Abstract: A gas turbine engine flow duct comprising a flow duct disposed along an engine centerline of the gas turbine engine and defining a stream flow passage, and first and second rows of heat exchangers disposed along the engine centerline of the gas turbine engine and integrated in the flow duct in fluid communication with the stream flow passage of the flow duct.
GAS TURBINE ENGINE FLOW DUCT HAVING TWO ROWS OF INTEGRATED HEAT EXCHANGERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/784,492 filed March 14, 2013, the contents of which are hereby incorporated in their entirety.

TECHNICAL FIELD

[0002] The present application relates to gas turbine engines, and more particularly, to a gas turbine engine flow duct having one or more integrated heat exchangers.

BACKGROUND

[0003] Gas turbine engines, and gas turbine engine flow ducts having heat exchangers remain an area of interest. Some existing systems have various shortcomings, drawbacks, and disadvantages relative to certain applications. Accordingly, there remains a need for further contributions in this area of technology.

SUMMARY

[0004] One embodiment of the present application is a gas turbine engine flow duct including a flow duct in which first and second rows of heat exchangers are disposed along an engine centerline of the gas turbine engine in fluid communication with a stream flow passage of the flow duct to adjust a pressure drop across the heat exchangers. Other embodiments include unique methods, systems, devices, and apparatus to provide for a gas turbine engine flow duct. Further embodiments, forms, objects, aspects, benefits, features, and advantages of the present application shall become apparent from the description and figures provided herewith.

BRIEF DESCRIPTION OF THE FIGURES

[0005] Features of the application will be better understood from the following detailed description when considered in reference to the accompanying drawings, in which:

[0006] FIG. 1 is an axial sectional schematic showing a gas turbine engine including a flow duct having integrated heat transfer components according to an embodiment.
FIG. 2 is an end sectional view of a portion of the FIG. 1 gas turbine engine flow duct having integrated heat transfer components, showing a circumferential arrangement of the heat transfer components according to an embodiment.

FIG. 3 is a schematic showing an outer diameter to engine centerline view of a sector of the FIG. 1 gas turbine engine flow duct having integrated heat transfer components, showing an axial arrangement of the heat transfer components according to an embodiment.

FIG. 4 is a schematic showing an outer diameter to engine centerline view of a sector of a gas turbine engine flow duct having integrated heat transfer components and an axial displacing device according to an embodiment, showing a relatively decreased axial spacing between first and second rows of heat transfer components.

FIG. 5 is a schematic showing the FIG. 4 arrangement with a relatively increased axial spacing between the first and second rows of heat transfer components.

FIG. 6 is a schematic showing an outer diameter to engine centerline view of a sector of a gas turbine engine flow duct having integrated heat transfer components and a fluid flow passage door mechanism according to an embodiment, showing fluid flow passage doors in a closed state.

FIG. 7 is a schematic showing the FIG. 6 arrangement, with the fluid flow passage doors in an open state.

FIG. 8 is a schematic showing an outer diameter to engine centerline view of a sector of a gas turbine engine flow duct having integrated heat transfer components and ejector systems according to an embodiment.

FIG. 9 is an axial section schematic showing the arrangement of the heat transfer components of FIG. 8 integrated in various fluid stream locations according to an embodiment.

FIG. 10 is a schematic showing an outer diameter to engine centerline view of a sector of a gas turbine engine flow duct having integrated heat transfer components, ejector systems, and fluid flow injection systems according to an embodiment.
FIGS. 10A is a schematic showing a portion of an ejector system of a FIG. 10 gas
turbine engine flow duct according to an embodiment.

FIGS. 10B is a schematic showing a portion of an ejector system of a FIG. 10 gas
turbine engine flow duct according to an embodiment.

FIGS. IOC is a schematic showing a portion of an ejector system of a FIG. 10 gas
turbine engine flow duct according to an embodiment.

FIG. 11 is an axial section schematic showing inner and outer flow ducts of a gas
turbine engine, heat transfer components and upstream and downstream fluid flow passage
doors according to an embodiment, with the upstream and downstream fluid flow passage
doors in an open state.

FIG. 12 is a schematic showing the FIG. 11 arrangement, with the upstream and
downstream fluid flow passage doors in a closed state.

FIG. 13 is a schematic showing the FIG. 11 arrangement, with the upstream fluid
flow passage door in a closed state and the downstream fluid flow passage door in an open
state.

FIG. 14 is a forward looking aft schematic showing an arrangement of heat transfer
components integrated with upstream and downstream rotatable cylinder fluid flow passage
assemblies according to an embodiment.

FIG. 15 is a schematic showing the FIG. 14 arrangement, with the upstream and
downstream rotatable cylinder fluid flow passage assemblies in an open state.

FIG. 16 is a schematic showing the FIG. 14 arrangement, with the upstream and
downstream rotatable cylinder fluid flow passage assemblies in a closed state.

FIG. 17 is a schematic showing the FIG. 14 arrangement, with the upstream
rotatable cylinder fluid flow passage assembly in a closed state and the downstream rotatable
cylinder fluid flow passage assembly in an open state.
FIG. 18 is a schematic showing the FIG. 14 arrangement, with the upstream rotatable cylinder fluid flow passage assemblies in an open state and the downstream rotatable cylinder fluid flow passage assemblies in a closed state.

DETAILED DESCRIPTION

While the present invention can take many different forms, for the purpose of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Any alterations and further modifications of the described embodiments, and any further applications of the principles of the invention as described herein, are contemplated as would normally occur to one skilled in the art to which the invention relates.

FIGS. 1-3 show a gas turbine engine 10 including a flow duct 16 and an arrangement of heat exchangers and/or condensers 20, 22 according to an embodiment. As used herein, the term "heat exchanger" and "HX component" refers to heat exchangers and/or condensers. FIG. 1 shows the major components of the gas turbine engine 10, including the flow duct 16, a fan 24, a compressor section 26, a combustion section 28, and a turbine section 30. The flow duct 16 depicted in the FIG. 1 embodiment is an axially extending, that is forward to aft extending, annular bypass flow duct that surrounds all or part of the core of the gas turbine engine 10. The flow duct 16 can receive airflow from the fan 24 at the forward end of the gas turbine engine 10 and convey the airflow to the aft end of the gas turbine engine 10, where it is expelled coaxially with the engine exhaust to produce additional thrust. As will be appreciated, the gas turbine engine 10 and the flow duct 16 are not limited to the configuration shown in FIG. 1, and other embodiments are contemplated. For example, in one form, the flow duct 16 can comprise a high bypass flow duct. In another form, the flow duct 16 can comprise a ram air flow duct. In another form, multiple flow ducts can be provided comprising bypass flow ducts and/or ram air flow ducts. For example, in an embodiment a first bypass flow duct can surround the core of the gas turbine engine 10 to define a second stream flow, and a second bypass flow duct can surround the first bypass flow duct to define a third stream flow. In other embodiments, the flow duct, or multiple flow ducts, may have other configurations suited to the particular application of the gas turbine engine 10.
Referring to FIGS. 2 and 3, the HX COMPONENTS 20, 22 are integrated in the flow duct 16 in fluid communication with the bypass stream flow of the flow duct 16. The HX components 20, 22 can be used to cool a fluid and/or one or more components and/or systems of the gas turbine engine 10 or external to the gas turbine engine 10. For example, the object of cooling can be one or more of hydraulic fluid and/or related systems/components, electrical and/or electronic circuits and/or systems, mechanical components and/or systems, and/or other components and/or systems, such as refrigeration components and/or systems.

In FIG. 3 embodiment, first and second, or forward and aft, rows 40, 42 of HX components 20, 22 are integrated in the flow duct 16. As shown in FIG. 3, the first row 40 of HX components 20 can be axially spaced apart a distance B from the second row 42 of HX components 22 along an engine centerline A of the gas turbine engine 10. Further, as shown in FIG. 2, the HX components 20 of the first row 40 can be circumferentially disposed about the engine centerline A at a radial distance R1 from the engine centerline A, and the HX components 22 of the second row 42 can be circumferentially disposed about the engine centerline A at a radial distance R2 from the engine centerline A. In the present embodiment, the HX components 20 are equally circumferentially spaced apart, and the HX components 22 are equally circumferentially spaced apart, and the radial distance R1 is substantially the same as the radial distance R2. Further, the quantity of HX components 20, 22 can be the same in each row 40, 42, for example as illustrated. Referring to FIGS. 2 and 3, the HX components 22 of the second row 42 can be angularly offset, or staggered, by an angle alpha (0) in the clockwise direction relative to the HX components 20 of the first row 40. In the present embodiment, the angular offset is such that the HX components 22 are equally angularly displaced from circumferentially adjacent HX components 20. The configuration of the HX components 20, 22 of FIGS. 1-3 can be used to adjust the pressure drop that the airflow path in the flow duct 16, represented by arrows in FIG. 3, undergoes when passing from the upstream end of the first row 40 of HX components 20 to the downstream end of the second row 42 of HX components 22.

The multiple rows 40, 42 of HX components 20, 22 configured as shown for example in FIGS. 1-3 can reduce the pressure drop across the HX components 20, 22, for a given amount of heat rejection to the flow duct 16. By reducing the pressure drop, the gas turbine engine 10 can burn less fuel in maintaining a given thrust, for example a constant...
thrust. The configuration of multiple rows 40, 42 of HX components 20, 22 can reduce the
pressure drop which, in turn, can reduce the amount of fuel burn at constant thrust for a given
amount of heat rejection as compared to for example a single row of HX components. This
can provide, for example, fuel savings and increased vehicle range capability per amount of
heat rejected.

[0032] The integrated flow duct 16 and HX components 20, 22 are not limited to the
arrangement shown in FIGS. 1-3, other embodiments are also contemplated herein. For
example, rather than first and second 40, 42 rows of HX components 20, 22, there can be
three or more rows of HX components for an application. Further, the type and/or quantity of
HX components 20 in the first row 40 need not be the same as the type and/or quantity of HX
components 22 in the second row 42, and HX components 20, 22 within a given row 40, 42
need not be the same type. Further, the first row 40 of HX components 20 is not limited to
being axially spaced apart from the second row 42 of HX components 22 by the distance B as
illustrated, and instead the HX components 20 of the first row 40 can be disposed along
different axial locations, and the HX components 22 of the second row 42 can be disposed
along different axial locations, such that for example the axial spacing between the HX
components 20 of the first row 40 and the HX components 22 of the second row 42 is not a
constant distance B but rather for example a distance B for some HX components 20,22 and a
different distance for other HX components 20, 22.

[0033] Also, the circumferential and radial distribution of the HX components 20, 22 about
the engine centerline A is not limited to that which is depicted in the embodiment shown in
FIGS. 1-3. In one form, the radial distance R1 of the HX components 20 from the engine
centerline A can be different from that of the radial distance R2 of the HX components 22
from the engine centerline A, for example in an application where the annular shape of the
flow duct 16 changes along the engine centerline A. Further, the circumferential spacing
between the HX components 20 need not be equal, and the circumferential spacing between
the HX components 22 need not be equal; the circumferential spacing can be different for the
HX components 20 and/or the HX components 22. Still further, the angular offset alpha (0)
between the HX components 20 and the HX components 22 is not limited to that shown in
FIG. 2; for example, the angular offset alpha (0) for HX components 20, 22 can be different
for different sectors of the arrangement of HX components 20, 22.
FIGS. 4 and 5 show first and second rows 50, 52 of HX components 60, 62, and an axial displacing device 68 for integration into for example the flow duct 16 of the gas turbine engine 10 according to an embodiment. The quantity and/or spacing of the HX components 60, 62 can be the same, or different, from that of the HX components 20, 22 of the FIG. 1 embodiment. The axial displacing device 68 can be any suitable linear motion driving mechanism, for example a linear servo drive, that relatively axially displaces the first and second rows 50, 52 of HX components 60, 62 along the engine centerline A (see FIG. 1). In FIG. 4, the axial displacing device 68 relatively axially displaces the second row 52 of HX components 62 by a distance XI from the first row 50 of HX components 60. In FIG. 5, the axial displacing device 68 relatively axially displaces the second row 52 of HX components 62 by a distance X2 from the first row 50 of HX components 60.

The integration of multiple rows 50, 52 of HX components 60, 62 and axial displacement capability into the flow duct 16 having an arrangement as shown for example in FIGS. 4-5 can be used for example to adjust the amount of heat rejection most suited for a particular application and/or engine cycle condition. For example, by relatively decreasing the distance between the first and second rows 50, 52 of HX components 60, 62, for example from X2 in FIG. 5 to XI in FIG. 4, a greater amount of airflow passes through the HX components 60, 62, and therefore the heat rejection capacity of the HX components 60, 62 increases. This also can result in increased flow duct pressure losses and associated fuel burn penalty increases. On the other hand, for example, by relatively increasing the distance between the first and second rows 50, 52 of HX components 60, 62, for example from XI in FIG. 4 to X2 in FIG. 5, a less amount of airflow passes through the HX components 60, 62, and therefore the flow duct pressure losses decrease and the associated fuel burn penalty decreases. This also can result in reduced heat rejection capacity. The embodiment of FIGS. 4-5 thus provides for varying the geometry of the integrated HX components 60, 62 relative to the flow duct 16 and/or relative to each other in such a way as to selectively increase system heat rejection and/or decrease flow duct pressure losses and associated fuel burn penalty for a particular application, depending on operating conditions such as heat rejection requirements and engine operation requirements, and/or environmental conditions, as would occur to those skilled in the art. Thus, the variable geometry system of FIGS. 4-5 provides greater flexibility in adjusting to variable engine cycles and/or variable heat loads. For example, in one form, increasing pressure loss increases heat rejection for a given engine
operating condition. In another form, when engine operating conditions change, the first and second rows 50, 52 of HX components 60, 62 can be moved relative to one another to meet heat rejection requirements while minimizing the pressure losses. In one form, the variable geometry system of FIGS. 4-5 can be configured to provide adjustability to engine cycle changes and to provide just enough pressure difference across the HX components 60, 62 to enable a desired and/or required amount of cooling.

[0036] FIGS. 6 and 7 show first and second rows 70, 72 of HX components 80, 82, and a movable vane or door assembly 88 for integration into for example the flow duct 16 of the gas turbine engine 10 according to an embodiment. The quantity and/or spacing of the HX components 80, 82 can be the same, or different, from that of the HX components 20, 22 of the FIG. 1 embodiment. The movable door assembly 88 includes a plurality of fluid flow passage doors 90 that in the depicted embodiment are rotatable about a radially projecting axis Y disposed generally between for example the outer diameter of the flow duct 16 and the inner diameter of the flow duct 16. The fluid flow passage doors 90 are rotatable between an open state as shown for example in FIG. 7, at which airflow can pass through intermediate fluid flow passages 94 defined between adjacent HX components 80, 82 of the respective first and second rows 70, 72, and a closed state as shown for example in FIG. 6, at which airflow is blocked or substantially inhibited from passing through the intermediate fluid flow passages 94. The movable door assembly 88 can include any suitable mechanical, electrical, or electromechanical device 96 (only partially shown in FIGS. 6 and 7), for example a motor driven gear arrangement, that is operative to drive the fluid flow passage doors 90 to the open and closed states or to any suitable angular position between the open and closed states.

[0037] The integration of multiple rows 70, 72 of HX components 80, 82 and an intermediate fluid flow passage adjustment capability into the flow duct 16 having an arrangement as shown for example in FIGS. 6-7 can be used for example to adjust the amount of heat rejection most suited for a particular application and/or engine cycle condition. For example, by moving the fluid flow passage doors 90 to the closed position as shown in FIG. 6, the intermediate fluid flow passages 94 are blocked and a greater amount of airflow passes through the HX components 80, 82, and therefore the heat rejection capacity of the HX components 80, 82 increases. This also can result in increased flow duct pressure losses and associated fuel burn penalty increases. On the other hand, for example, by moving the fluid flow passage doors 90 to the open position as shown in FIG. 7, some airflow passes
through the intermediate fluid flow passages 94 and a less amount of airflow passes through the HX components 80, 82, and therefore the flow duct pressure loss decreases and the associated fuel burn penalty decreases. This also can result in reduced heat rejection capacity. The embodiment of FIGS. 6-7 thus provides for varying the geometry of the integrated HX components 80, 82 relative to the flow duct 16 and/or relative to each other in such a way as to selectively increase system heat rejection and/or decrease flow duct pressure losses and associated fuel burn penalty for a particular application, depending on operating conditions such as heat rejection requirements and engine operation requirements, and/or environmental conditions, as would occur to those skilled in the art. Thus, the variable geometry system of FIGS. 6-7 provides greater flexibility in adjusting to variable engine cycles and/or variable heat loads. For example, in one form, increasing pressure loss increases heat rejection for a given engine operating condition. In another form, when engine operating conditions change, the movable door assembly 88 can be moved to meet heat rejection requirements while minimizing the pressure losses. In one form, the variable geometry system of FIGS. 6-7 can be configured to provide adjustability to engine cycle changes and to provide just enough pressure difference across the HX components 80, 82 to enable a desired and/or required amount of cooling.

[0038] Referring now to FIG. 8, multiple HX components 100 and ejector systems 110 can be integrated into for example the flow duct 16 of the gas turbine engine 10 according to an embodiment. The HX components 100 and ejector systems 110 can be circumferentially disposed about the engine centerline A of the gas turbine engine 10 (FIG. 1), and FIG. 8 is an outside diameter to engine centerline view that shows a single sector of the arrangement. In one form, axially extending lines M and N, shown respectively at the top and bottom of FIG. 8, can constitute a plane of cyclic symmetry such that for example half of a single HX component 100 is shown in the top left of FIG. 8 and half of a different, that is circumferentially adjacent, single HX component 100 is shown in the bottom left of FIG. 8. In one form, the arrangement shown in FIG. 8 can be repeated circumferentially about the engine centerline A.

[0039] The ejector systems 110 can have a forward section comprising an adjustable nozzle 114 disposed substantially between circumferentially adjacent HX components 100, and an aft section comprising an adjustable diffuser 118 disposed relatively downstream of the adjustable nozzle 114 and the HX components 100. In one form, the ejector system 110 may
comprise a forward section adjustable nozzle 114 without the aft section adjustable diffuser 118, or with a different type of aft section component that realizes the functions of the aft section adjustable diffuser 118 described herein. The adjustable nozzle 114 is adjustable in a direction substantially transverse to the fluid flow path of the flow duct 16. In the depicted embodiment, the adjustable nozzle 114 is flanked on circumferentially opposite sides of the adjustable nozzle 114 by a first wall assembly 120 comprising four walls 121-124 and a second wall assembly 130 comprising four walls 131-134. The adjustable nozzle 114 is formed by the fluid surface walls 121, 122 of the first wall assembly 120 and the fluid surface walls 131, 132 of the second wall assembly 130.

[0040] The four walls 121-124 of the first wall assembly 120 form a four-body linkage in which the links, or bodies, are connected in a loop by two joints at reference numerals 126 and two joints at reference numerals 127. The four walls 131-134 of the second wall assembly 130 form a four-body linkage in which the links, or bodies, are connected in a loop by two joints at reference numerals 136 and two joints at reference numerals 137. The walls 123, 133 can be positioned circumferentially adjacent to the HX components 100, and can be fixed to, or fixed relative to, a support structure (not shown) of the radially inner and/or radially outer surface wall of the flow duct 16, or to other surrounding structure. The joints 126, 136 at opposite ends of the respective walls 123, 133 can be pivotally connected to the radially inner and/or radially outer surface walls of the flow duct 16, or to other surrounding structure. The joints 127, 137 at opposite ends of the respective walls 121, 131, along with the walls 121, 122, 124, and 131, 132, 134 in the illustrative embodiment are moveable within the radially inner and outer boundaries of the flow duct 16. As will be appreciated, the first and second wall assemblies 120, 130 can be positioned relative to one another such that the walls 121, 131 can move in substantially parallel planes to increase and decrease the circumferential span R of the flow path of the adjustable nozzle 114, and the walls 122, 132 can move in mirrored fashion to form a converging path or adjustable narrowing taper extending aft to the walls 121, 131. Any suitable drive mechanism (not shown) can be used to drive the first and second wall assemblies 120, 130 to adjust the circumferential span R of the adjustable nozzle 114, as will be appreciated.

[0041] The adjustable diffuser 118 (if present) is disposed downstream of the adjustable nozzle 114 and the HX components 100. The adjustable diffuser 118, like the adjustable nozzle 114, is adjustable in a direction substantially transverse to the fluid flow path of the
flow duct 16. In the depicted embodiment, the adjustable diffuser 118 is flanked on circumferentially opposite sides of the adjustable diffuser 118 by a first wall assembly 150 comprising three fluid surface walls 151-153 and a support member 154, and a second wall assembly 160 comprising three fluid surface walls 161-163 and a support member 164. The adjustable diffuser 118 is formed by the fluid surface walls 151-153 of the first wall assembly 150 and the fluid surface walls 161-163 of the second wall assembly 160.

[0042] The walls 151, 152 and the support member 154 of the first wall assembly 150, and the connecting structure (e.g. duct wall) between two joints at reference numerals 156, together form a four-body linkage in which the links, or bodies, are connected in a loop by the two joints 156 and two joints at reference numerals 157. The walls 161, 162 and the support member 164 of the second wall assembly 160, and the connecting structure (e.g. duct wall) between two joints at reference numerals 166, together form a four-body linkage in which the links, or bodies, are connected in a loop by the two joints 166 and two joints at reference numerals 167. The joints 156, 166 disposed along the respective axes M, N can be pivotally connected to the radially inner and/or outer surface walls of the flow duct 16, or to other surrounding structure. The joints 157, 167 at opposite ends of the respective walls 151, 161, along with the walls 151-153 and support member 154, and the walls 161-163 and support member 164 in the illustrative embodiment are movable within the radially inner and outer boundaries of the flow duct 16. The walls 153, 163 extend aft circumferentially outward toward the respective planes of cyclic symmetry M, N, at which a suitable sliding mechanism 158, 168 is provided to enable axial sliding movement of the aft end of the walls 153, 163. As will be appreciated, the first and second wall assemblies 150, 160 can be disposed relative to one another such that the walls 151, 161 can move in substantially parallel planes to increase and decrease the circumferential span S of the flow path of the adjustable diffuser 118, the walls 152, 162 can move in mirrored fashion to form a converging path or adjustable narrowing taper extending aft to the walls 151, 161, and the walls 153,163 can move in mirrored fashion to form an adjustable divergent channel or adjustable expanding taper extending aft from the walls 151, 161. Any suitable drive mechanism (not shown) can be used to drive the first and second wall assemblies 150, 160 in a manner to adjust the circumferential span S of the adjustable diffuser 118, as will be appreciated.
[0043] In the FIG. 8 embodiment, the aft end of the walls 121 and 131 of the adjustable nozzle 114 project into the forward end of the adjustable diffuser 118 between the walls 151 and 161 of the adjustable diffuser 118, and define a variable dimension T between the wall 121 of the adjustable nozzle 114 and the wall 151 of the adjustable diffuser 118, and between the wall 131 of the adjustable nozzle 114 and the wall 161 of the adjustable diffuser 118. As will be appreciated, the variable dimension T is a function of the movement of the adjustable nozzle 114 and the adjustable diffuser 118.

[0044] The integration of the variable geometry system of FIG. 8 into the flow duct 16 of the gas turbine engine 10 can be used for example to adjust the amount of heat rejection most suited for a particular application and/or engine cycle condition. For example, by adjusting the adjustable nozzle 114 to decrease the circumferential span R, the static pressure downstream of the HX components 100 decreases and a greater amount of airflow passes through the HX components 100, and therefore the heat rejection capacity of the HX components 100 increases. Furthermore, the adjustable diffuser 118 (if present) downstream of the adjustable nozzle 114 can be used to recover the dynamic pressure and thus reduce the pressure loss penalty in the flow duct 16. The amount of pressure recovery can be controlled for example by adjusting the adjustable diffuser 118 relative to the adjustable nozzle 114 by varying the dimension T. The embodiment of FIG. 8 thus provides for varying the geometry of the integrated adjustable nozzles 114 and the adjustable diffusers 118 relative to the HX components 100 and/or the flow duct 16 in such a way as to selectively increase the system heat rejection and/or decrease the flow duct pressure losses and associated fuel burn penalty for a particular application, depending on operating conditions such as heat rejection requirements and engine operation requirements, and/or environmental conditions, as would occur to those skilled in the art. Thus, the variable geometry system of FIG. 8 provides greater flexibility in adjusting to variable engine cycles and/or variable heat loads. For example, in one form, increasing pressure loss increases heat rejection for a given engine operating condition. In another form, when engine operating conditions change, the ejector systems 100 can be actuated to meet heat rejection requirements while minimizing the pressure losses. In one form, the variable geometry system of FIG. 8 can be configured to provide adjustability to engine cycle changes and to provide just enough pressure difference across the HX components 100 to enable a desired and/or required amount of cooling. In one form, the adjustable nozzle 114 can serve as a flow restriction device, for example at the
nozzle flow path \( R \), to create more pressure difference across the HX components 100, and the adjustable diffuser 118 can serve as a dynamic pressure recovery device to recover the dynamic pressure passing through the nozzle path \( R \) to minimize overall system pressure losses.

[0045] Referring to FIG. 9, in an embodiment, the HX components 100 and the ejector systems 110 can be immersed in the flow duct 16. As described above, the immersed adjustable nozzle 114 of the ejector system 110 can be used to lower the static pressure to obtain a greater amount of airflow through the HX components 100 while the adjustable diffuser 118 can be used to recover pressure. In another embodiment, also shown in FIG. 9, HX components 100 can be immersed in a bulbous passage or flow duct 206 that is radially external to the flow duct 16 and is disposed for example in available engine bay space to provide for example easier access to the HX components 100. In still another embodiment, the HX components 100 can be disposed in both the flow duct 16 and the radially external passage 206. In one form, the radially external passage 206 spreads out the air stream to provide more room for placing heat exchangers 100. Further, the radially external passage 206 is not limited to the bulbous shape and configuration depicted in FIG. 9. For example, the radially external passage 206 can extend from the forward to the aft of the gas turbine engine 10 and movable walls may be incorporated to transfer airflow to and from the flow duct 16.

[0046] FIG. 10 is an embodiment similar to that of the FIG. 8 embodiment, and further including a fluid flow injection system 218. The fluid flow injection system 218 can inject air into the adjustable diffuser 118 of the ejector system 110 to reduce flow separation in the adjustable diffuser 118. The fluid flow injection system 218 depicted in the FIG. 10 arrangement includes for example a scoop 222 and/or a passage 224, which can be used together or singly to produce a high velocity fluid stream to energize the flow coming from the downstream end of the HX component 100 and to reduce the flow separation in the adjustable diffuser 118. In this way, the scoop 222 and/or passage 224 of the fluid flow injection system 218 can be used to improve pressure recovery.

[0047] The scoop 222 can be integrated with and disposed at the aft end of the wall 121 of the adjustable nozzle 114. The passage 224 can take air from a high pressure location, for example from the upstream end of the adjustable nozzle 114 and transfer the air to for
example a location near the start of the adjustable diffuser 118. Thus, for example, the
passage 224 can extend aft from opening 228 to opening 230 integrated in respective walls
132 and 134 of the adjustable nozzle 114, and to an opening 236 integrated with and disposed
at the aft end of the wall 131 of the adjustable nozzle 114. As will be appreciated, the
passage 224 can be bordered on one side by the walls 132 and 131 of the adjustable nozzle
114 and at an opposing side by corresponding walls 241-243.

[0048] The integration of the fluid flow injection system 218 with respect to the HX
components 100 and the ejector systems 110 of the FIG. 10 embodiment is not limited to the
arrangement as shown. In an embodiment, the fluid flow injection system 218 can be located
elsewhere in the adjustable diffuser 118, for example further downstream from that which is
shown in FIG. 10, as may be suitable for an application. In one form, the fluid flow injection
system 218 may comprise scoops 222 and no passages 224. In another form, the fluid flow
injection system 218 may comprise passages 224 and no scoops 222. Further, the fluid flow
injection system 218 is not limited to its high pressure source being from the upstream end of
the adjustable nozzle 114; the fluid flow injection system 218 can use any suitable higher
pressure air source(s), for example a high pressure air source from the gas turbine engine 10.

[0049] FIG. 10A shows an aft portion of the ejector system 110 that includes an alternative
and/or additional fluid flow injection site 246, in which pressurized air from the engine is
injected through a passage 248 of the ejector system 110. As will be appreciated, any
suitable flow control means may be employed, including for example any of a family of
plasma actuators. FIG. 10B, for example, shows locations of plasma actuators 249 for flow
control in any of the flow duct embodiments of FIG. 8, FIG. 10, or FIG. 10A, or other flow
duct embodiments described herein.

[0050] FIGS. 11 and 12 show an arrangement of inner and outer flow ducts 16, 236, HX
components 240, and a movable vane or door assembly 250, for integration into for example
the gas turbine engine 10 according to an embodiment. The movable door assembly 250
enables selection of an air stream to be used for the cold side of the HX component 240, as
will be described in greater detail below.

[0051] The inner flow duct 16 can be an annular bypass flow duct that surrounds the core
of the gas turbine engine 10, such as described with respect to the FIG. 1 embodiment.
Ejector systems 110 can be integrated into the inner flow duct 16, such as in the manner
described with respect to the FIG. 8 embodiment. The outer flow duct 236 can be an annular flow duct that surrounds the inner flow duct 16, for example an annular ram air flow duct. In one form, the outer flow duct 236, for example as a ram air flow duct, can collect air from the inlet of the gas turbine engine 10, which can then be exhausted into an exhaust nozzle of the gas turbine engine 10 or to a port on an aircraft surface with which the outer flow duct 236 is in fluid communication. As will be appreciated, the flow ducts 16, 236 can be configured for low observable (LO) requirements suited for an application.

[0052] The HX components 240 (one shown in FIGS. 11 and 12) can be integrated into the outer flow duct 236 in a circumferentially disposed manner about the engine centerline A. Radially projecting fluid flow passages 242, 244 are provided respectively upstream and downstream of the HX component 240 and enable fluid communication between the flow duct 16 and the flow duct 236.

[0053] The movable door assembly 250 can be integrated in, relative to, and/or between the outside diameter wall of the inner flow duct 16 and/or the inside diameter wall of the outer flow duct 236. The movable door assembly 250 includes an upstream fluid flow passage door 256 and a downstream fluid flow passage door 258 that are pivotable about respective hinges 266, 268 between an open state as shown for example in FIG. 11 and a closed state as shown for example in FIG. 12. With both doors 256, 258 in the open state, airflow in the inner flow duct 16 can pass through the fluid flow passage 242 to the outer flow duct 236 and to the cold side of the HX component 240 and from the downstream end of the HX component 240 through the fluid flow passage 244 back to the inner flow duct 16, with the aid of the ejector system 110 or similar device that serves to provide reduced-flow cross-sectional area or otherwise modify the flow area of the flow duct 16 to reduce static pressure, but airflow in the outer flow duct 236 is blocked or substantially inhibited from passing through the outer flow duct 236 to the cold side of the HX component 240. With both doors 256, 258 in the closed state, airflow in the outer flow duct 236 can pass through the outer flow duct 236 to the cold side of the HX component 240 and further downstream in the outer flow duct 236, and airflow in the inner flow duct 16 can pass through the inner flow duct 16 but is blocked or substantially inhibited from passing through the fluid flow passage 242 to the outer flow duct 236 and to the cold side of the HX component 240. The movable door assembly 250 can include any suitable mechanical, electrical, or electromechanical device (not shown), for example a motor driven gear arrangement, that is operative to pivot
the fluid flow passage doors 256, 258 to the open and closed states or to an angular position between the open and closed states.

[0054] The movable door assembly 250 can be used to select the airflow of the inner flow duct 16 or the airflow of the outer flow duct 236 for example to adjust the amount of heat rejection most suited for a particular application and/or engine cycle condition. For example, in some applications, the fluid flow passage doors 256, 258 can be moved to the open state (FIG. 11) so that airflow in the inner flow duct 16 is conveyed through the fluid flow passage 242 to the outer flow duct 236 and to the cold side of the HX component 240. In other applications, for example in high Mach applications where fluid temperatures in the inner flow duct 16 become too hot for a particular application, the fluid passage doors 256, 258 can be moved to the closed state (FIG. 12) so that airflow in the flow duct 16 is blocked or substantially inhibited from the HX component 240 and instead airflow in the flow duct 236 is conveyed to the cold side of the HX component 240. In one form, by switching the cold side heat sink, the vehicle's Mach number operating range for a cooling system can be extended.

[0055] FIG. 13 is another example of a use of the movable door assembly 250 to control air streams of the inner and outer flow ducts 16, 236 to adjust the amount of heat rejection suitable for a particular application and/or engine condition. Here, the upstream fluid flow passage door 256 is moved to a closed state and the downstream fluid flow passage door 258 is moved to an open state. As such, airflow in the inner flow duct 16 passes through the inner flow duct 16, and airflow in the outer flow duct 236 passes to the cold side of the HX component 240, through the HX component 240, and downstream from the HX component 240, at which the fluid flow passage door 258 conveys the airflow through the fluid flow passage 244 to the inner flow duct 16. Thus, the arrangement of FIG. 13 can be used for example to lower the static pressure in the airstream of the inner flow duct 16, with the aid of the ejector system 110 or similar device that serves to provide reduced-flow cross-sectional area or otherwise modify the flow areas of the flow duct 16 to reduce static pressure, so that ram air in the outer flow duct 236 can be pulled through the HX component 240. The inner and outer flow ducts 16, 236 are not limited to the configuration shown in FIG. 13, and other embodiments are contemplated. For example, in an embodiment, a portion of the outer flow duct 236 downstream from the fluid flow passage door 258 can be eliminated at the aft end of the gas turbine engine 10.
FIGS. 14 to 18 show an arrangement of inner and outer flow ducts 16, 336, HX components 340, and a rotatable duct assembly 350, for integration into for example the gas turbine engine 10 according to an embodiment. The rotatable duct assembly 350 enables selection of an air stream to be used for the cold side of the HX component 340, as will be described in greater detail below.

The inner flow duct 16 can be an annular bypass flow duct that surrounds the core of the gas turbine engine 10, such as described with respect to the FIG. 1 embodiment. Ejector systems 110 can be integrated into the inner flow duct 16 (shown only with respect to FIGS. 15 to 18 for purposes of ease and clarity of description), such as in the manner described with respect to the FIG. 8 embodiment. The outer flow duct 336 can be an annular flow duct that surrounds the inner flow duct 16, for example an annular ram air flow duct. In one form, the outer flow duct 336, for example as a ram air flow duct, can collect air from the inlet of the gas turbine engine 10, which can then be exhausted into an exhaust nozzle of the gas turbine engine 10 or to a port on an aircraft surface with which the outer flow duct 336 is in fluid communication. As will be appreciated, the flow ducts 16, 336 can be configured for low observable (LO) requirements suited for an application.

The HX components 340 (only one shown in FIGS. 15 to 18 for ease and clarity of description) can be integrated into the outer flow duct 336 in a circumferentially disposed manner about the engine centerline A, as will be appreciated. The rotatable duct assembly 350 is selectively rotatable to enable fluid communication between the inner flow duct 16 and the outer flow duct 336.

The rotatable duct assembly 350 can be integrated in, relative to, and/or between the outside diameter wall of the inner flow duct 16 and/or the inside diameter wall of the outer flow duct 336. The rotatable duct assembly 350 includes upstream and downstream rotatable cylinder fluid flow duct assemblies 352,354 disposed respectively axially upstream and downstream of the row of HX components 340. Each assembly 352, 354 is rotatable about the engine centerline A of the gas turbine engine 10, and comprises a rotatable cylinder 366, 368 and a plurality of circumferentially disposed fluid flow ducts 356, 358 projecting radially from the cylinder 366, 368 and spaced apart in alternating fashion by gaps G. As shown in FIG. 14, the rotatable duct assembly 350 further includes a flow barrier 370 disposed in the outer flow duct 336 circumferentially about the engine centerline A between
circumferentially adjacent HX components 340. For purposes of ease and clarity of
description, FIG. 14 shows only the upstream rotatable cylinder fluid flow duct assembly
352; the downstream rotatable cylinder fluid flow duct assembly 352 can be similarly
configured, as is apparent from FIGS. 15 to 18 and the description relating to FIGS. 15 to 18.

[0060] In the illustrative embodiment, the upstream rotatable cylinder fluid flow duct
assembly 352 can be selectively rotated so that the fluid flow duct 356 is axially aligned, that
is in registry with, the HX component 340, or axially out-of-alignment with the HX
component 340. When the fluid flow duct 356 is in axial alignment with the HX component
340, the fluid flow duct 356 opens fluid communication from the inner flow duct 16 to the
cold side of the HX component 340 and closes off fluid communication from the outer flow
duct 336 to the cold side of the HX component 340. When the fluid flow duct 356 is axially
out-of-alignment with the HX component 340, the flow barrier 370 blocks, that is closes,
fluid communication from the inner flow duct 16 to the cold side of the HX component 340,
and the gaps G between the circumferentially spaced fluid flow ducts 356 allow fluid
communication from the outer flow duct 336 to the cold side of the HX component 340. The
downstream rotatable cylinder fluid flow duct assembly 354 (not shown in FIG. 14) operates
in a similar manner to selectively open and block off fluid communication, the fluid
communication being from the HX component 340 to the inner flow duct 16 or the
downstream portion of the outer flow duct 336.

[0061] Referring to FIG. 15, with both the upstream and downstream rotatable cylinder
fluid flow duct assemblies 352, 354 in an open state” that is with their respective fluid flow
ducts 356, 358 in alignment with the HX component 340 on opposite sides thereof, airflow in
the inner flow duct 16 can pass through the fluid flow duct 356 to the cold side of the HX
component 340 and from the downstream end of the HX component 340 back to the inner
flow duct 16, with the aid of the ejector system 110 or similar device that serves to provide
reduced-flow cross-sectional area or otherwise modify the flow areas of the flow duct 16 to
reduce static pressure, but airflow in the outer flow duct 336 is blocked from passing through
the outer flow duct 336 to the cold side of the HX component 340. Referring to FIG. 16, with
both the upstream and downstream rotatable cylinder fluid flow duct assemblies 352, 354 in
the closed state, that is with their respective fluid flow ducts 356, 358 out-of-alignment with
the HX component 340 on opposite sides thereof, airflow in the outer flow duct 336 can pass
through the outer flow duct 336 to the cold side of the HX component 340 and further
downstream in the outer flow duct 336, and airflow in the inner flow duct 16 can pass through the inner flow duct 16 but is blocked from passing through the fluid flow duct 356 to the cold side of the HX component 340. The rotatable duct assembly 350 can include any suitable mechanical, electrical, or electromechanical device (not shown), for example a motor driven gear arrangement, that is operative to rotate the upstream and downstream rotatable cylinder fluid flow duct assemblies 352, 354 to the open and closed states or to an angular position between the open and closed states.

[0062] The rotatable duct assembly 350 can be used to select the airflow of the inner flow duct 16 or the airflow of the outer flow duct 336 for example to adjust the amount of heat rejection most suited for a particular application and/or engine cycle condition. For example, in some applications, the fluid flow ducts 356, 358 can be rotated to the open state (FIG. 15) so that airflow in the inner flow duct 16 is conveyed to the cold side of the HX component 340. In other applications, for example in high Mach applications where fluid temperatures in the inner flow duct 16 get too hot, the fluid flow ducts 356, 358 can be rotated to the closed state (FIG. 16) so that airflow in the inner flow duct 16 is blocked from the cold side of the HX component 340 and instead airflow in the outer flow duct 336 is conveyed to the cold side of the HX component 340. In one form, by switching the cold side heat sink, the vehicle's Mach number operating range for a cooling system can be extended.

[0063] FIGS. 17 and 18 show other examples or modes of operation of the rotatable duct assembly 350 to control air streams of the inner and outer flow ducts 16, 336 to adjust the amount of heat rejection suitable for a particular application and/or engine condition. In FIG. 17, the upstream rotatable cylinder fluid flow duct assembly 352 is rotated to a closed state and the downstream rotatable cylinder fluid flow duct assembly 354 is rotated to an open state. As such, airflow in the inner flow duct 16 passes through the inner flow duct 16, and airflow in the outer flow duct 336 passes to the cold side of the HX component 340, through the HX component 340, and downstream from the HX component 340 to the fluid flow duct 358, which conveys the airflow to the inner flow duct 16. Thus, the arrangement of FIG. 17 can be used for example to lower the static pressure in the airstream of the inner flow duct 16, with the aid of the ejector system 110 or similar device that serves to provide reduced-flow cross-sectional area or otherwise modify the flow areas of the flow duct 16 to reduce static pressure, so that ram air in the outer flow duct 336 can be pulled through the HX component 340. The inner and outer flow ducts 16, 336 are not limited to the configuration shown in
FIG. 17, and other embodiments are contemplated. For example, in an embodiment, a portion of the outer flow duct 336 downstream from the fluid flow duct 358 can be eliminated at the aft end of the gas turbine engine 10.

[0064] In the FIG. 18 mode of operation, the upstream rotatable cylinder fluid flow duct assembly 352 is rotated to an open state and the downstream rotatable cylinder fluid flow duct assembly 354 is rotated to a closed state. As such, airflow in the inner flow duct 16 passes through the fluid flow duct 356 to the cold side of the HX component 340 and from the downstream end of the HX component 340 to further downstream in the outer flow duct 336, and airflow in the outer flow duct 336 is blocked from passing through the outer flow duct 336 to the cold side of the HX component 340. The inner and outer flow ducts 16, 336 are not limited to the configuration shown in FIG. 18, and other embodiments are contemplated.

[0065] Although the variable geometry configuration of HX components has been described herein as having applicability to gas turbine engines, it will be appreciated that other applications may also be suitable.

[0066] Any theory, mechanism of operation, proof, or finding stated herein is meant to further enhance understanding of embodiment of the present invention and is not intended to make the present invention in any way dependent upon such theory, mechanism of operation, proof, or finding. In reading the claims, it is intended that when words such as "a," "an," "at least one," or "at least one portion" are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. Further, when the language "at least a portion" and/or "a portion" is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

[0067] While embodiments of the invention have been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the selected embodiments have been shown and described and that all changes, modifications and equivalents that come within the spirit of the invention as defined herein of by any of the following claims are desired to be protected.
CLAIMS

What is claimed is:

1. A gas turbine engine flow duct comprising:
   a flow duct disposed along an engine centerline of the gas turbine engine and
defining a stream flow passage; and
   first and second rows of heat exchangers disposed along the engine centerline of
   the gas turbine engine and integrated in the flow duct in fluid communication with the
   stream flow passage of the flow duct.

2. The gas turbine engine flow duct of claim 1 in which the flow duct is an annular
   bypass flow duct that surrounds a core of the gas turbine engine.

3. The gas turbine engine flow duct of claim 1 in which the flow duct comprises a third
   stream flow duct that surrounds a second stream flow duct that surrounds a core of the gas
turbine engine.

4. The gas turbine engine flow duct of claim 1 in which the flow duct comprises a ram
   air duct.

5. The gas turbine engine flow duct of claim 1 in which the heat exchangers of the first
   row are equally circumferentially disposed about the engine centerline.

6. The gas turbine engine flow duct of claim 1 in which the heat exchangers of the first
   row are circumferentially disposed about the engine centerline at a first radial distance from
   the engine centerline, and the heat exchangers of the second row are circumferentially
   disposed about the engine centerline at a second radial distance from the engine centerline.

7. The gas turbine engine flow duct of claim 6 in which the first and second radial
   distances are substantially the same.

8. The gas turbine engine flow duct of claim 1 in which the heat exchangers of the first
   row are angularly offset from the heat exchangers of the second row.
9. A gas turbine engine flow duct comprising:
   a flow duct disposed along an engine centerline of the gas turbine engine and defining
   a flow duct passage; and
   a plurality of heat transfer components integrated in the flow duct and configured to
   have a variable geometry arrangement for adjusting static pressure in the flow duct passage
   downstream of the heat transfer components.

10. The gas turbine engine flow duct of claim 9 in which the variable geometry
    arrangement of heat transfer components includes first and second rows of heat transfer
    components in fluid communication with the flow duct passage of the flow duct, wherein the
    first and second rows of heat transfer components are relatively axially adjustable along the
    engine centerline of the gas turbine engine.

11. The gas turbine engine flow duct of claim 9 in which the variable geometry
    arrangement of heat transfer components includes first and second rows of heat transfer
    components in fluid communication with the flow duct passage of the flow duct that define
    therebetween intermediate adjustable fluid flow passages.

12. The gas turbine engine flow duct of claim 9 in which the variable geometry
    arrangement of heat transfer components includes the heat transfer components and nozzle
    components circumferentially disposed about the engine centerline.

13. The gas turbine engine flow duct of claim 9 in which the variable geometry
    arrangement of heat transfer components includes the heat transfer components and ejectors
    circumferentially disposed about the engine centerline, in which the ejector comprises a
    nozzle component and a diffuser component disposed along the engine centerline.

14. The gas turbine engine flow duct of claim 9 in which the flow duct is an annular
    bypass flow duct that surrounds a core of the gas turbine engine.

15. The gas turbine engine flow duct of claim 9 in which the flow duct comprises an outer
    flow duct that surrounds an inner flow duct, and the inner flow duct surrounds a core of the
    gas turbine engine.
16. A method of adjusting pressure distribution in a gas turbine engine flow duct having heat exchangers comprising:
   providing fluid flow through a stream flow passage of a flow duct disposed along an engine centerline of the gas turbine engine; and
   using first and second rows of heat exchangers disposed along the engine centerline of the gas turbine engine and integrated in the flow duct in fluid communication with the stream flow passage of the flow duct to adjust the pressure difference across the first and second rows of heat exchangers.

17. The method of claim 16 in which the providing fluid flow comprises providing bypass air flow.

18. The method of claim 16 in which the providing fluid flow comprises providing ram air flow.

19. The method of claim 16 in which the providing fluid comprises providing fluid through a third stream flow passage.

20. The method of claim 16 in which the providing fluid comprises providing fluid through a ram air stream flow passage.
FIG. 3
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. F02K3/115 F02C7/14

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED:

Minimum documentation searched (classification system followed by classification symbols)

F02K F02C

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<td>US 2012/128467 AI (RUTHEMEYER MICHAEL ANTHONY [US]) 24 May 2012 (2012-05-24)</td>
<td>1,2, 4-12, 14, 16-18,20</td>
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X Further documents are listed in the continuation of Box C.

X See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“B” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“Z” document member of the same patent family

Date of the actual completion of the international search

10 March 2014

Date of mailing of the international search report

17/03/2014

Name and mailing address of the ISA/

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Authorized officer

Steinhauser, Udo
### DOCUMENTS CONSIDERED TO BE RELEVANT

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