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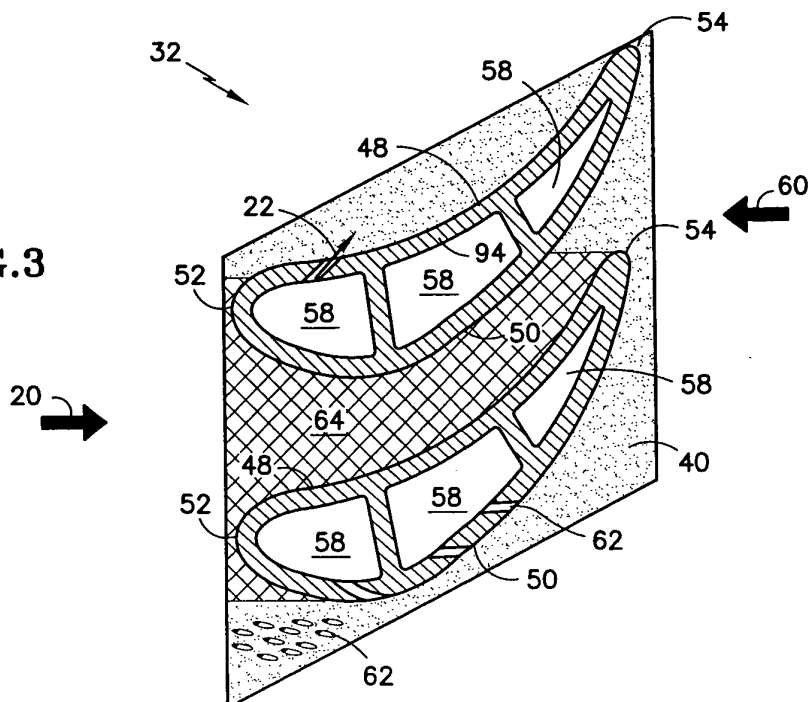
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(54) **Cooled vane cluster**

(57) A cast vane cluster (32) with enhanced cooling contains an inner and an outer platform (34, 36) and at least two airfoils (38) for directing a primary fluid stream axially rearward. A duct (56) is bounded by inner and outer endwall surfaces (40, 44), and adjacent airfoil fluid directing surfaces. One or more cooling holes (62) in the duct are drilled using an electrodischarge machine

(EDM) method without a line of sight from the drilling equipment to the cooling hole location. One or more cooling holes (62), located in portions of the duct, may not be visible when viewed from an external location. Additionally, one or more cooling holes (62) may only have an outlet cross sectional area (66) visible when viewed along a longitudinal axis from an external location.

FIG.3



Description

BACKGROUND OF THE INVENTION

(1) FIELD OF THE INVENTION

[0001] The invention relates to gas turbine engine components, and more particularly to a cast vane cluster with enhanced cooling.

(2) DESCRIPTION OF THE RELATED ART

[0002] A gas turbine engine includes a compressor for directing a primary fluid stream axially rearward, through a combustor and into a turbine. The turbine extracts power from a primary fluid stream and transmits the power through a shaft to rotate the forward-mounted compressor. A portion of the primary fluid stream is also directed to one or more secondary fluid streams for use in cooling components of the gas turbine engine. Disposed within the turbine section are alternating, annular stages of rotating blades and stationary vanes. The blades and vanes are disposed circumferentially about a central, longitudinal axis of the gas turbine engine.

[0003] Individual turbine vanes are comprised of an inner platform, an outer platform and an airfoil spanning radially outward from the inner platform to the outer platform. The airfoil contains a forward facing leading edge and a rearward facing trailing edge. The airfoil is staggered on the platforms in relation to the primary fluid stream direction, with the airfoil trailing edges of adjacent vanes forming an overlapping array. Together, the platforms and airfoils of adjacent vanes bound a duct for directing the primary fluid stream rearward. An inlet to the duct is bounded by adjacent airfoil leading edges and inner and outer endwall surfaces. An outlet to the duct is bounded by adjacent airfoil trailing edges and inner and outer endwall surfaces. The duct area generally converges in the axially rearward direction.

[0004] Vanes are typically investment cast of high-strength Nickel or Cobalt alloys and may contain multiple airfoils within a single casting. Vane castings with multiple airfoils are referred to as cast vane clusters and have the advantage of reducing the number of inter-platform interfaces in a turbine stage. Inter-platform interfaces are costly to manufacture and are a source of primary fluid stream leakage, which is detrimental to the operating efficiency of the gas turbine engine.

[0005] In cast vane clusters requiring cooling, one or more hollow passages extend through the interior of the airfoils forming a series of internal airfoil surfaces. The hollow passages direct a secondary fluid stream into the interior of the cast vane cluster. A multitude of cooling holes pass through the airfoil walls and into the hollow passages, allowing the secondary fluid stream to discharge into the primary fluid stream. Each hole comprises an inlet, an outlet and a bore extending from the inlet to the outlet along a central, longitudinal axis. Preferably,

the multitude of cooling holes are drilled from the direction of the airfoil trailing edge and at an acute angle to the cast vane cluster surfaces. The drilling direction and angle are necessary to ensure that the secondary fluid stream is discharged in a substantially rearward direction. This optimizes the cooling effectiveness of the secondary fluid stream and reduces aerodynamic losses in the primary fluid stream.

[0006] Typically, cooling holes are drilled after a vane cluster casting is made. The standard methods used for drilling cooling holes in cast articles are laser and electrodischarge machining (EDM). Laser drilling methods utilize short pulses of a high-energy beam, an example is shown in U.S. Pat. No. 5,037,183. Electrodischarge machining (EDM) drilling methods pass an electrical charge through a gap between an electrode and a surface, an example is shown in U.S. Pat. No. 6,403,910. Both the laser and the EDM drilling methods require a line of sight from the drilling equipment to the hole location, limiting the surfaces that may be drilled.

[0007] Due to the stagger of the airfoils on the platforms of a cast vane cluster, portions of the duct surfaces are obstructed by the airfoil trailing edges and cannot be drilled using conventional laser or EDM drilling methods. The durability of cast vane clusters would be vastly improved if cooling holes could be placed wherever needed on the duct surfaces. What is needed is a cast vane cluster with cooling holes drilled into portions of the duct without a line of sight from the drilling equipment to the hole location.

BRIEF SUMMARY OF THE INVENTION

[0008] Provided is a cast vane cluster with cooling holes drilled into surfaces without a line of sight from the drilling equipment to the hole location.

[0009] In accordance with an exemplary embodiment, a cast vane cluster with enhanced cooling contains an inner and an outer platform and at least two airfoils for directing a primary fluid stream axially rearward. A duct is bounded by inner, an outer endwall surfaces, and adjacent airfoil fluid directing surfaces. The duct boundary contains at least one cooling hole for directing a secondary fluid stream to enhance cooling and extend the life of the cast vane cluster.

[0010] Other features and advantages will be apparent from the following more detailed descriptions, taken in conjunction with the accompanying drawings, which illustrate, by way of example, a preferred embodiment cast vane cluster with enhanced cooling.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0011]

FIG. 1 is a simplified schematic of a gas turbine engine along a longitudinal axis.

FIG. 2 is an isometric view of a cast vane cluster of the type used in the gas turbine engine of FIG. 1. FIG. 3 is a sectional top view of a cast vane cluster of FIG. 2 showing an obstructed surface area. FIG. 4 is an isometric view of an embodiment of a hole drilling guide for use in drilling holes into an obstructed surface area of a cast vane cluster. FIG. 5 is an isometric view of an alternate embodiment of a hole drilling guide for use in drilling holes into an obstructed surface area of a cast vane cluster. FIG. 6 is a sectional top view of a cast vane cluster of FIG. 2 showing a hole-drilling guide of FIG. 4 in place. FIG. 7 is a sectional side view of a cast vane cluster of FIG. 2 showing a hole-drilling guide of FIG. 4 in place. FIG. 8 is a sectional side view of a vane cluster of FIG. 2 showing a hole-drilling guide of FIG. 5 in place. FIG. 9 is a partial sectional view of a cooling hole of a cast vane cluster of FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

[0012] A gas turbine engine 10 with a central, longitudinal axis 12 is shown in FIG. 1. The gas turbine engine contains a compressor section 14, a combustor section 16 and a turbine section 18. A primary fluid stream 20 is directed axially rearward from the compressor section 14, through the combustor section 16 and into the turbine section 18. Within the compressor section 14, a portion of the primary fluid stream 20 is directed to one or more secondary fluid streams 22, which bypass the combustor section 16, for use in cooling components within the gas turbine engine 10. The turbine section 18 typically comprises multiple, alternating stages of rotating blades 24 and stationary vanes 26. Multiple vanes may be cast as a single piece, which is typically called a cast vane cluster 32 (shown in FIG. 2). **[0013]** A cast vane cluster 32 comprises an inner platform 34, an outer platform 36 and at least two airfoils 38 spanning radially outward from the inner platform 34 to the outer platform 36. The inner platform 34 has an inner endwall surface 40 facing the airfoils and one or more inboard cavities 42 (shown in FIGS. 7 and 8) opposite the airfoils. The outer platform 36 has an outer endwall surface 44 facing the airfoils and one or more outboard cavities 46 opposite the airfoils. As shown in FIG. 3, each of the airfoils 38 are comprised of a concave fluid directing surface 48, a convex fluid directing surface 50, a forward facing leading edge 52 and a rearward facing trailing edge 54. Collectively, the platform endwall surfaces 40, 44 and airfoil fluid directing surfaces 48, 50 delineate a duct 56, as shown in FIG. 2, for directing the primary fluid stream 20 rearward. One or more hollow passages 58 extend through the interior of the airfoils 38, connecting the inboard 42 and outboard cavities 46,

(shown in FIG. 8). In surfaces that have a line of sight from a drilling equipment direction 60, a multitude of cooling holes 62 may be drilled using conventional laser or electrodischarge machining EDM drilling methods.

[0014] A typical cooling hole 62, as shown in FIG. 9, is comprised of an inlet cross sectional area 65, an outlet cross sectional area 66 and a bore 67. The bore 67 extends through an airfoil wall 94, from the inlet cross sectional area 65 to the outlet cross sectional area 66, along a central, longitudinal axis 68. Although this example shows a cooling hole 62 with circular inlet and outlet cross sectional areas 65, 66, it is to be understood that any shape may be used. In addition, a cooling hole 62 may pass through an inner platform 34 or an outer platform 36 as well as an airfoil wall 94.

[0015] Each of FIGS. 6, 7 and 8, shows an exemplary embodiment cast vane cluster including one or more cooling holes 62 located in an obstructed area 64 (shown in FIG 3) of duct 56 (shown in FIG. 2). Duct 56, extends axially across portions of the platform endwall surfaces 40, 44, and radially across portions of the airfoil fluid directing surfaces 48, 50. One or more cooling holes 62, located in portions of the duct 56, may not be visible when viewed from an external location. Additionally, one or more cooling holes 62, may only have an outlet cross sectional area 66 visible when viewed along a longitudinal axis 68 from an external location. An exemplary cast vane cluster, with enhanced cooling as described above, may be made using one or more of the hole-drilling guides and methods described below.

[0016] FIG. 4 shows an embodiment of a hole-drilling guide 70 for guiding a flexible, hole-drilling instrument 72 to a surface without a line of sight from the hole drilling equipment to a required hole location. The hole-drilling guide 70 comprises a body 74, one or more inlet apertures 76, one or more exit apertures 78 and a hollow, nonlinear raceway 80 connecting each corresponding inlet 76 and exit 78 apertures. Shown in this example are three raceways; however, any number may be used. An inlet aperture 76 may contain a conical, bell-shaped or a similar shaped entrance 82 to simplify insertion of the flexible, hole-drilling instrument 72. The raceways 80 are a similar cross sectional shape as the flexible, hole-drilling instrument 72 and are slightly larger in sectional area. The clearance required between the flexible, hole-drilling instrument 72 and the nonlinear raceway 80 depends on the material of the hole-drilling guide 70 and the degree of curvature of the nonlinear raceway 80. In this example, a radial clearance of approximately 0.004 inch (0.1 mm) is used. Each of the exit apertures 78 penetrates a substantially conforming face 84 of the hole-drilling guide 70. The position of an exit aperture 78 in relation to an obstructed surface of an article is controlled by the substantially conforming faces 84, and by other locating features such as rolls, pins, tabs, balls, bumps 86. A clamping lug 88 allows the hole-drilling guide 70 to be rigidly secured to the article, once positioned.

[0017] FIG. 5 shows an alternate embodiment of a hole-drilling guide 70. In the embodiment shown, the hole-drilling guide 70 comprises a body 74 and faces 84, which substantially conform to an internal cavity or passage of an article. A clamping lug 88 allows the hole-drilling guide 70 to be rigidly secured to the article, once positioned, and contains one or more inlet apertures 76. One or more exit apertures 78 penetrate the substantially corresponding surfaces 84 and are connected to the inlet apertures 76 by one or more nonlinear raceways 80. Shown in this example are three nonlinear raceways; however, any number may be used.

[0018] In each of the above-described embodiments, the flexible, hole-drilling instrument 72 is an EDM electrode. The EDM electrode is formed of a flexible, electrically conductive wire with a diameter of between approximately 0.009 - 0.016 inches (0.23 - 0.41 mm). For noncircular shaped holes, a flexible, electrically conductive foil strip of a comparable dimension may be used. The body 74 of the hole-drilling guide 70 is preferably made of an electrically insulating material using solid freeform fabrication, casting, molding, machining or any other suitable technique. Alternately, the body 74 may be formed of an electrically conductive material and the nonlinear raceways 80 may be coated with an electrically insulating material.

[0019] In one aspect of a hole-drilling method, shown in FIG. 6, a hole-drilling guide 70 is used to guide an EDM electrode 72 to a portion of an obstructed surface area 64 (shown in FIG. 3) of a cast vane cluster 32. In this example, the obstructed surface area is located on an airfoil convex fluid directing surface 50. A cast vane cluster 32 is loaded in a single or multiple axis EDM station using a conventional tooling fixture 90. In this example, an AMCHEM model HSD6-11, high-speed EDM station was used. A hole-drilling guide 70 is placed into a duct 56 (shown in FIG. 2) of the cast vane cluster 32 and accurately positioned in relation to the cast vane cluster 32 by conforming surfaces 84 and a locating feature 86. The hole-drilling guide 70 is rigidly secured by a clamp 92 contacting a clamping lug 88. An EDM electrode 72 is inserted into an inlet aperture 76 and advanced along a nonlinear raceway 80, until the electrode contacts the airfoil convex fluid directing surface 50. Once loaded into the raceway 80, the EDM electrode 72 is secured to the EDM station and plunged through an airfoil wall 94 into a hollow passage 58, forming a hole 62. Upon completion of the hole 62, the EDM electrode 72 is retracted and the process is repeated as required.

[0020] In another aspect of a hole-drilling method, shown in FIG. 7, a hole-drilling guide 70 is used to guide an EDM electrode 72 to a portion of an obstructed surface area 64 (shown in FIG. 3) of a cast vane cluster 32. In this example, the obstructed surface area is located on an inner endwall surface 40. A cast vane cluster 32 is loaded in a single or multiple axis EDM station using a conventional tooling fixture 90. In this example an AMCHEM model HSD6-11, high-speed EDM station or

equivalent may be used. A hole-drilling guide 70 is placed into a duct 56 (shown in FIG. 2) of the cast vane cluster 32 and accurately positioned in relation to the cast vane cluster 32 by a conforming surface 84. The hole-drilling guide 70 is rigidly secured by a clamp 92 contacting a clamping lug 88. An EDM electrode 72 is inserted into an inlet aperture 76 and advanced along a nonlinear raceway 80, until the electrode contacts the inner endwall surface 40. Once loaded into the raceway 80, the EDM electrode 72 is secured to the EDM station and plunged through an inner platform 34 into an inner cavity 42 of the vane cluster 32, forming a hole 62. Upon completion of the hole 62, the EDM electrode 72 is retracted and the process is repeated as required.

[0021] In yet another aspect of a hole-drilling method, shown in FIG. 8, a hole-drilling guide 70 guides an EDM electrode 72 to a portion of an obstructed surface area 64 (shown in FIG. 3) of a cast vane cluster 32. In this example, the obstructed surface area is located on an airfoil concave fluid directing surface 48, and is accessed via a hollow passage 58. A cast vane cluster 32 is loaded in a single or multiple axis EDM station using a conventional tooling fixture 90. In this example, an AMCHEM model HSD6-11, high-speed EDM station or equivalent may be used. A hole-drilling guide 70 is inserted into the hollow passage 58 of the vane cluster 32 and accurately positioned in relation to the hollow passage 58 by conforming surfaces 84 and locating features 86. The hole-drilling guide 70 is rigidly secured by a clamp 92 contacting a clamping lug 88. An EDM electrode 72 is inserted into an inlet aperture 76 and advanced along a nonlinear raceway 80, until the electrode contacts the surface of the hollow passage 58. Once loaded into the raceway 80, the EDM electrode 72 is secured to the EDM station and plunged through the airfoil wall 94, forming a hole 62 (not shown). Upon completion of the hole 62, the EDM electrode 72 is retracted and the process is repeated as required.

[0022] The foregoing has described a cast vane cluster with enhanced cooling and its method of manufacture. It will be apparent to those skilled in the art that various modifications thereto can be made without departing from the scope of the invention as described in the appended claims.

Claims

1. A vane cluster (32) comprising:

An inner platform (34) including an inner end-wall surface (40);

An outer platform (36) including an outer end-wall surface (44) wherein said outer platform (36) is spaced radially outboard of said inner platform (34) and said outer endwall surface (44) faces said inner endwall surface (40);

At least two airfoils (38) spanning between said inner and outer endwall surfaces (40, 44), each including a concave surface (48), a convex surface (50), a leading edge (52) and a trailing edge (54) located axially rearward of said leading edge (52), wherein said concave and convex surfaces (48, 50) of adjacent airfoils (38) face each other;

A duct (56) bounded by said adjacent concave and convex surfaces (48, 50) and said inner and outer endwall surfaces (40, 44);

At least one hole (62) including an inlet cross sectional area (65) and an outlet cross sectional area (66); and

wherein said at least one hole outlet cross sectional area (66) is located on said duct boundary.

2. A vane cluster (32) comprising:

An inner platform (34) including an inner endwall surface (40);

An outer platform (36) including an outer endwall surface (44) wherein said outer platform (36) is spaced radially outboard of said inner platform (34) and said outer endwall surface (44) faces said inner endwall surface (40);

At least two airfoils (38) spanning between said inner and outer endwall surfaces (40, 44), each including a concave surface (48), a convex surface (50), a leading edge (52) and a trailing edge (54) located axially rearward of said leading edge (52), wherein said concave and convex surfaces (48, 50) of adjacent airfoils (38) face each other;

A duct (56) bounded by said adjacent concave and convex surfaces (48, 50) and said inner and outer endwall surfaces (40, 44);

At least one hole (62) including an inlet cross sectional area (65) and an outlet cross sectional area (66); and

wherein said at least one hole (62) is not visible when viewed from a location external of said duct region.

3. The vane cluster of claim 2 wherein said external location is axially rearward of said trailing edges (54).

4. The vane cluster of claim 2 wherein said external location is axially forward of said leading edges

(52).

5. A vane cluster (32) comprising:

An inner platform (34) including an inner endwall surface (40) and an inboard cavity (42);

An outer platform (36) including an outer endwall surface (44) and an outer cavity (46) wherein said outer platform (36) is spaced radially outboard of said inner platform (34) and said outer endwall surface (44) faces said inner endwall surface (40);

At least two airfoils (38) spanning between said inner and outer endwall surfaces (40, 44), each including a concave surface (48), a convex surface (50), a leading edge (52) and a trailing edge (54) located axially rearward of said leading edge (52), wherein said concave and convex surfaces (48, 50) of adjacent airfoils (38) face each other;

A duct (56) bounded by said adjacent concave and convex surfaces (48, 50) and said inner and outer endwall surfaces (40, 44);

A duct inlet area bounded by said at least two airfoil leading edges (52), said inner endwall surface (40) and said outer endwall surface (44);

A duct outlet area (66) bounded by said at least two airfoil trailing edges (54), said inner endwall surface (40) and said outer endwall surface (44);

At least one hole (62) including an inlet cross sectional area (65), an outlet cross sectional area (66), a bore (67) extending between said inlet and said outlet areas (65, 66) wherein said bore (67) has a central, longitudinal axis; and

Wherein said at least one outlet cross sectional area (66) is located on said duct boundary and said at least one inlet cross sectional area (65) is not visible when viewed along said longitudinal axis from an external location.

6. The vane cluster of claim 5 wherein said external location is located forward of said duct inlet area.

7. The vane cluster of claim 5 wherein said external location is located rearward of said duct outlet area.

8. The vane cluster of claim 5, 6 or 7, further comprising at least one hollow passage (58), extending through an airfoil (38), said at least one hollow pas-

sage (58) communicating with said inboard and outboard cavities (and forming an internal airfoil surface.

9. The vane cluster of claim 8 wherein said at least one hole inlet cross sectional area (65) is located on said internal airfoil surface. 5
10. The vane cluster of any preceding claim wherein said at least one hole (62) is formed using an electrodischarge machine method. 10
11. The vane cluster of any preceding claim wherein said at least one hole outlet cross sectional area (66) is circular shaped. 15

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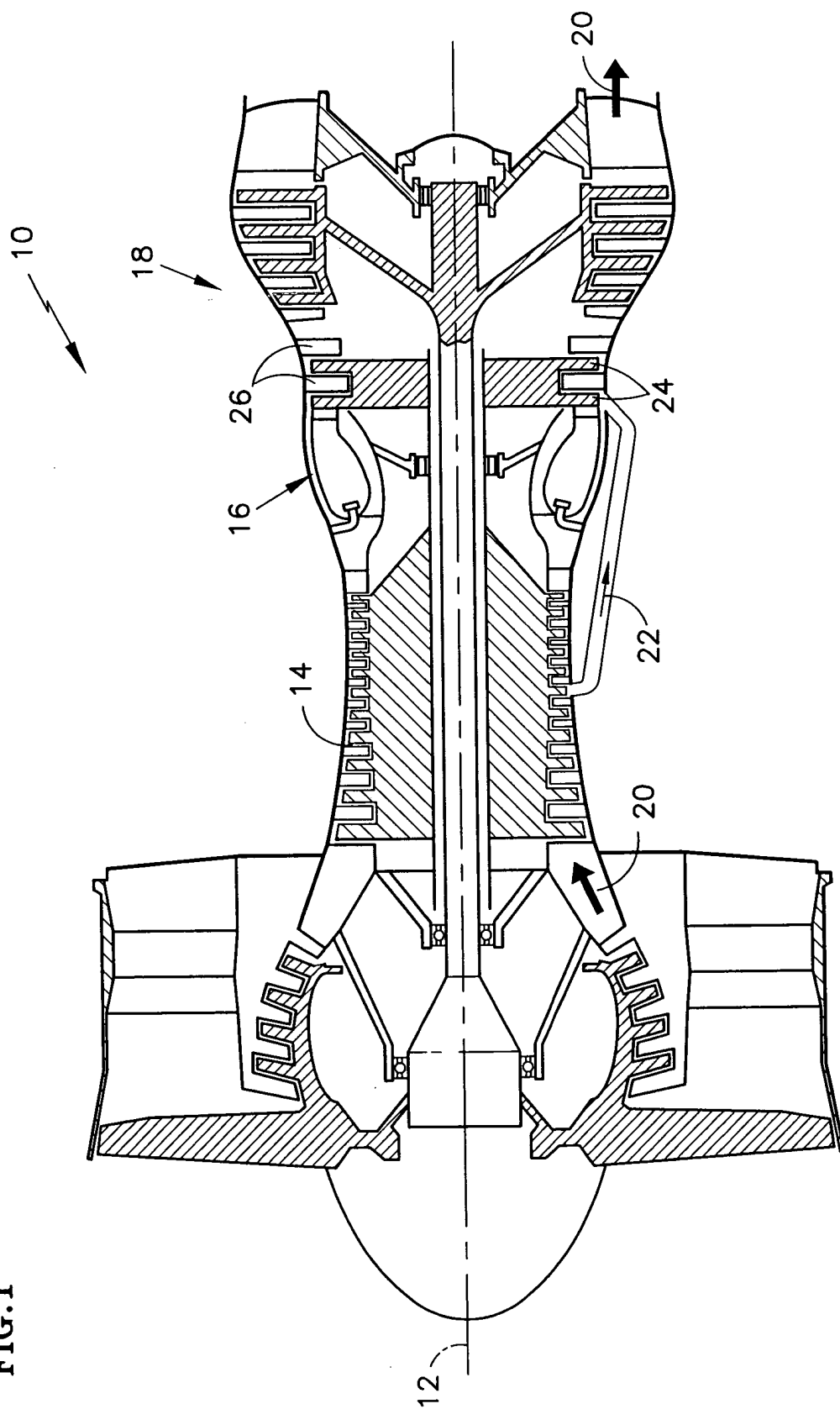
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FIG.1



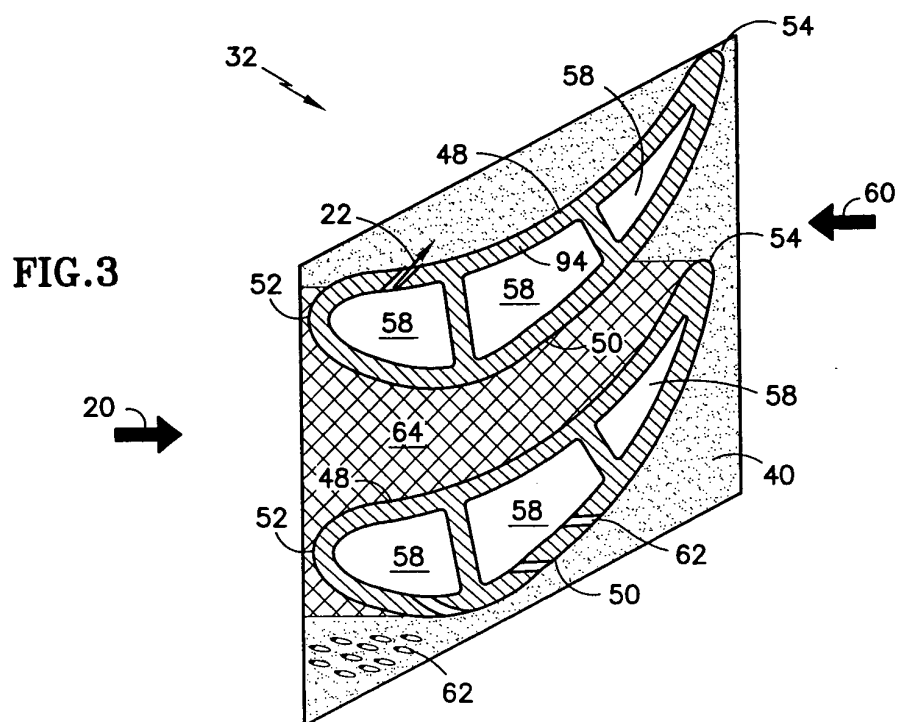
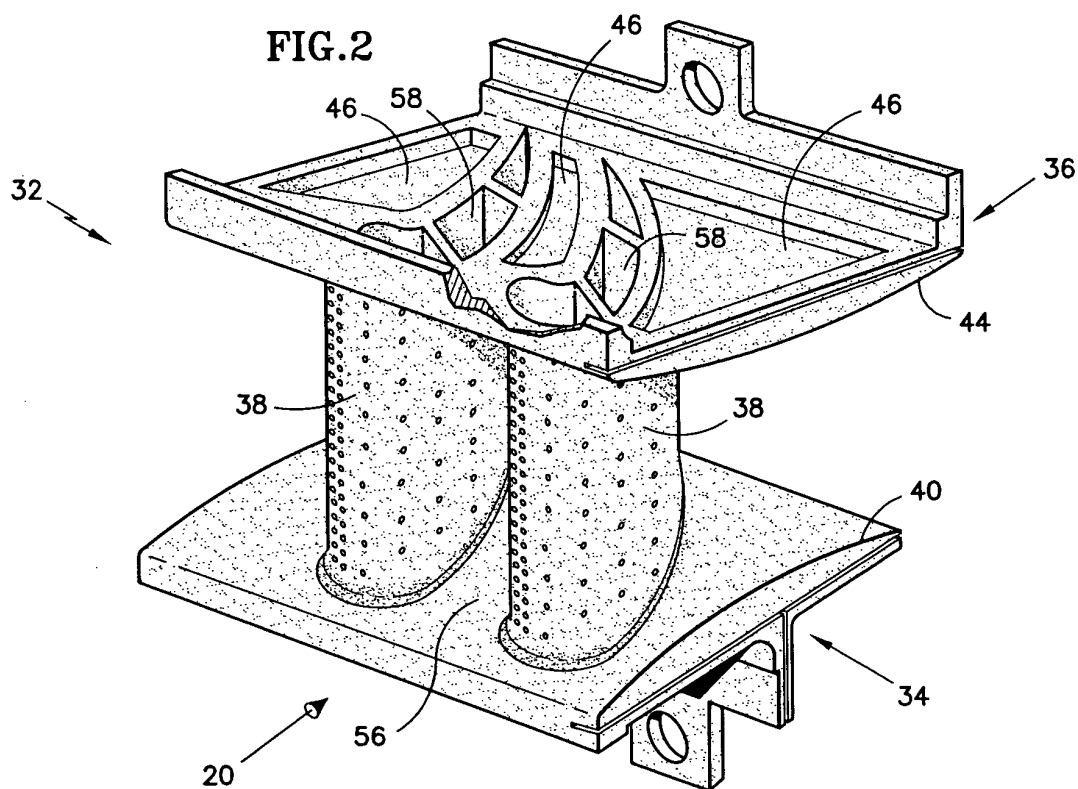


FIG.4

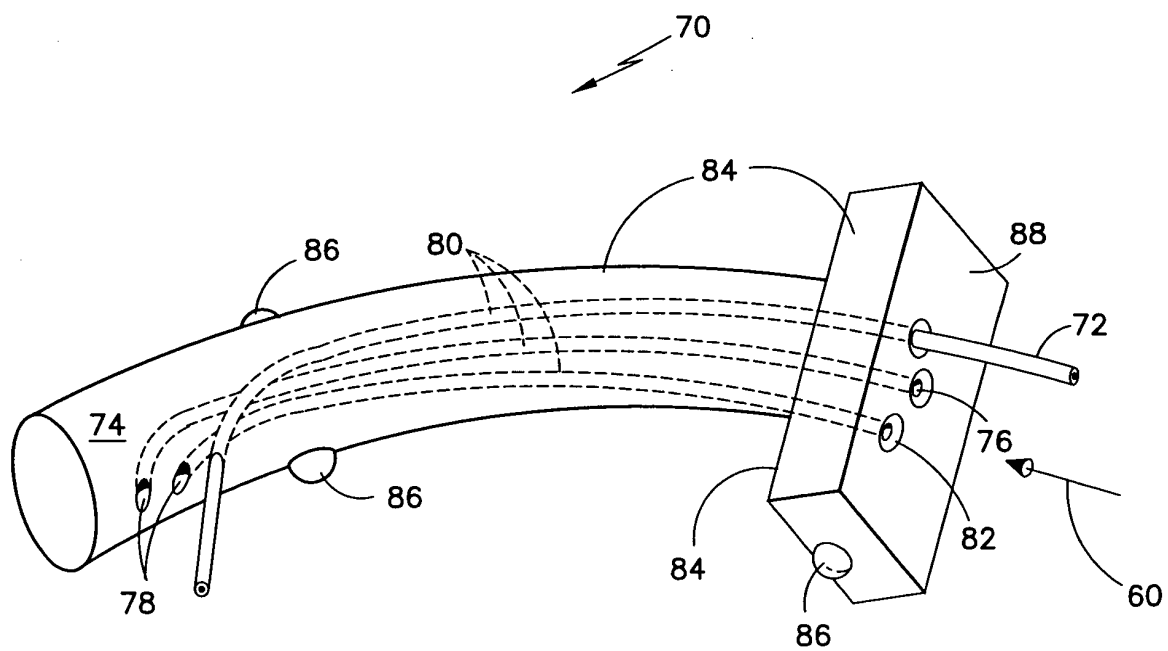
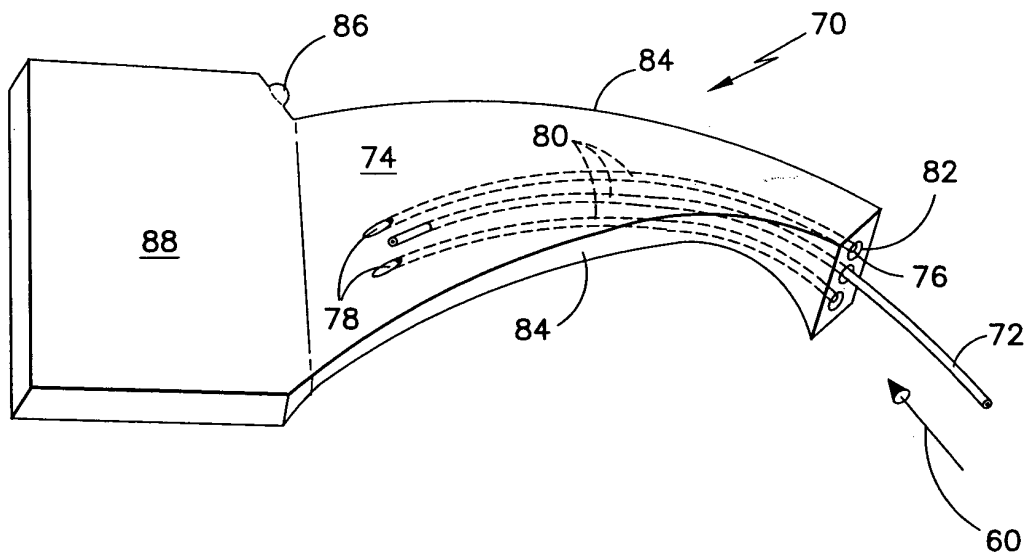


FIG.5

FIG.6

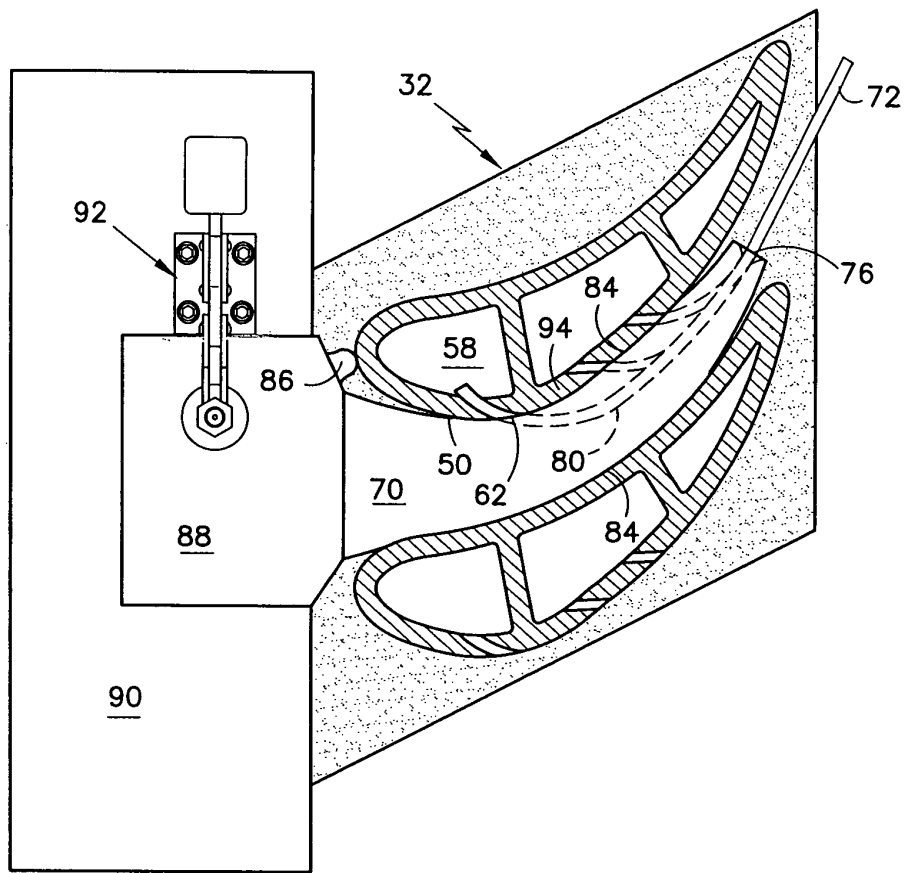


FIG.7

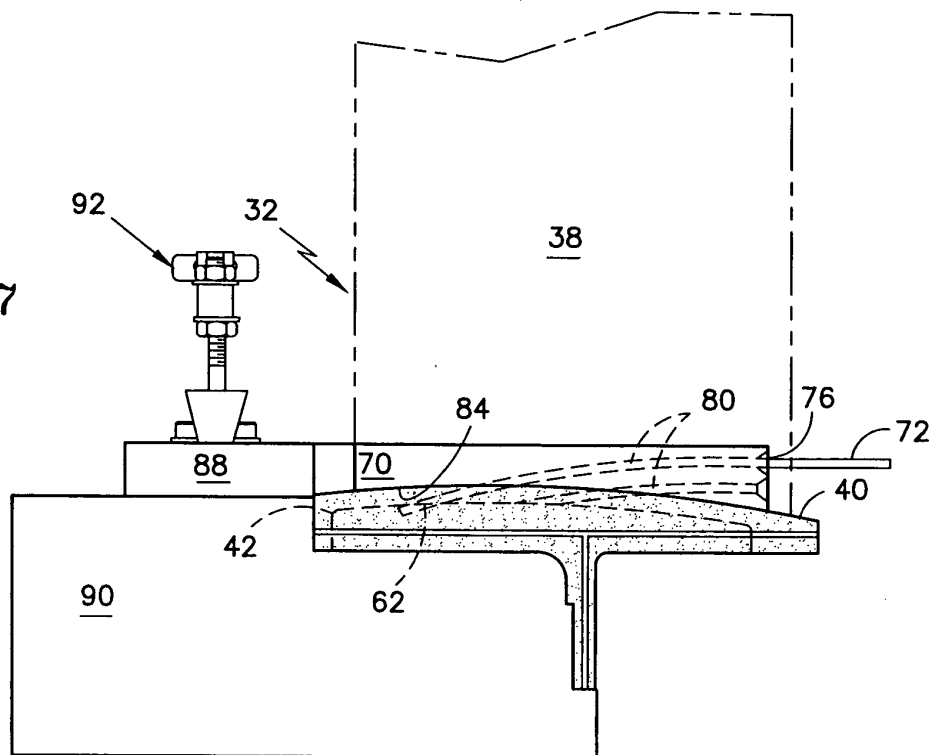
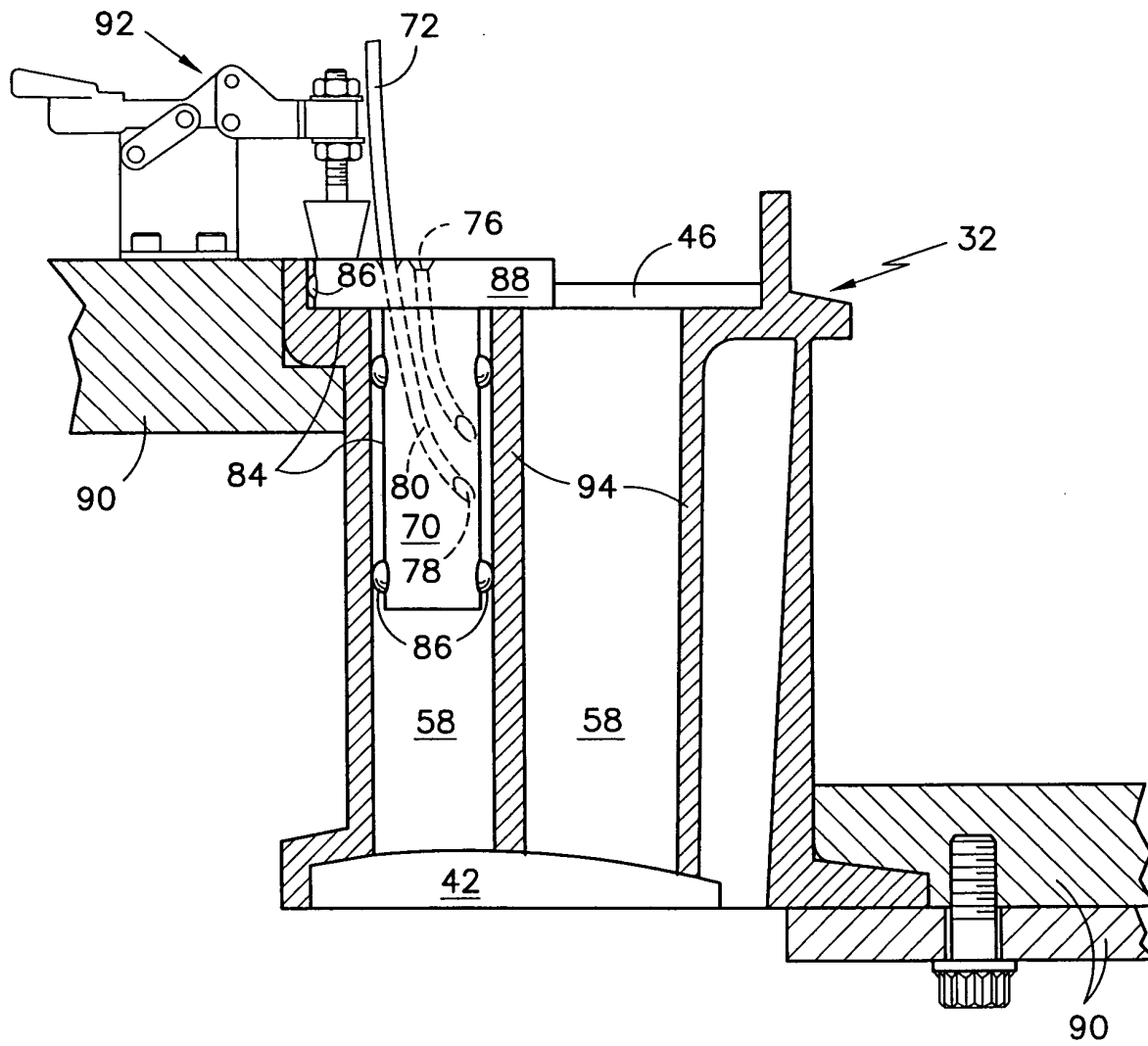


FIG.8



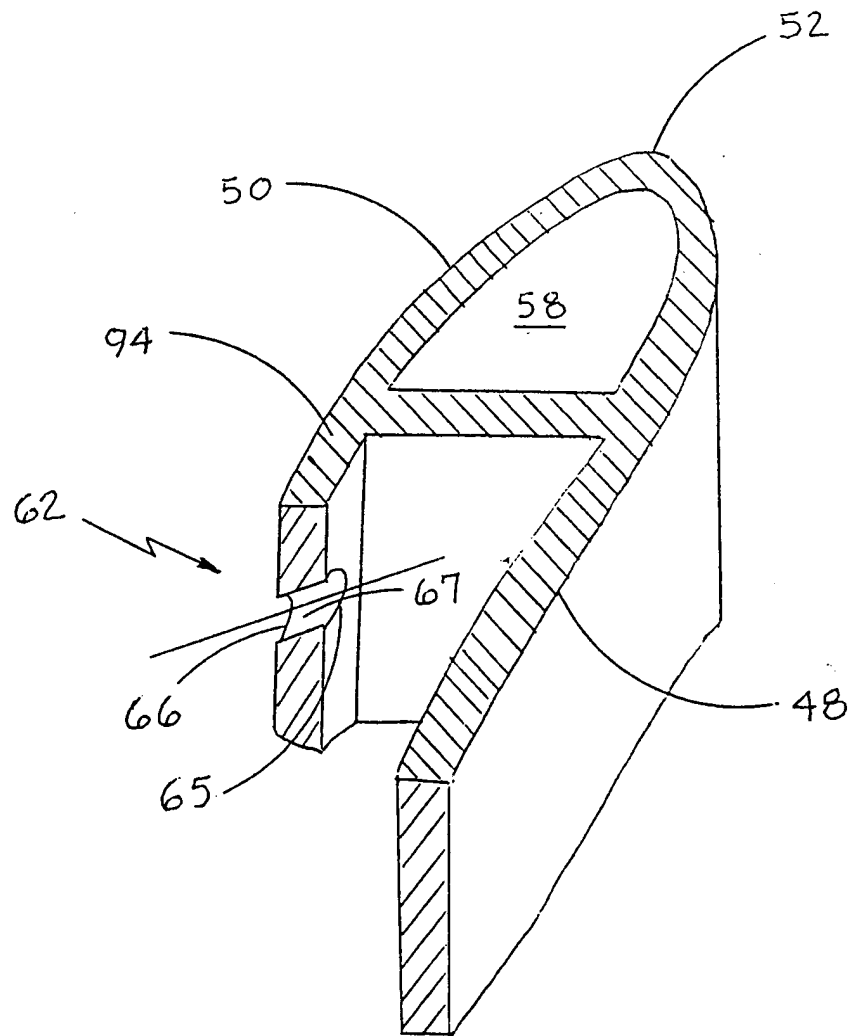


FIG. 9