducting arrangement subcomponent **30** that includes one cone **12** at a cone end **32** and one common duct structure end **34**. Within the common duct structure end **34** is an arc-segment **36** that forms part of the annular chamber **14** when a plurality of the ducting arrangement subcomponents **30** are assembled together and a discrete flow path portion **38** leading to the arc-segment **36**. (Other exemplary embodiments exist where a common duct structure is formed but it does not take the form of the annular chamber **14**.) Where walls **40** of the discrete flow path portion **38** intersect with walls **42** of the arc-segment **36** a junction **44** is formed. Upon reaching a junction **44** combustion gases from adjacent flows are not prevented from mixing by duct structure. If each flow were theoretically fully collimated, incompressible, and without momentum, then adjacent flows would likely not mix. However, it is expected that some mixing may occur due to expansion, shear interactions, and a momentum-induced flattening of the flow as it is turned by the annular chamber **14** against its wish to continue flowing along a straight path. At an upstream region **46** of the junction **44** it can be seen that corners **48** of merging walls **40**, **42** intersect at a relatively small angle and this angle results in the upstream region **46** taking on the shape of a fillet, which is a stress riser. This fillet is located in a region of the ducting arrangement **10** subject to the “prying” action of the discrete flow path portion **38** from the common duct structure end **34** as a result of the pressure difference pushing the annular chamber **14** aft (out of the page in this view).

[0019] FIG. **4** shows a perspective view of the common duct structure end **34** (only) of the ducting arrangement subcomponent **30** from a different angle. In this exemplary embodiment an insert **50** has been positioned in the common duct structure end **34** and shaped so that it includes the upstream region **46** of the junction **44**. The common duct structure end **34** includes the insert **50** and a remainder **52** of the common duct structure end **34**. The remainder **52** of the common duct structure end **34** is simply that part of the common duct structure end **34** not including the insert, (the common duct structure end **34** with the opening for the insert **50**). The annular chamber **14** (common duct structure) includes the inserts **50** and a remainder (not shown) of the annular chamber **14**. The remainder of the annular chamber **14** is simply that part of the annular chamber **14** not including the inserts **50**, (the annular chamber **14** with the openings for the insert **50**). Likewise, the ducting arrangement **10** includes the inserts **50** and a remainder (not shown) of the ducting arrangement **10**. The remainder of the ducting arrangement **10** is simply that part of the ducting arrangement **10** not including the inserts **50**, (the ducting arrangement **10** with the openings for the insert **50**).

[0020] The opening for a respective insert **50** essentially matches a shape of the respective insert **50** that rests therein. The insert **50** and the remainder **52** of the common duct structure end **34** meet at an interface **54**. The insert may include the upstream region **46** of the junction **44**, and the upstream region **46** experiences relatively high temperatures when compared to other locations of the ducting arrangement **10**. Consequently, even if a same material is used for the insert **50** and the material that defines the opening, the upstream region **46** may expand or contract differently than other locations of the ducting arrangement. In order to prevent excessive thermal growth mismatch, where relative growth causes internal stresses beyond a yield strength of either material, the ducting arrangement **10** may include a gap (not visible) between the insert **50** and a perimeter **56** of the opening at one temperature. The gap may shrink and/or disappear at another operating condition. This can be configured such that when the gap disappears there is no stress created in the insert **50**, or only an amount of stress that is within the yield strength of the insert material. The gap may be uniform around the insert **50**, or it may be locally tailored to accommodate thermal growth that may not be uniform. For example, if the geometry of the insert results in greater thermal growth in one direction over another, the gap may be sized to accommodate the local differences. Conversely, the arrangement can be configured such that a yield strength of the ducting material surrounding the insert **50** is not exceeded.

[0021] Accommodating the relative thermal growth may be particularly important when the insert material is relatively weaker than the ducting material that defines the opening. In this case it is important to ensure a yield strength of the insert **50** is not exceeded as a result of the insert **50** thermally growing into the perimeter **56** of the opening and then experiencing a compressive force imparted by the ducting material that may resist that thermal growth. While it is possible that the ducting material that defines the opening may have a lower yield strength, it is more likely that the material of the throat insert will have a lower yield strength that must not be exceeded. A lower yield strength often accompanies materials characterized by a better high-temperature stability. High temperature stability materials do not oxidize or disintegrate as quickly at higher temperatures. General examples of high temperature stability materials include oxide dispersion strengthened alloys and ceramic matrix composites. CMSX-4® (of the Cannon Muskegon Corporation, Muskegon Mich.), is an example high temperature stable material that may be used for the insert **50**. An example of a material for the remainder **52** of the common duct structure end **34** is Inconel® 939 (of the Special Metals Corporation of Huntington W. Va.).

[0022] If the insert **50** and the ducting material that defines the perimeter **56** have different coefficients of thermal expansion, this relationship can also be exploited in order to control stresses in the insert. For example, the insert material may have a relatively small coefficient of thermal expansion when compared to the ducting material defining the opening. The ducting arrangement **10** can be configured such that the greater temperature increase experienced by the insert **50** and the lower coefficient of thermal expansion result in a thermal growth that equals (or is essentially equal to) a thermal growth of the ducting material that defines the opening, because it has a lesser temperature increase but a greater coefficient of thermal expansion. Controlling these factors can enable control of the amount of stress within the insert **50** so that a yield strength of the material of the insert **50** is not exceeded.

[0023] In an exemplary embodiment the common duct structure end **34** may be formed by bi-casting ducting material around the throat insert **50**, where the throat insert **50** was previously cast. Such a bi-casting process is disclosed in U.S. Patent Application Publication Number 2011/0243724 to Campbell et al., published Oct. 6, 2011, which is incorporated by reference in its entirety herein. The bi-casting process necessarily occurs at elevated temperatures. However, a temperature of the insert **50** can be controlled in order to maintain a desired relationship between the thermal growth of the insert **50** and the remainder **52** of the common duct structure end **34**. For example, in an instance when the insert material is characterized by a higher coefficient of thermal expansion, a temperature of the insert **50** may be elevated during the bi-casting such that the insert **50** has grown thermally to approximate a condition the insert **50** will experience during operation of the gas turbine engine. Both the insert **50** and the ducting material would cool to ambient temperatures, and the insert would contract more. A gap may be formed at lower temperatures, and this gap may be configured to fully disappear at operating conditions without the insert expanding to the point where it expands into the perimeter **56** of the opening. Expanding into the perimeter **56** would produce a compressive stress on the insert **50** that may not be desired. Alternately, a certain amount of thermal growth interference between the two may be desired, and could be controlled such that the resulting compressive stress did not exceed a yield strength of either material. This can be accomplished by heating the insert **50** to a lower temperature than in the last example. During subsequent operation the insert **50** would heat more and thereby grow more into the ducting material surrounding the insert **50**. Should the insert **50** be characterized by a lower coefficient of thermal expansion, keeping the insert **50** cooler during the casting operation may permit it to expand more during subsequent operation, thereby minimizing any gap formed at the interface **54**. Using these techniques and known variations can result in an insert that is thermally decoupled from, or less thermally coupled with the remainder **52** of the common duct structure end **34**.

[0024] Bi-casting in this manner will trap the insert **50** in place but will do so without forming a metallurgical bond at the interface **54** of the insert and the ducting material defining the opening. As shown in FIG. **5**, an interlocking feature such as a groove **58** can be formed in an interface surface **60** of the insert **50**, which will geometrically interlock with the ducting material that is bi-cast around the insert **50**. This can be made to form a tortuous path for any air that leaks through the interface **54**, thereby slowing the rate of leakage.

[0025] In a ducting arrangement **10** without the insert **50** a small angle **62** is formed by the corners **48** of the merging walls **40**, **42** and this is a stress riser **64** that experiences relatively high mechanical stress when operating forces act on the discrete ducts, such as to increase the small angle **62**. In the exemplary embodiment, the insert **50** includes the stress riser **64** of the upstream region **46** of the junction and a length **66** of the junction **44** from where the corners **48** begin to intersect until they have fully run together inside the common duct structure end **34**. Such an insert **50** may be termed a throat insert. Since the insert **50** now includes this upstream region **46** of the junction **44**, and since the insert **50** is not metallurgically bonded to the remainder **52** of the common duct structure end **34**, the remainder **52** does not experience the stiffness of the upstream portion **46** of the junction **44** to the same extent as it would without the insert **50**, and conversely, the remainder **52** does not transfer stresses to the upstream region **46** of the junction **44** to the same extent as without the insert **50**.

[0026] The ducting arrangement **10** must then be configured to accommodate this interface **54** that is not characterized by a metallurgical bond and hence transfers load less effectively. To do so the remainder **52** of the common duct structure end **34** may be made flexible enough to flex yet withstand operating forces the ducting arrangement **10** experiences during operation including the cantilever prying action. Alternately, or in addition, the ducting material in the portion of the remainder **52** of the common duct structure end **34** that surrounds the insert **50** may be thickened to increase a structural strength of the remainder **52**. In this way the upstream region **46** of the junction **44** is mechanically decoupled, or coupled to a lesser degree, with the remainder **52** of the common duct structure end **34** when compared to ducting arrangements **10** not having the insert **50**. Consequently, the upstream region **46** of the junction experiences reduced stresses during operation. Lowering the stress experienced increases the number of materials can be used for the insert because many materials that satisfy the high temperature are characterized by lower yield strengths. Many of these lower yield strengths are satisfactory for use in the mechanically decoupled (or less-coupled) configuration but would not be satisfactory without the mechanical decoupling (or decreased coupling). Mechanical loads and thermal growth mismatch both contribute to the stresses in the upstream region **46** of the junction. Consequently, optimal designs can balance the amount of mechanical decoupling, thermal decoupling, high temperature tolerance of the material, and yield strength to reach an appropriate configuration. In another exemplary embodiment the ducting arrangement **10**

may be configured such that the insert **50** experiences stresses associated only with its aerodynamic function.

[0027] In this exemplary embodiment the insert **50** also uniquely defines a portion **70** of a flow path **72** associated with the discrete flow path portion **38** as well as a portion **74** of a flow path **76** associated with the arc-segment **36**, and hence with the annular chamber **14** and the common duct structure.

[0028] FIG. **6** shows a different view of the insert **50** looking at the upstream region **46** of the junction **44** and the stress riser **64**. A corner **80** of the flow path **72** associated with the discrete flow path portion **38** and a corner **80** the flow path **76** associated with the arc-segment **36** actually merge with each other at a converging flow junction **84**. The respective flow paths **72**, **76** do not necessarily intersect each other here, but instead may be configured to share a common plane, though the flows of combustion gases in the respective flow paths **72**, **76** may blend via expansion, shear, and momentum etc.

[0029] Separately forming the insert **50** provides yet another advantage. The upstream region **46** of the junction **44** experiences relatively high operating temperatures. While the remainder **52** of the common duct structure end **34** and the remainder of the ducting arrangement **10** may or may not require cooling, the upstream region **46** may benefit from cooling. However, when the upstream region **46** is cast with the remainder **52** of the of the common duct structure end **34** any cooling channels must be machined in subsequent to the casting operation. In contrast, when the insert **50** is cast separately, cooling channels can be cast using a fugitive casting insert. As a result, the cooling channels can be more complex and can incorporate features in a surface of the cooling channel such as pins, fins, and turbulators to increase a cooling effectiveness.

[0030] FIG. **8** shows a schematic representation of a cooling arrangement **100** in the insert **50** having a cooling air channel **102**. Cooling features **104** in the cooling channel **104** may increase a surface area of a cooling channel surface **106** to increase cooling efficiency, and may further increase the cooling efficiency by causing turbulence in the cooling air. Forming the cooling channel **102** and cooling features **104** during a casting operation allows for more detail and ease of manufacturing than is possible through machining methods, such as STEM drilling, and avoids secondary operations such as weld plugging etc. While a single cooling air channel **102** is shown, the number and arrangement of cooling channels used can vary as needed.

[0031] From the foregoing it can be seen that the inventors have recognized a new problem associated with an emerging technology, have created a solution, and have done so using existing technology but applying it in a novel manner. The solution increases service life and improves cooling efficiency and so it represents an improvement in the art.

[0032] While various embodiments of the present invention have been shown and described herein, it will be obvious that such embodiments are provided by way of example only. Numerous variations, changes and substitutions may be made without departing from the invention herein. Accordingly, it is intended that the invention be limited only by the spirit and scope of the appended claims.

The invention claimed is:

1. A ducting arrangement, comprising:

a plurality of discrete ducts, each defining a flow path and configured to receive a flow of combustion gases from a respective combustor can, wherein the plurality of discrete ducts merge to form a common duct structure; and

a throat insert configured to define at least part of a junction of one of the discrete ducts and the common duct structure.

2. The ducting arrangement of claim **1**, wherein the ducting arrangement is formed by bicasting ducting material around the throat insert.

3. The ducting arrangement of claim **1**, wherein the throat insert is configured to define part of a flow path associated with the one discrete duct.

4. The ducting arrangement of claim **1**, wherein the throat insert comprises an intersection of a corner of the one discrete duct and a corner of the common duct structure.

5. The ducting arrangement of claim **1**, wherein a throat material of the throat insert comprises a different mechanical property than a ducting material immediately surrounding the throat insert.

6. The ducting arrangement of claim **1**, further comprising an expansion gap between the throat insert and ducting material surrounding the throat insert effective to prevent internal stress in the throat insert from exceeding a yield strength of a material of the throat insert.

7. The ducting arrangement of claim **1**, wherein an interface between the throat insert and a remainder of the ducting arrangement forms a tortuous path.

8. The ducting arrangement of claim **1**, wherein an interface between the throat insert and a remainder of the ducting arrangement forms a geometric interlock effective to secure the throat insert in place.

9. A ducting arrangement, comprising:

a plurality of discrete ducts, each defining a flow path configured to receive a flow of combustion gases from a respective combustor can;

a common duct structure into which the plurality of discrete ducts merge; and

a plurality of discrete throat inserts, each configured to define at least part of a junction between one of the discrete ducts and the common duct structure,

wherein the ducting arrangement is configured to structurally compensate for a non-metallurgical bond at an interface of the discrete throat inserts with a remainder of the ducting arrangement.

10. The ducting arrangement of claim **9**, wherein the ducting arrangement is formed by bi-casting ducting material around the plurality of discrete throat inserts.

11. The ducting arrangement of claim **9**, wherein the ducting arrangement is configured to flex in order to structurally compensate for the non-metallurgical bond.

12. The ducting arrangement of claim **9**, wherein a portion of the ducting arrangement immediately surrounding the throat inserts is thickened with respect to a remainder of the ducting arrangement to structurally compensate for the non-metallurgical bond.

13. The ducting arrangement of claim **9**, wherein a throat material of the throat inserts comprises a greater high-temperature stability than a ducting material in which the throat inserts reside.

14. The ducting arrangement of claim **9**, wherein ducting material defines a plurality of openings in each of which a respective throat insert resides, and wherein each opening is sized to permit thermal growth interference between the throat insert and the ducting material without exceeding a yield strength of a material of the throat insert.

15. The ducting arrangement of claim **9**, wherein each throat insert defines a portion of a flow path associated with a respective discrete duct.

16. A ducting arrangement, comprising:

a ducting arrangement subcomponent comprising a discrete duct and a downstream end, the discrete duct defining a flow path and configured to receive a flow of combustion gases from a respective combustor can, wherein the downstream end constitutes part of a common duct structure configured to deliver combustion gases to a turbine inlet annulus when assembled to other ducting arrangement subcomponents; and

a throat insert disposed configured to define at least part of a junction of the discrete duct and the downstream end,

wherein the junction is formed by bi-casting a ducting material around the throat insert.

17. The ducting arrangement of claim **16**, wherein a throat material of the throat insert comprises a reduced yield strength relative to the ducting material.

18. The ducting arrangement of claim **16**, wherein a throat material comprises an increased high-temperature stability relative to a remainder of the junction.

19. The ducting arrangement of claim **16**, wherein the throat insert and a remainder of the ducting arrangement are free to thermally grow relative to each other.

20. The ducting arrangement of claim **16**, wherein the throat insert and the ducting material around the throat insert are configured to accommodate thermal growth interference there between without exceeding a yield strength of the throat insert.

* * * * *