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[54] **COOLING FILM PROMOTER FOR COMBUSTION CHAMBERS**

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[52] **U.S. Cl.** **60/39.65,** 60/39.66, 431/352

[51] **Int. Cl.** **F02c 7/18**

[58] **Field of Search** 60/39.65, 39.66, 265, 264; 431/352

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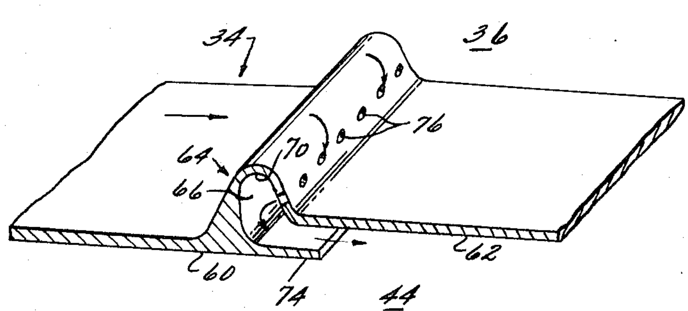
[57] **ABSTRACT**

A combustion chamber is provided with a cooling film promoter for passing cool fluid from a surrounding plenum in a protective film barrier upon a liner partially defining a hot gas passage. The combustion chamber liner defines a pocket at a position spaced from the hot gas passage. Means are provided for passing the cool fluid from the plenum to the pocket and from the pocket in a protective film upon the heated side of the liner downstream from the pocket. In order to form a substantially homogeneous circumferential cool air flow (thereby preventing aspiration of hot gases and direct contact thereof with the liner) the pocket includes means for diffusing the cool fluid flow within the pocket prior to passing the fluid from the exit. The means for diffusing can have a variety of configurations, notably means for reversing fluid flow within the pocket and a baffle for turning the fluid prior to exit.

11 Claims, 10 Drawing Figures



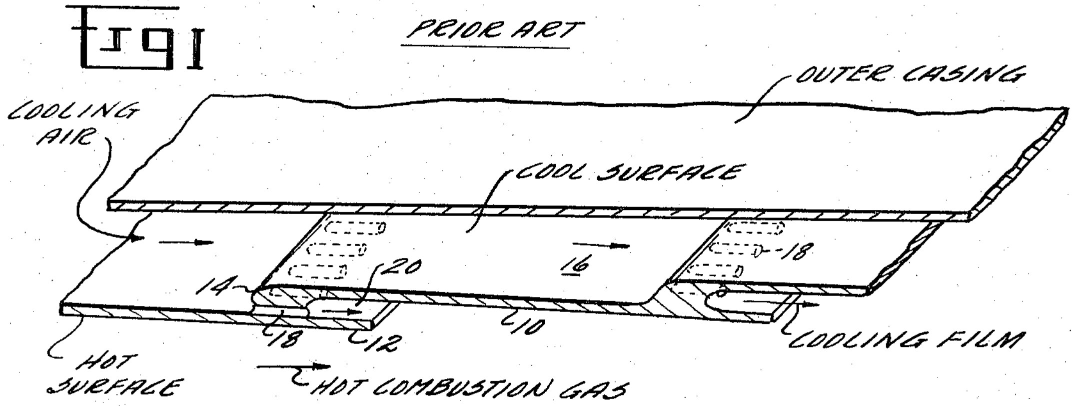


FIG 1

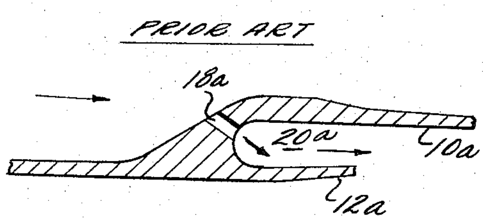


FIG 1a

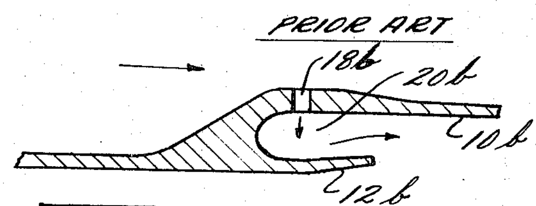


FIG 1b

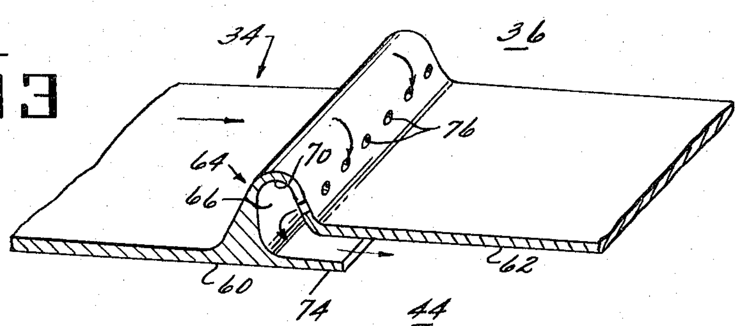


FIG 3

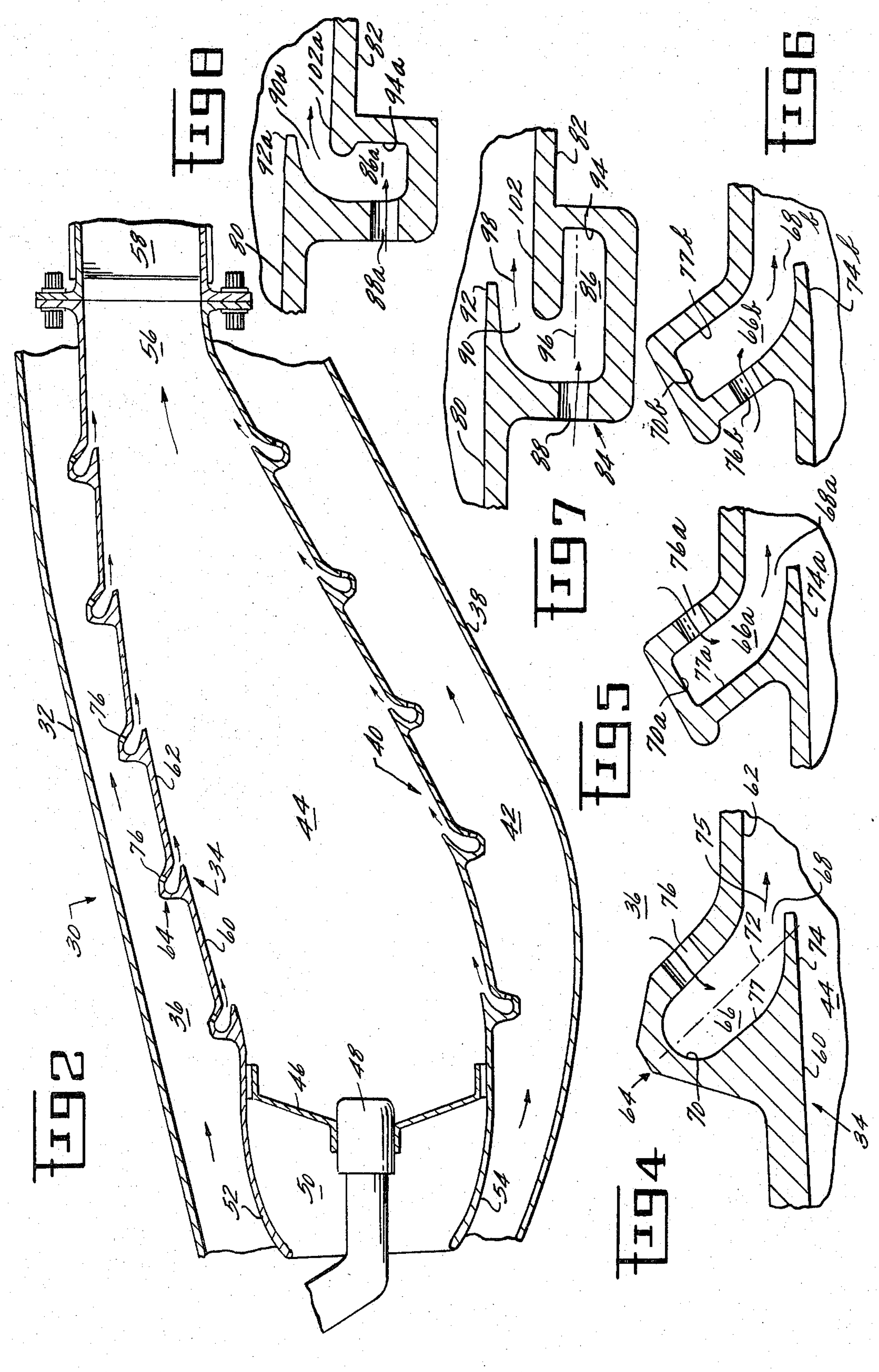


Fig 2
Fig 4
Fig 5
Fig 6
Fig 7
Fig 8

COOLING FILM PROMOTER FOR COMBUSTION CHAMBERS

BACKGROUND OF THE INVENTION

This invention relates to combustion chambers and, more particularly, to means for effectively cooling combustion chambers. The present invention will be discussed in the environment of combustion chambers for use in gas turbine engines; however, the concepts of this invention are broadly applicable to any situation wherein similar combustion chambers are utilized.

The invention herein described was made in the course of or under a contract, or a subcontract thereunder, with the United States Department of the Air Force.

Development of high temperature operating cycles within gas turbine engines has put increased emphasis upon the development of combustion chambers capable of withstanding extremely high temperatures. Improvements in liner alloys and other combustion chamber materials has aided in this quest. To further enhance combustion chamber dependability, efficient and reliable means for cooling combustion chamber liners are necessary.

To date, the most efficient combustion chamber cooling techniques have involved, in part, the formation of a protective film boundary of cool air or other cooling fluid between the hot gases of combustion and the liner portions forming and defining the combustion chamber. Typically, a combustion chamber liner defining a combustion zone also partially defines a cool fluid plenum usually circumscribing the combustion zone. Means are commonly provided for transferring a portion of the cool fluid from the plenum into the combustion zone to form the protective film barrier.

In order to accomplish effective film propagation, means must be provided for directing the fluid in a film upon the liner inner surface. This means must effectively perform "attachment" (that is, the disposition of the fluid in a boundary layer immediately adjacent the liner to be protected) without aspirating or entraining hot gases from the combustion zone. Such entrainment would negate the effectiveness of the film cooling by creating a turbulent interchange whereby hot gases of combustion would directly impinge the liner.

Effective attachment requires substantially uniform velocity cool fluid flow from the source of the film circumferentially about the liner in order to avoid excessive turbulence as well as spaced hot streaks or hot spots which naturally arise in the absence of uniform film protection. At the same time, the means for transferring cool fluid from the surrounding plenum to the liner has, in the past, commonly taken the form of a plurality of spaced apertures circumferentially disposed about the liner. These apertures are used for a number of reasons. One such reason is that large mechanical stresses upon the liner require substantial mechanical strength and thus prevent a more homogeneous transfer system, such as a continuous circumferential slot or the like. Also the apertures provide a more accurate metering device than does a uniform slot.

As a result, it has become common to utilize a relatively long, axially-extending, overhanging lip to direct the fluid upon the heated side of the liner and to give the fluid an opportunity to coalesce from individual jets into a substantially uniform circumferential velocity. While this extended overhanging lip has performed relatively well with respect to avoiding aspiration and providing attachment, there has been an unfortunate structural repercussion of this design in that, under the thermal stresses associated with combustion, the lip has often become warped and structurally incapable of continuing its proper function.

The present invention alleviates these problems by providing a mechanism for substantially diffusing and coalescing the velocities of cool fluid entering through spaced, circumferential apertures from a plenum while contemporaneously enabling the use of a substantially shorter overhanging lip.

BRIEF SUMMARY OF THE INVENTION

It is therefore a primary object of the present invention to provide a cooling film promoter for use with combustion chambers which permits the utilization of a reduced length overhanging lip and which effectively achieves attachment of a low turbulence boundary layer barrier of cool fluid by providing for diffusion of fluid velocity prior to engagement with the overhanging lip.

In order to accomplish this and other objects which will become apparent from the detailed description hereinafter, the present invention, in one embodiment thereof, provides a combustion chamber liner which comprises a number of sections, the sections combining to define a diffusion pocket through which cool fluid passes from a circumscribing cool air plenum before reaching the heated liner surfaces to be protected. The pocket is disposed and oriented with respect to the pocket entrance apertures in such a way that the cool fluid is directed initially against an opposed surface and is required to substantially reverse its direction of flow from the inlet apertures before reaching an exit from the pocket for passage onto the overhanging lip. In an alternative embodiment, the velocity of the incoming cool fluid is diffused within the pocket by the imposition of a baffle around which the fluid must flow between the inlet apertures and the pocket exit. In both embodiments, the substantial portion of the pocket is offset from the direction imparted to the cooling film by the overhanging lip by either an angular orientation or a radial spacing, and the entrance apertures are arranged so that the incoming cool fluid must occupy the pocket prior to reaching the pocket exit for disposition upon the overhanging lip.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts a combustor liner having an elongated overhanging lip according to the prior art;

FIG. 1*a* depicts a variation of FIG. 1 illustrating a second prior art device;

FIG. 1*b* illustrates a further prior art variation;

FIG. 2 depicts a cross-sectional view of a combustor incorporating a combustor liner according to the present invention;

FIG. 3 is an enlarged perspective view of a portion of FIG. 2;

FIG. 4 is an enlarged cross-sectional view of a portion of FIG. 2;

FIG. 5 is an enlarged cross-sectional view of a portion of a combustor similar to that in FIG. 2 but with a modified version of the present invention;

FIG. 6 is similar to FIG. 4, but with a different variation of the present invention;

FIG. 7 is a view similar to that in FIG. 4, but showing another variation of the present invention; and

FIG. 8 is a view similar to that in FIG. 4, but showing still another variation of the present invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

A prior art cooling film promoter, disposed adjacent the heated combustion zone of a combustion chamber, is depicted in FIG. 1. It involves liner segments 10 to be protected; a relatively long overhanging lip 12 extending axially in an overlapping fashion with respect to an upstream portion of each segment 10; a substantially annular junction 14 between axially adjacent liner segments 10; a plenum 16 substantially surrounding the liner segments; and a plurality of apertures 18 providing communication between the plenum and the heated side of liner segments 10.

Due to the plurality of apertures 18, the cooling air entering the heated chamber does so in a plurality of circumferentially spaced jets with the result that fluid velocity distribution is uneven in the circumferential direction. As a consequence of this velocity distribution, the overhanging lip 12 must be extended substantially in the axial direction downstream of apertures 18 to provide a space 20 between itself and the radially adjacent liner segment 10. This space 20 is protected by the lip from aspiration of the hot gases of the combustion chamber and provides an area for the cool fluid to coalesce by virtue of frictional engagement with wall 16 and lip 12 and to thereafter achieve attachment.

FIGS. 1*a* and 1*b* depict alternative prior art devices for bringing substantially uniform circumferential fluid velocities into existence prior to disposition of a film barrier onto the liner. In FIG. 1*a* the inlet apertures 18*a* are angled so that cool fluid from the plenum is directed against lip 12*a*, to a degree, so that buffetting of the fluid against the lip reduces velocity gradients. Subsequently, the fluid is directed along the lip within space 20*a* where frictional forces supplement the coalescence.

FIG. 1*b* differs from 1*a* in the angle of apertures 18*b* with respect to lip 12*b*. Here, the cool fluid from the plenum impinges directly against lip 12*b* to further aid in the removal of circumferential velocity gradients. Thereafter, once again, the fluid is directed along space 20*b* where frictional engagement with lip 12*b* and liner segment 10*b* develop a fairly uniform circumferential velocity profile.

The major drawback of each of these three prior art embodiments resides in the use of the space between the overhanging lip and associated liner segment to perform the function of removing velocity gradients from the cool fluid. The reason this is a drawback is that the mechanism of friction between the fluid and respective lip and liner surfaces requires a predetermined substantial length within which to act for its effect to be felt. Hence, the lip must be long.

As stated hereinabove, the length of lip 12 detracts from its structural integrity and often leads to undesirable buckling owing to the effects of thermal stress. However, the prior art requires this extent of lip 12, as stated, because of the danger of aspiration of hot gases and consequent breakdown of the protective film barrier.

Referring now to the remaining Figures, the present invention will be described. FIG. 2 depicts a combustion chamber designated generally 30 and illustrating the relationship of the present invention to substantially typical combustion chambers of the gas turbine engine variety. An outer liner 32 combines with an axially segmented liner 34 to define an outer plenum 36. An inner liner 38 combines with an inner portion of the combustion zone liner 40 for the purpose of defining a radially inner cooling fluid plenum 42. The combustion zone itself is designated 44 and is defined by liners 34 and 40 as well as by an upstream dome 46 which cooperates with a fuel nozzle 48 through which the fuel for combustion is directed into the combustion zone. An air/fuel inlet 50 is defined between axial extensions 52 and 54 of liners 34 and 40, respectively.

In general operation, the combustion chamber described is substantially similar to those in present use. A flow of atmospheric air is pressurized by means of a compressor (not shown) upstream of the combustion zone 44 with the compressor discharge directed partially into plena 36 and 42 as well as into the fuel/air inlet 50. A quantity of fuel is mixed with the portion of air entering fuel/air inlet 50 and is ignited within combustion zone 44. The rapid expansion of the burning gases and the configuration of liners 34 and 40 results in the gases being forced from combustion zone 44 through an outlet 56 and into engagement with a turbine 58. Rotary portions of the turbine are driven by this exiting fluid and a portion of the energy thereof serves to drive the upstream compressor through an interconnecting shaft. The remaining energy of the gas stream provides a driving thrust to the left in FIG. 2.

The cooling of liners 34 and 40 is the subject of the present invention, and will be described with respect to the remaining figures. FIG. 3 illustrates a pictorial representation of a section liner 34 illustrating one embodiment of the present invention, that same embodiment being illustrated in an enlarged view in FIG. 4. The figures show that liner 34 is divided substantially into a number of axially adjacent segments. A typical segment 60 can be seen to be in telescopic cooperation with a typical downstream segment 62 by means of a junction designated generally 64. At this junction is disposed a configuration which, in substance, comprises a cooling film promoter for passing cool fluid from plenum 36 in a protective film barrier upon the liner 34 which partially defines a hot gas passage (the combustion zone 44). Segment 60 can be seen to partially define the plenum 36 as well as the combustion zone 44. Segment 62, likewise, partially defines the plenum and the hot gas passage, and these liner segments cooperate to form a pocket 66 having a substantially downstream facing exit 68. The pocket, likewise, has an upstream closed end portion 70. The pocket 66 extends circumferentially about liner 34 and thus forms a substantially annular space which is isolated from the combustion zone except for communication through exit 68. In the embodiment depicted in FIGS. 3 and 4, the major portion of pocket 66 lies along an axis 72 angularly offset from the direction 75 finally imparted to fluid exiting the pocket at 68.

For the purpose of giving this final direction to the fluid from the pocket an overhanging lip 74 is provided, this lip being substantially shorter in axial length than similar lips of the prior art. For this reason, the lip of the present invention (which is able to utilize this shorter axial length due to characteristics of the present invention) is substantially more mechanically reliable and is less prone to warp over extended use than similar lips of the prior art.

The basic function of pocket 66 is to provide an area substantially isolated from the combustion zone and within which velocity diffusion of the cooling fluid may occur. Thus, the fluid may be directed by lip 74 in a cooling and protective film barrier upon liner 34 without the danger of turbulence and aspiration of the hot gases. Further, this is accomplished without the requirement for the relatively long overhanging lip of the prior art.

In order to maintain the structural strength of the liner 34, as well as to help meter an appropriate flow of cooling fluid, the present invention incorporates a plurality of circumferentially spaced apertures 76 which provide a communication between pocket 66 and plenum 64. These apertures provide a transfer means operative to deliver cool fluid (air) from the plenum 36 to the pocket in a plurality of discrete jets such that velocity gradients in the circumferential direction exist, as in the prior art, near the apertures within the pocket. It is gradients similar to these which are the basis for the requirement of the extended lip of the prior art and which, absent this lip, cause hot streaks and permit excessive turbulence and aspiration of the hot gases thus reducing the effectiveness of the protective film barrier.

As stated, the function of the prior art overhanging lip was not only to direct the cool fluid in a film upon the combustor liner, but also to provide an elongated axial space downstream of the cool air inlet associated with that lip so that circumferential gradients of fluid velocity could be reduced by viscous interaction with the lip itself. This was necessary so that the fluid exiting the lip would have a substantially homogeneous circumferential velocity thus reducing the likelihood of excessive turbulence, aspiration and hot streaks. The present invention accomplishes this same purpose by providing means for diffusing the cool fluid flow by a more effective means and in a rapid manner within pocket 66 prior to passing the cool fluid from exit 68 and onto lip 74.

In this first embodiment, the diffusion is accomplished by means of the relative positions of the pocket, apertures 76, wall 77 and exit 68. It can be seen, from FIG. 4, that the apertures 76 are disposed opposite and oriented to open against an opposed wall 77 of the pocket. Moreover, they are disposed between a substantial portion of the pocket 66 (including closed end 70) and the exit 68 relative to the flow direction of the cool fluid. As a result, a portion of the cool fluid entering the pocket through the apertures is first buffetted against wall 77 and then partially reversed in its flow direction by means of engaging closed end 70 prior to passing through the exit 68. This buffetting and flow reversal causes the existent velocity profiles of the fluid entering apertures 76 to be substantially broken down and coalesced or redefined in a substantially homogeneous circumferential formation as the flow leaves the closed end and traverses the length of pocket 66. In this fashion, velocity gradients in the circumferential direction are substantially eliminated by the time the fluid passes through exit 68. Thereafter, the overhanging lip 74 operates to direct the flow (in a substantially uniform circumferential velocity) as a smooth boundary layer against the heated side of the liner segment 62 downstream of the pocket 66.

FIG. 5 illustrates an enlarged cross-sectional view of a second embodiment of the present invention in which a pocket 66*a* is defined. This pocket is similar to pocket 66 of FIG. 4 in all functional respects differing therefrom only in means of fabrication; hence, the different cross-sectional appearance. Once again, in this Figure, the major portion of the pocket lies along an axis angularly offset from the final direction imparted to the cool fluid by the overhanging lip 74*a*. In addition, the pocket has a closed end 70*a* upstream of the exit 68*a* (which opens in a downstream direction); and the transfer means includes a plurality of circumferentially spaced apertures in the liner segment, the apertures disposed downstream of the closed end and upstream of the exit and to the radially outward side of the pocket. As a result, the cool fluid entering the pocket is directed against opposed wall 77*a* and partially upstream prior to encountering the closed end and thereby being directed downstream. In this fashion, this second embodiment provides for substantially homogeneous circumferential velocity distribution prior to engagement of the fluid by lip 74*a*.

The third embodiment depicted in FIG. 6 is the same as that in FIG. 5, except that apertures 76*b* are disposed to the radially inward side of pocket 66*b* but remain downstream of closed end 70*b* and upstream of downstream facing exit 68*b*. Once again, the function is to breakdown and reverse the flow direction of a portion of incoming cool fluid to provide diffusion therefor prior to engagement of overhanging lip 74*b*.

FIG. 7 depicts an embodiment of the present invention substantially different from that in FIG. 4. In FIG. 7, liner segment 80 partially defines the hot gas passage as well as the plenum, and axially downstream segment 82 does likewise. The two segments cooperate at a junction designated generally 84 and thereat form a pocket 86 substantially similar to that in the foregoing embodiments. Means for transferring cool fluid from the plenum to the pocket include apertures 88 spaced circumferentially about the liner at junction 84. A downstream facing exit 90 empties onto a relatively short overhanging lip 92. Pocket 86 forms a substantially annular, axially extending space and lies downstream of apertures 88. Apertures 88 are disposed between the major portion of pocket 86 (and a downstream closed end 94 thereof) and exit 90, relative to fluid flow direction. Furthermore, the major portion of pocket lies upon an axis 96 which is radially spaced from the final direction 98 imparted to the cool fluid by the overhanging lip 92.

In operation, cool air from the surrounding plenum is transferred through apertures 88 and into the pocket 86. Due to the directional orientation of the apertures 88, the air is directed thereby against closed end 94 and the velocities of the plurality of discrete jets of air are broken down. The flow is subsequently reversed in direction and further diffused so that the velocities coalesce. The flow is then directed and turned about baffle 102 prior to reaching exit 90. This turning of the flow further aids in the establishing of a substantially uniform circumferential velocity profile. The flow is finally directed by lip 92 as a film upon liner segment 82.

In this fashion, the cooling film promoter embodiment of FIG. 7 operates to provide a fully attached low turbulence boundary layer to serve as a barrier against the direct exposure of the segments of liner 34 and liner

40 to the extreme temperatures of the burning gases within hot gas passage 44. The fact that effective diffusion of the velocities of the individual jets of cool air fed into pocket 86 occurs prior to engagement by the fluid of the overhanging lip 92 permits the use of a relatively short and structurally reliable lip while maintaining effective film propagation.

FIG. 8 depicts still another embodiment of the present invention which differs from that of FIG. 7 primarily in relative dimensional proportions. In this figure, the pocket 86*a* has an exit 90*a* which is substantially co-planar with closed end 94*a*. The overhanging lip 92*a* is extremely short, as is baffle 102*a*. In this embodiment it can be presumed that relatively low velocity gradients are required to be diffused within pocket 86*a* so that the overall dimensions of the pocket may be kept to a minimum. In function, this embodiment is substantially equivalent to that with respect to FIG. 7.

A concurrent advantage of the present invention is that the radially extending junctions 64 at the intersections of axially adjacent liner segments provide compatibility with often desirable adjunct cooling devices. For example, a perforated impingement cooling liner (not shown) can be bridged across adjacent junctions 64 to provide additional cooling.

The present invention has thus been illustrated to provide structure for substantial improvement in structural integrity of combustion chamber liners contemporaneously with maintaining or improving the formation of protective laminar film boundaries of cooling fluid. While the concepts of this invention have been illustrated with respect to several embodiments thereof, it is apparent that these concepts are subject to broad applicability and that numerous variations of the structure of the incorporated embodiments may be made by those skilled in the art without departing from the spirit of the present invention. For example, the relative dimensioning or disposition of the diffusion pockets may be varied depending upon flow rates and other variables. Furthermore, alternative means for diffusing flows and coalescing velocity profiles may be utilized to perform the same functions as herein described. Alternatively, the overhanging lip might be dispensed with, the exit from the pocket being designed to direct the flow against the liner. These and other variations are intended to be covered by the appended claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A cooling film promoter for passing, from a plenum containing cooling fluid flowing in a predetermined direction, a portion of the cooling fluid in a protective film upon a liner partially defining a hot gas passage, the promoter comprising:

a first liner segment partially defining the plenum;

a second liner segment partially defining the hot gas passage, the first and second liner segments cooperating to form a pocket, said second liner segment having a downstream end portion spaced from said first liner segment to form an exit from said pocket for directing cooling air along said first liner segment,

aperture means in said first liner segment for providing communication between the pocket and the plenum, wherein said aperture is open to the direction generally opposite said predetermined direction within the plenum, whereby the cooling fluid entering the pocket is partially directed upstream with respect to the fluid flow in the plenum; and

means for diffusing the cooling fluid flow within the pocket prior to the passing of the cooling fluid from said exit.

2. The promoter of claim 1 wherein said downstream end portion comprises a relatively short overhanging lip for directing cooling fluid from the pocket exit onto the first liner segment.

3. The promoter of claim 2 wherein the means for diffusing includes a wall within said pocket against which said cooling fluid is directed upon entering said pocket.

4. The promoter of claim 2 wherein the pocket extends substantially circumferentially about the liner and the aperture means further includes a plurality of apertures spaced circumferentially relative to the liner for providing communication between the plenum and the pocket, and wherein said apertures are open to the direction generally opposite said predetermined direction within the plenum.

5. The promoter of claim 4 wherein the pocket further comprises a closed end, and the apertures are disposed between a substantial portion of the pocket including said closed end, and said exit.

6. The promoter of claim 2 wherein said aperture means is operative to deliver the cooling fluid from the plenum to the pocket in a plurality of discrete jets, and wherein the means for diffusing coalesces the cooling fluid within the pocket so that the cooling fluid leaving the exit has substantially circumferentially uniform flow velocity prior to engaging the overhanging lip.

7. The promoter of claim 6 wherein the major portion of said pocket lies along an axis angularly offset from the direction imparted to the cooling fluid by said overhanging lip.

8. The promoter of claim 6 wherein the major portion of said pocket lies along an axis radially spaced from the direction imparted to the cooling fluid by said overhanging lip.

9. The promoter of claim 6 wherein the pocket has a closed end upstream of said exit with respect to the predetermined fluid flow direction in the plenum and the aperture is disposed between the closed end and the exit.

10. The promoter of claim 9 wherein the major portion of the pocket lies on an axis angularly offset from the direction imparted to the cooling fluid by the overhanging lip and wherein the cooling fluid entering the pocket encounters the closed end, thereby being directed to the exit.

11. A cooling film promoter for passing cooling fluid from a plenum in a protective film upon a liner partially defining a hot gas passage, the promoter comprising:

a first liner segment partially defining the plenum;

a second liner segment partially defining the hot gas passage, the first and second liner segments cooperating to form a pocket, said second liner segment having a downstream end portion spaced from said first liner segment to form an exit from said pocket for directing cooling air along said first liner segment means in said first liner segment for transferring cooling fluid from the plenum to the pocket;

means for diffusing the cooling fluid flow within the pocket prior to the passing of the cooling fluid from said exit; and wherein said downstream end portion comprises a relatively short overhanging lip for directing cooling fluid from the pocket onto the first liner segment;

wherein said promoter is further characterized in that said transfer means is operative to deliver the cooling fluid from the plenum to the pocket in a plurality of discrete jets, and wherein the means for diffusing coalesces the cooling fluid within the pocket so that the cooling fluid leaving the exit has substantially uniform flow velocity prior to engaging the overhanging lip; and

wherein said promoter is further characterized in that the pocket has a closed end, the exit opens in a direction parallel to the hot gas flow, the aperture is disposed upstream of both the closed end and the exit, and a baffle is disposed between the closed end and the exit about which the cool fluid is turned prior to reaching the exit.

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