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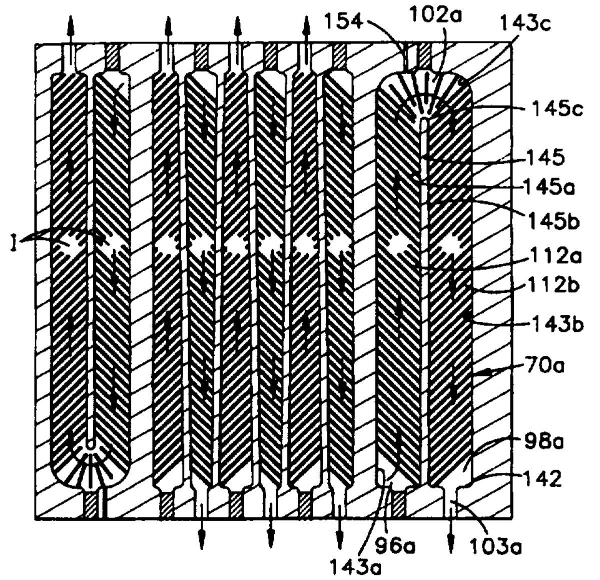
(54) Title: CONFIGURATION OF THE BENT PARTS OF SERPENTINE COOLING CHANNELS FOR TURBINE SHROUDS

(57) Abstract

A turbine shroud segment for use in a gas turbine engine includes a serpentine channel along at least one axial edge of the segment. Various construction details are developed that disclose a channel for efficiently flowing cooling fluid through an axial edge of a shroud segment. In a particular embodiment, a turbine shroud segment includes a leading edge serpentine channel having a bend passage which includes a purge hole to avoid separating flow in the bend passage.



Description

CONFIGURATION OF THE BENT PARTS OF SERPENTINE COOLING CHANNELS FOR TURBINE SHROUDS

Cross Reference to Related Application

The subject matter of this application is related to U.S. Patent Application Serial No. 08/220,316, filed March 30, 1994, entitled "Turbine Shroud Segment With Serpentine Cooling Channels" by Thompson and Kane and assigned to the assignee of the present application.

Technical Field

This invention relates to gas turbine engines, and more specifically to turbine shroud segments for such engines.

Background of the Invention

Axial flow gas turbine engines include a compressor, a combustor, and a turbine spaced sequentially along a longitudinal axis. An annular flow path extends axially through the compressor, combustor and turbine. The compressor includes an array of rotating blades that engage incoming working fluid to compress the working fluid. A portion of the compressed working fluid enters the combustor where it is mixed with fuel and ignited. The products of combustion or hot gases then flow through the turbine. The turbine includes alternating arrays of vanes and rotating blades. In the turbine, energy is transferred from the flowing hot gases to the turbine blades. A portion of this energy is then transferred back to the compressor section via a rotor shaft.

To optimize the efficiency of the interaction between the turbine blades and the hot gases flowing through the turbine, the hot gases are confined to an annular space by inner and outer turbine shrouds. The inner turbine shroud is typically a plurality of platforms integral to the blades. The platforms mate with platforms of adjacent blades to form an inner flow surface for the hot gases. The outer shroud is typically a ring-like assembly disposed radially outward of, but in close radial proximity to, the outer tips of the rotating blades. The outer shroud includes a plurality of arcuate segments spaced circumferentially to provide an outer flow surface for the hot gases.

Since the shroud segments are in direct contact with the hot gases, some form of cooling is required to maintain the shroud segments within acceptable temperature limits. Cooling methods have included impingement cooling, by injecting cooling fluid onto the radially outward or back side of the shroud segment, and film cooling, by forming cooling holes through the shroud segment that produce a film of cooling fluid over the flow surface of the shroud segment. The problem is made more difficult because the shroud is a non-rotating part in the engine. As a result, the shroud cannot benefit from the rotational effects that are exerted on the cooling fluid, such as occur in a rotor blade. Flow separation is a particular problem in such coolable non-rotating structures.

Although both impingement cooling and film cooling have proven adequate in most situations, advancements in gas turbine engines have resulted in higher temperature gases flowing through the turbine. This hotter working fluid has dictated the need for improved and more efficient cooling methods. One such recently developed method is disclosed in commonly assigned, pending U.S. patent application, Serial No. 07/993,862, entitled "Turbine Blade Outer Air Seal With Optimized Cooling and Method of Fabrication". This application discloses cooling channels extending laterally through the shroud segment in a counter flow array. The channels include inlets in the back side of the shroud segment, exits ejecting cooling fluid into the inter-segment gap, and a taper in the direction of flow through the channels to control the Mach number of the fluid flowing through the channels.

A limitation to all the above arrangements is the ability to provide cooling fluid to the leading edge and trailing edge regions of the shroud segment. Each shroud segment includes retaining means adjacent the leading edge and trailing edge regions to retain the shroud segment into position within the stator structure. The retaining means are typically hooks or rails that extend laterally along the edges and radially outward from the back side of the shroud segment. The hooks and rails present an obstruction to flowing cooling fluid to this region to impinge upon the back side near the edges. Although film cooling passages may be angled to direct cooling fluid partially into these regions, forming film cooling passages at angles shallow enough to provide complete coverage is impractical. Finally, the hooks and rails prevent direct injection of cooling fluid into lateral channels under the hooks and rails and would require a cavity to extend from the back side, under the hooks and rails and over the leading edge and trailing edge regions. The latter would extend the hooks and rails further outward from the shroud segments, adding weight and stiffness to the shroud segments.

One solution is to provide a serpentine channel in the shroud segment. The serpentine channel extends along at least one of the axial edges of the segment. The serpentine channel includes an inner passage, an outer passage and a duct. The outer passage is nearest the edge and is in fluid communication through a bend passage with the inner passage. The bend passage has an upstream turn portion and a downstream turn portion. Each turn portion has an outer radius and an inner radius which bound the bend passage. The duct extends to the inner passage from an opening in the back side of the segment to permit cooling fluid to flow into and through the serpentine passage.

The feature of the serpentine channel results in convective cooling of the edge of the segment. Since this region of the segment is outward of a retaining means, such as a hook or rail, the typical methods of impingement cooling and/or film cooling are not available to this region. The retaining means presents an obstruction to getting cooling fluid into this region. The duct provides means to flow cooling fluid into the serpentine channel, which flows through the serpentine channel to the edge before exiting.

The above art notwithstanding, scientists and engineers under the direction of Applicants' Assignee are working to develop efficiently cooled turbine shroud segments for gas turbine engines.

Disclosure of Invention

This invention is in part predicated on the recognition that separation of flow can occur in the bend passage of a serpentine channel in those constructions in which the outer radius of the bend passage is much greater than the inner radius of the bend passage. The flow separation has an adverse impact on the ability of the cooling fluid to cool all portions of the shroud segment adjacent the serpentine channel.

According to the present invention, a bend passage for a serpentine channel of a turbine shroud segment includes a purge hole which extends from the bend passage to the exterior of the turbine shroud segment to draw cooling fluid into critical regions of the bend passage to block flow separation in the outer radius region of the bend passage.

In accordance with the present invention, a rib extends laterally between the outer passage and the inner passage to separate the passages, a plurality of trip strips extend from the rib in the inner passage in the downstream direction and extend in the outer passage from the rib in the upstream direction, and a plurality of trip strips are disposed in the bend passage in a fan shaped pattern and spaced from the rib to provide turbulent flow without blocking the fluid from flowing through part of the bend passage.

In accordance with one detailed embodiment of the invention, the bend passage has an upstream turn region having an outer radius which is approximately ten times the radius of the rib which bounds the inner radius of the bend passage. The purge hole is downstream of the upstream turn region of the bend passage.

A primary feature of the present invention is a serpentine channel having a bend passage. The bend passage has an upstream turn and a downstream turn. Another feature is a purge hole disposed downstream of the upstream turn in the bend passage. In one detailed embodiment, the trip strips extend toward the bend passage from a rib separating the outer passage from the inner passage in both the outside passage and the inside passage.

A primary advantage of the present invention is the durability of a turbine shroud segment which results from providing adequate cooling to critical regions of the shroud segment by using a serpentine channel and blocking separation in a bend passage of the serpentine channel through use of a purge hole. Another advantage of the present invention is the durability of the turbine shroud segment which results from providing adequate cooling through the use of trip strips and avoiding the blockage of flow to critical locations in the bend passage by providing spacing of the trip strips from the rib separating the inner passage from the outer passage.

The foregoing and other objects, features and advantages of the present invention become more apparent in light of the following detailed description of the exemplary embodiments thereof, as illustrated in the accompanying drawings.

Brief Description of the Drawings

FIG. 1 is a side view, partially cut away, of a gas turbine engine.

FIG. 2 is a side view of a turbine having stator assembly including a turbine shroud assembly.

FIG. 3 is a side view of a shroud segment, with the dashed lines representing cooling channels.

FIG. 4 is sectioned top view of the shroud segment, cut away to show the serpentine passages and the lateral passages.

FIG. 5 is a top view of the shroud segment showing the inlets for the cooling channels.

FIG. 6 is a top view of a portion of the shroud segment showing a serpentine channel that tapers in the downstream direction.

FIG. 7 is a side view of an alternate embodiment of the shroud segment shown in FIG. 3, with the dashed lines representing cooling channels.

FIG. 8 is a sectioned top view of the shroud segment shown in FIG. 3, cut away to show the serpentine passages, the lateral outside and inside passages and a bend passage connecting the lateral passages.

FIG. 9 is a top view of an enlarged portion of the shroud segment shown in FIG. 8 showing the bend passage which connects the outside passage with the inside passage.

Best Mode for Carrying Out the Invention

A gas turbine engine 12 is illustrated in FIG. 1. The gas turbine engine 12 includes an annular flow path 14 disposed about a longitudinal axis 16. A compressor 18, combustor 22 and turbine 24 are spaced along the axis with the flow path 14 extending sequentially through each of them. The turbine 24 includes a plurality of rotor assemblies 26 that engage working fluid flowing through the flow path 14 to transfer energy from the flowing working fluid to the rotor assemblies 26. A portion of this energy is transferred back to the compressor 18, via a pair of rotating shafts 28 interconnecting the turbine 24 and compressor 18, to provide energy to compress working fluid entering the compressor 18.

Referring now to FIG. 2, a rotor assembly 32 is axially positioned between an upstream vane assembly 34 and a downstream vane assembly 36. The rotor assembly 32 includes a rotating disk 38 having a plurality of rotor blades 42 extending radially therefrom. Each of the rotating blades 42 includes a root portion 44, an airfoil portion 46 having a tip 48, and an inner platform 52. The root portion 44 retains the blade 42 to the disk 38 during rotation of the rotor assembly 32. The airfoil portion 46 extends radially through the flow path 14 and provides a flow surface 54 to engage the working fluid flowing through the turbine 24. The inner platform 52 extends laterally from the blade 42 and mates with the platforms of circumferentially adjacent blades to define a radially inner flow surface 56. The radially inner flow surface 56 urges the flowing working fluid to over the flow surface 54 of the airfoil portion 46.

A turbine shroud 58 extends circumferentially about and radially outward of the rotor assembly 32. The tips 48 of the rotating blades 42 are in close radial proximity to a radially outer flow surface 62 defined by the turbine shroud 58. The flow surface 62 discourages the working fluid from flowing radially outward and urges the working fluid to flow over the flow surface 54 of the airfoil portion 46. The flow surface 62 of the turbine shroud 58 and the flow surface 56 of the platforms 52 in conjunction confine the working fluid into an annular passage through which the blades 42 extend to optimize engagement between the working fluid and rotating blades 42.

The turbine shroud 58 includes a plurality of shroud segments 64 spaced circumferentially about the flow path 14 and means to flow cooling fluid onto the outward surfaces 66 of the segments 64.. As shown in FIGs. 3 to 5, each shroud segment 64 includes a substrate 68 having a plurality of hooks 72 and a coating layer 74. The hooks 72 provide means to retain the shroud segment 64 to the adjacent structure of the turbine shroud 58. The coating layer 74 is a combination of a thermal barrier coating, to insulate the segment from the hot gases flowing through the turbine, and an abradable coating, to engage the tips of the rotor blades during rotation of the rotor assembly.

Each segment 64 includes a plurality of cooling channels 76 extending through the substrate 68. The plurality of channels 76 includes a serpentine channel 78 along the leading edge of the segment 64, another serpentine channel 82 along the trailing edge of the segment 64, and a plurality of lateral channels 84 therebetween. The serpentine channel 78 is in fluid communication with the outward surface of the segment 64 via a duct 86 having an inlet 88 in the outward surface. The inlet 88 is located immediately inward of the leading edge hooks 72 such that the duct 86 extends under the hooks 72. The duct 86 provides a convenient mechanism to flow cooling fluid into the serpentine channel 78 without disrupting the sealing along the leading edge and without extending the hooks 72 outward from the substrate 68 as would be necessary if a cavity was extended under the hooks 72. The trailing edge serpentine channel 82 is similar to the leading edge serpentine channel 78 and includes a duct 92 having an inlet 94.

The serpentine channel 78 includes a first passage 96, a second passage 98 outward of the first passage 96, a bend passage 102 interconnecting the two passages 96,98, and an exit 103. The serpentine channel 82 along the trailing edge is similar to serpentine channel 78 in that it includes a first passage 104, a second passage 106, a bend 108 interconnecting the two passages 104, 106, and an exit 109. Both of the serpentine channels 78,82 include trip strips 112 distributed throughout the lengths of the channels 78,82. The trip strips 102 provide means disturb the flow and produce regenerative turbulent flow through the channels 78,82 to increase heat transfer between the substrate 68 and the fluid flowing within the channels 78,82.

The lateral channels 84 extend laterally between the pairs of hooks 72 and include a first set of lateral channels 114 and a second set of lateral channels 116. The first set of lateral channels 114 have inlets 118 in the outward surface located along one lateral edge 119 of the segment 64 and exits 122 in the opposite lateral edge 120 of the segment 64. The second set of lateral channels 116 include inlets 124 in the outward surface located along lateral edge 120 and exits 126 located in the opposite lateral edge 120. The first set 114 and second set 116 are interposed with each other such that each lateral channel 84 shares a common divider wall 128 with one of the lateral channels 84 of the other set. As with the serpentine channels 78,82, the lateral channels include trip strips 132 distributed along the lengths of the channels 84 to produce a regenerative flow within the lateral channels 84. In addition, the lateral channels 84 taper from the inlet end to the exit end to control the Reynolds number of the fluid flow within the lateral channels 84. Increasing the Reynolds number also increases the heat transfer between the substrate and the fluid flowing within the channel.

Although the serpentine channels are shown as having generally constant area cross sections, the use of tapered channels to control the Reynolds number of the fluid flowing within the serpentine channels may be used. In current applications, however, it is not thought to be necessary to control the Reynolds number within the channels along the leading and trailing edge of the segments. Some applications may require this feature, illustrated in FIG. 6, to maximize the heat transfer from the substrate in the region of the leading edge or trailing edge. As shown in FIG. 6, a segment 64' includes a serpentine channel 28' that tapers from the end having a duct 86' to the opposite end.

FIG. 7 is an alternate embodiment 64a of the shroud segment 64 shown in FIG. 3. The alternate embodiment includes a serpentine channel 70a along the leading edge of the segment 64a and a second serpentine channel 82a along the trailing edge of the segment. A plurality of lateral channels 84a are disposed therebetween. The channels are fed radially by cooling air holes such as the holes 86a, 92a and 118a which extend radially from a location inward of the adjacent retaining means 72a. In particular, the serpentine channel 70a is in fluid communication with the outward surface of the segment 64a via the duct 86a having an inlet 88a inwardly of the retaining hooks 72a.

As shown in FIG. 8, the serpentine channel 70a includes the first (inner) passage 96a, and the second (outer) passage 98a outward of the first passage 96a. A bend passage 102a interconnects the two passages 96a, 98a. The serpentine channel has an exit 103a at the downstream end 142 of the outer passage. The inner passage has an outer boundary 143a, the outer passage has an outer boundary 143b and the bend passage has an outer boundary 143c.

A rib 145 is spaced axially from the upstream edge of the turbine shroud segment 64a. The rib extends laterally to separate the inner passage 96a from the outer passage 98a and terminates adjacent the bend passage 102a. The rib extends along an inner boundary 145a of the inner passage, an inner boundary 145b of the outer passage and an inner boundary 145c of the bend passage 102a. The rib has a radius R_i at its termination adjacent the bend passage. The rib thus extends along the inner boundary to the bend passage which also has an inner radius R_i. As shown in FIG. 9, the bend passage 102a has an upstream turn region 146 and a downstream turn region 148. The upstream turn region 146 has an outer radius R_{o1} and the downstream turn region 148 has an outer radius R_{o2}. The bend passage has an end region 152. The end region is bounded by the boundary 143c which extends tangent to the upstream turn region 146 and the downstream turn region 148 and in a generally axial direction. The outer radius R_{o1} of the first turn region of the bend passage is at least five times greater than the inner radius R_i of the bend passage (and the rib) and in the embodiment shown is approximately ten times the radius R_i.

A plurality of trip strips 112a are disposed in the inner passage 96a. The trip strips extend from the rib in the downstream direction toward the bend passage. A second plurality of trip strips 112b are disposed in the outer passage 98a. The second plurality of trip strips extend from the rib in the upstream direction toward the bend passage. A plurality of trip strips 112c in the bend passage are oriented in a fan shaped pattern. At least a portion of the trip strips 112c are spaced from the rib 145.

A purge hole 154 is downstream of the upstream turn region of the bend passage. The purge hole places the bend passage of the serpentine channel in flow communication with the exterior of the shroud segment.

During operation, cooling fluid flows through the stator assembly and impinges upon the outward surface of the segments 64. At least a portion of this cooling fluid then flows through the inlets 88,94 of the serpentine channels 78,82 and the inlets 118,122 of the lateral channels 84. The cooling fluid flowing through inlet 88 flows through the duct 86 and into the first serpentine channel 78. This cooling fluid engages the trip strips 112 as it flows through the first passage 96, around the bend passage 102, and through the second passage 98. The cooling fluid exits the second passage 102 through the exit 103. Fluid exiting the second passage 98 flows into the gap between adjacent segments 64, i.e. the inter-segment gap, to purge this gap of the hot gases that may have flowed into the gap. Cooling fluid flowing into inlet 94 flows through the duct 92 and through serpentine channel 82 along the trailing edge in much the same fashion and exits into the inter-segment gap along the opposite lateral edge 119 of the segment 64.

As the flow of cooling fluid enters the bend passage 102a, the trip strips 112c maintain high turbulence and encourage flow around the inner radius of the turn by being spaced from the radius of the rib to provide an open area to encourage flow to enter this region of the bend passage. The purge hole is shown downstream of the first turn of the bend passage which is marked by the outer radius R_{o1}. The purge hole is located so as to draw flow towards the outer radius of the turn. This construction blocks the formation of a region of flow separation and poor heat transfer in the region between the phantom line S and the outer boundary 143c in the end region 152 of the bend passage. Empirical results have shown that this region of separation will form even though the trip strips 112b are canted in the downstream direction away from the rib 145 to drive flow vortices in this direction. Thus, the purge hole draws cooling fluid into that region and thence into the second or downstream turn region 148 of the bend passage shown by the radius R_{o2}. In summary, the provision of the open area adjacent the inner radius R_i of the bend passage and the purge hole 154 downstream of the first turn of the outer radius of the bend passage provide a uniform flow distribution through the bend passage and adequate heat transfer to all regions of the bend passage.

Another portion of the cooling fluid flows into the inlets 118, 124 and flows through the lateral channels 84. Since each of the first set of lateral channels 114 is adjacent to one of the second set of lateral channels 116, the cooling fluid flows in counter directions in adjacent lateral channels 84. The cooling fluid engages the trip strips 132 to produce a regenerative turbulent flow and, as a result of the taper, the Reynolds number of the fluid flow is controlled through the lateral channels 84. Cooling fluid exits the lateral channels 84 through the exits 122,126 and into the inter-segment gaps on either side of the segment 64 to purge the inter-segment gaps of gas path fluid.

Distributing the channels 78,82,84 through the substrate 68, including into the leading edge and trailing edge regions, results in minimizing the occurrence of hot spots in the substrate 64. In addition, the inter-segment purge of the fluid exiting the exits 103,109,122,126 reduces the likelihood of hot gases flowing into or remaining within the inter-segment gap to cause damage to the lateral edges 119,120 of the segments 64.

Having such serpentine channels 78,82 efficiently utilizes the cooling fluid directed into the leading edge and trailing edge regions of the substrate 64. These areas are under lower heat loads, relative to the blade passing region of the segment 64, as a result of the blade pumping effect of the rotating blades 42. Blade pumping urges working fluid to flow outward and onto the segment 64 in the blade passing region. Although the leading edge is upstream of the blades 42 and is in an area of the flow path 14 having gas path fluid with the highest temperature, cooling fluid leaking around the leading edge of the segments 64 produces a film of cooling fluid over the leading edge region (as shown by arrow 134 in FIG. 2). The trailing edge region is downstream of the rotating blades 42 and is exposed to gas path fluid that has had energy removed from it by the rotating blades 42. Therefore, the leading edge and trailing edge regions require less cooling than the blade passing region of the segment 64, and the serpentine channels 78,82, which efficiently utilize cooling fluid, may be used in these regions.

The segments 64 may be fabricated by casting. This procedure includes the steps of forming a core to represent the channels 78,82,84 and casting the substrate 68 about the core. The core is supported by support rods that interrupt the continuity of the trip strips at locations I. After the casting step is complete, the casting holes, present along the lateral edges as a result of the core supports used to hold the channel cores during casting, may be filled, except for those to be used as exits. The inlets 88,94,118,124 and ducts 86,92 are formed in the outward surface in a conventional fashion, such as by electric discharge machining. The hooks 72 and seal lands are machined onto the substrate 68 and the coating layer 74 is then applied to the flow surface.

Although the invention has been shown and described with respect with exemplary embodiments thereof, it should be understood by those skilled in the art that various changes, omissions, and additions may be made thereto, without departing from the spirit and scope of the invention.

Claims

What is claimed is:

1. A shroud segment for a gas turbine engine having an annular flow path disposed about a longitudinal axis, a rotor assembly having a plurality of rotor blades extending radially through the flow path, and a shroud assembly including a plurality of the shroud segments being spaced circumferentially to define a flow surface radially outward of the rotor blades to bound a portion of the flow path, and means to inject cooling fluid onto the plurality of shroud segments, the shroud segment including a first surface, a back side disposed opposite of the first surface, a pair of axial edges defining a leading edge and a trailing edge, first retaining means adjacent the leading edge and extending from the back side, second retaining means adjacent the trailing edge and extending from the back side, and a serpentine channel including an outer passage extending along one of the edges and outward of the retaining means extending adjacent that edge, an inner passage being inward of the outer passage and a bend passage which extends between the outer passage and the inner passage to place the inner passage in fluid communication with the outer passage, a purge hole which extends from the bend passage to the exterior of the shroud segment to discharge cooling fluid from the bend passage, and a duct extending to the inner passage from a location inward of the adjacent retaining means, the duct permitting fluid communication between the back side of the shroud segment and the serpentine channel such that a portion of the cooling fluid injected onto the back side flows through the serpentine channel, wherein cooling fluid drawn toward the purge hole under operative conditions blocks separation of the cooling fluid in the bend passage.

2. The shroud segment as claimed in Claim 1, wherein the bend passage has an upstream turn region having an outer radius R_{o1} and an inner radius R_{i1} and a downstream turn region having an outer radius R_{o2} and an inner radius R_i and wherein the purge hole is disposed between the upstream turn region and the downstream turn region.

3. The shroud segment as claimed in Claim 2, wherein a plurality of trip strips are disposed in the bend passage in a fan shaped pattern.

4. The shroud segment as claimed in Claim 3, wherein a portion of the bend passage has an outer boundary having the radius R_{o1} and an inner boundary having the radius R_{i1} and wherein at least one of said trip strips in the bend passage is spaced from the outer boundary and the inner boundary.

5. The shroud segment as claimed in Claim 4, wherein the plurality of trip strips are spaced from the inner boundary.

6. The shroud segment according to Claim 1, wherein the serpentine channel includes an exit disposed along a lateral edge of the segment, the exit extending between and providing fluid communication between the lateral edge and the outer passage.

7. The shroud segment according to Claim 1, further including a second serpentine channel including an outer passage extending along the opposite edge and outward of the retaining means extending adjacent that edge, an inner passage being inward of the outer passage, and a duct extending to the inner passage from a location inward of the adjacent retaining means, the duct permitting fluid communication between the back side of the shroud segment and the second serpentine channel such that a portion of the cooling fluid injected onto the back side flows through the second serpentine channel.

8. The shroud segment according to Claim 1, further including a plurality of lateral channels extending laterally through the segment, the plurality of lateral channels located inward of the first and second retaining means, each of the lateral channels separated from an adjacent lateral channel by a wall therebetween, each of the lateral channels having an inlet disposed in the back side of the shroud segment and an exit disposed in a lateral edge of the segment, the inlet permitting fluid communication between the back side of the shroud segment and the lateral channels such that a portion of the cooling fluid injected onto the back side flows

through the lateral channels and exits the lateral channels along the lateral edge of the shroud segment.

9. A shroud segment for a gas turbine engine having an annular flow path disposed about a longitudinal axis, a rotor assembly having a plurality of rotor blades extending radially through the flow path, and a shroud assembly including a plurality of the shroud segments being spaced circumferentially to define a flow surface radially outward of the rotor blades to bound a portion of the flow path, and means to inject cooling fluid onto the plurality of shroud segments, which comprises:

a shroud segment including a first surface, a back side disposed oppositely of the first surface, a pair of axial edges defining a leading edge and a trailing edge, first retaining means adjacent the leading edge and extending from the back side,

the shroud segment including a serpentine channel including an outer passage having a downstream end, the outer passage extending along one of the edges and outward of the retaining means and extending adjacent that edge, an inner passage having an upstream end being inward of the outer passage, and a bend passage which extends between the outer passage and the inner passage to place the outer passage in flow communication with the inner passage,

a rib which is spaced axially from the edge and which extends laterally to separate the inner passage from the outer passage and which terminates adjacent the bend passage, the rib having a radius R_i adjacent the bend passage and the bend passage having an upstream turn region having an outer radius R_{o1} which is at least five times greater than the radius R_i,

a plurality of trip strips disposed in the inner passage which extend from the rib in the downstream direction toward the bend passage,

a plurality of trip strips disposed in the outer passage which extend from the rib in the upstream direction toward the bend passage, a plurality of trip strips in the bend passage which are oriented in a fan shaped pattern and at least a portion of which are spaced from the rib,

a purge hole downstream of the upstream turn region in the bend passage which places the serpentine passage in flow communication with the exterior of the shroud segment;

a duct extending to the inner passage from a location inward of the adjacent retaining means, the duct permitting fluid communication between the back side of the shroud segment and the serpentine channel such that a portion of the cooling fluid injected onto the back side flows through the serpentine channel;

wherein cooling fluid is drawn toward the purge hole under operative conditions and through the outer radius of the bend passage to decrease flow separation in the outer portion of the bend passage.

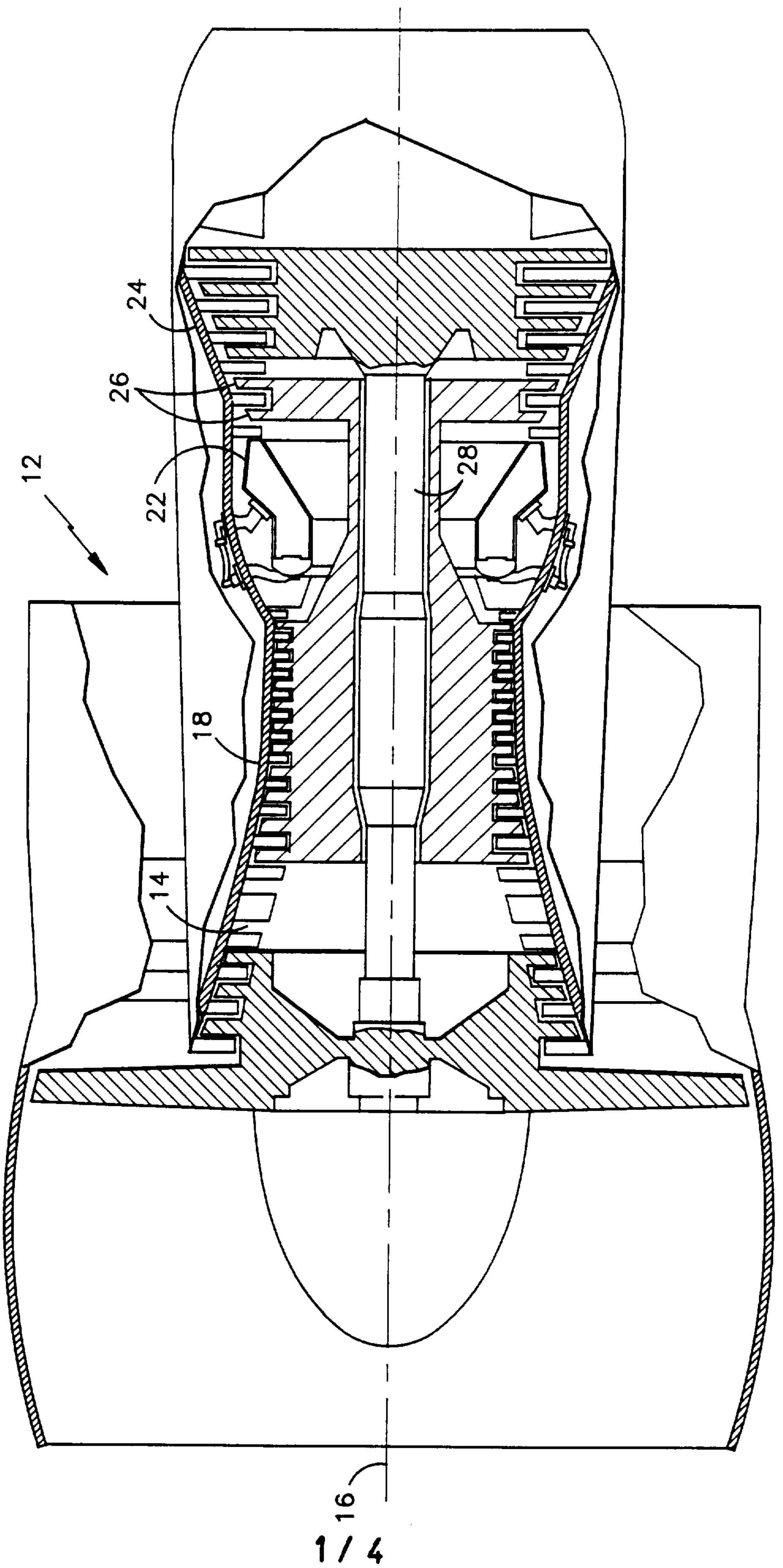


fig. 1

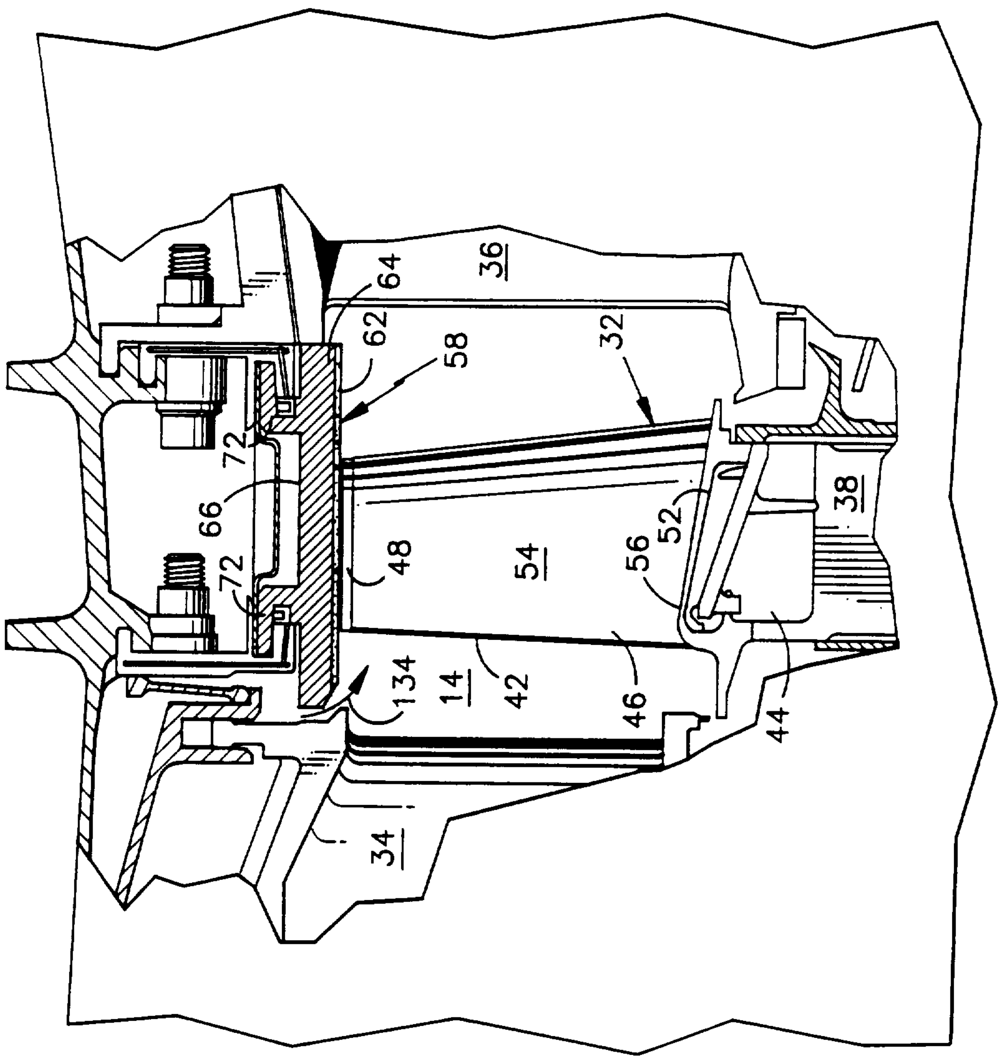


fig.2

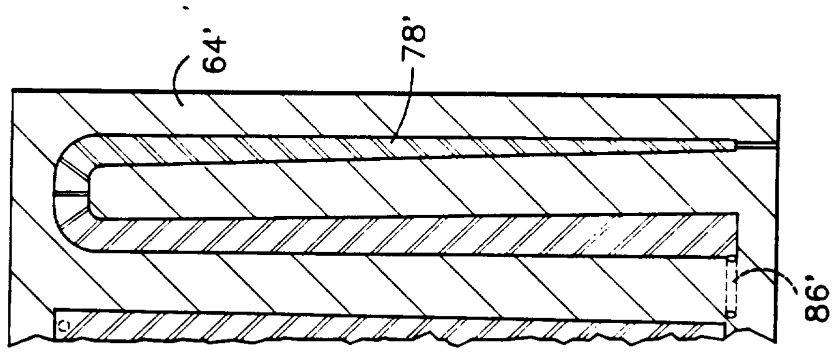


fig.6

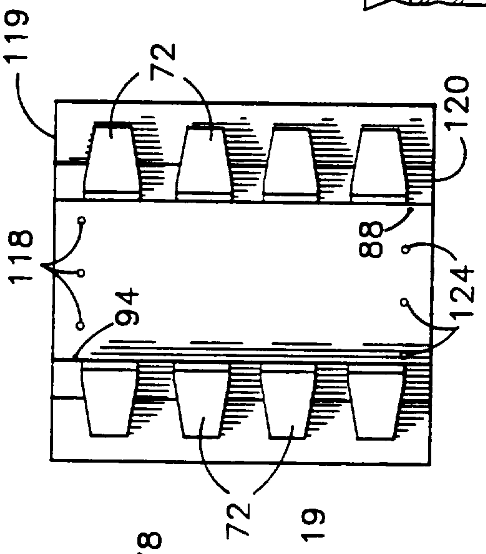


fig.5

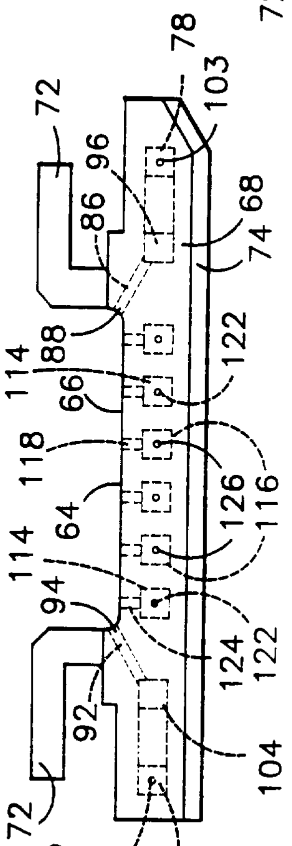


fig.3

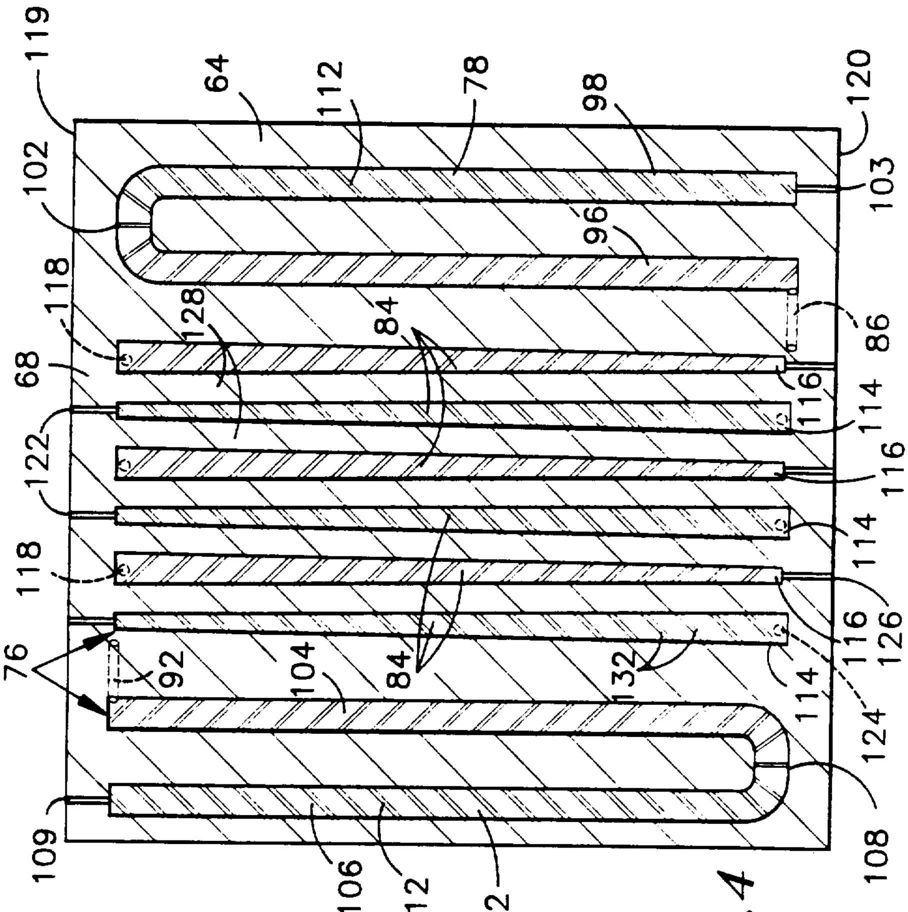


fig.4

fig.7

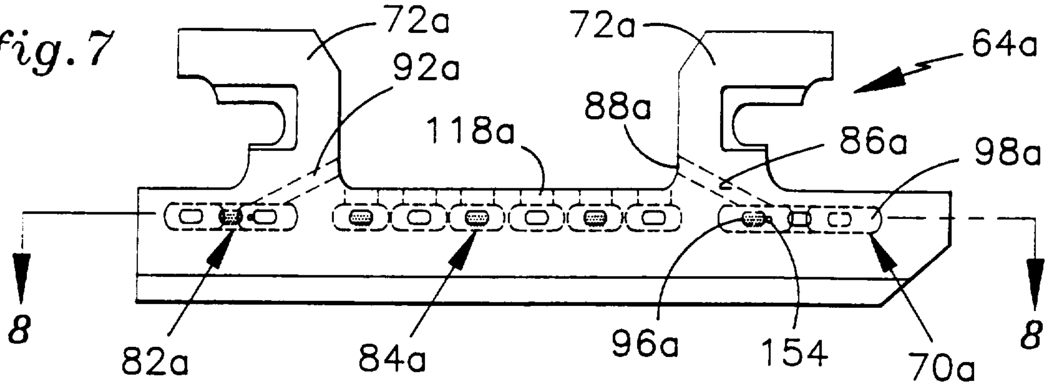


fig.8

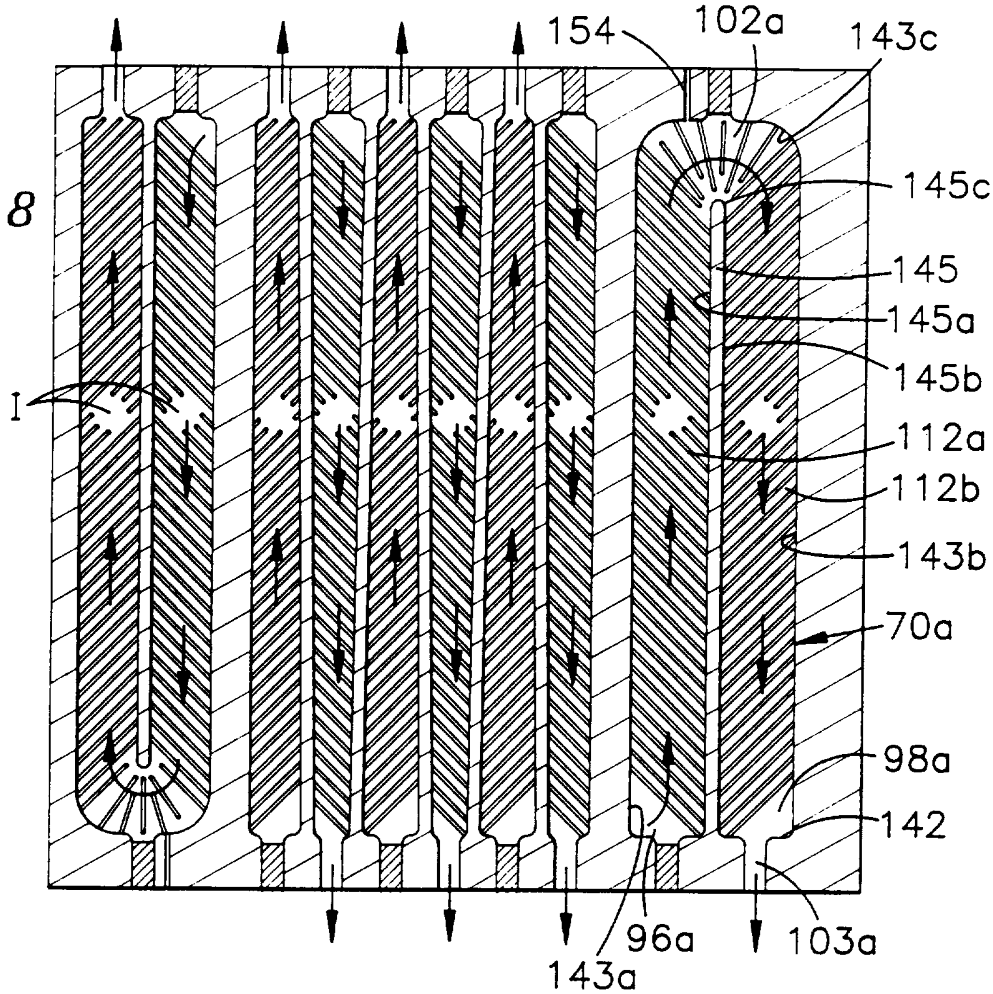
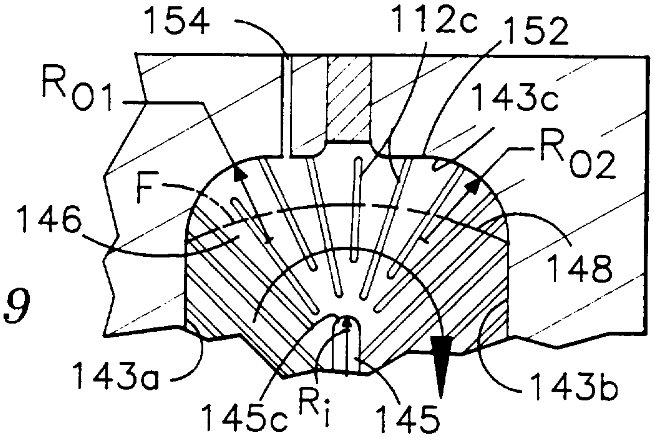


fig.9



INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F01D25/12 F01D11/08

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)
IPC 6 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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	WO,A,95 27126 (UNITED TECHNOLOGIES CORP) 12 October 1995 cited in the application see the whole document -----	1-9

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 May 1996	11. 06. 96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Iverus, D

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inten nal Application No
PCT/US 96/00426

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9527126	12-10-95	US-A- 5486090	23-01-96