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Bolger

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[45] **July 29, 1975**

[54] **HEAT EXCHANGER FOR GAS TURBINE ENGINES**

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[52] **U.S. Cl.** **165/86;** 65/105

[51] **Int. Cl.** **F28d 11/00**

[58] **Field of Search** 165/86, 105, 106, 107; 60/39.57

[56] **References Cited**

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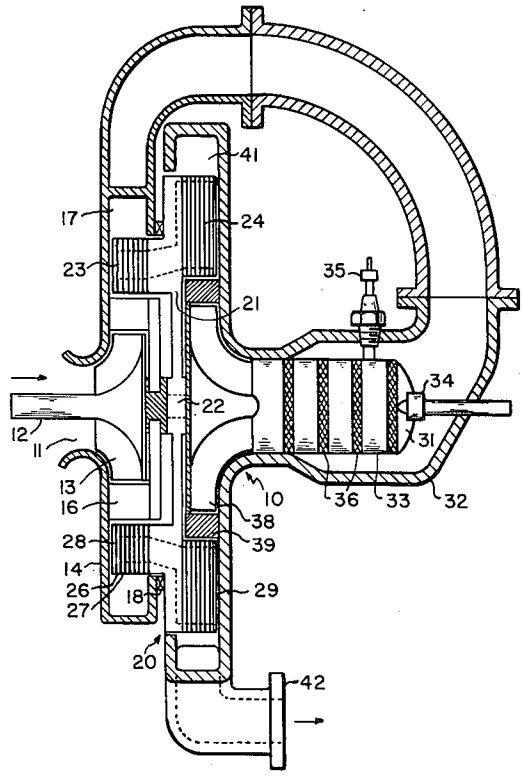
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Primary Examiner—Charles Sukalo
Attorney, Agent, or Firm—Thomas C. Wettach; Arland T. Stein

[57] **ABSTRACT**

The heat exchanger of the present invention includes a first and second matrix mounted for free rotation about the main shaft of the gas turbine. The first matrix is in contact with compressed air from the turbine compressor and the second matrix is in contact with the exhaust gases of the turbine. Each matrix includes a plurality of air passageways for flow therethrough of the respective contacting gases. Additionally each matrix includes at least one and preferably a plurality of fluid chambers positioned perpendicularly to the passageways wherein each chamber is in communication with an associated fluid chamber of the other matrix. Each fluid chamber includes a fluid which is vaporizable in the second matrix to extract thermal energy therefrom and which condenses in the first matrix to release thermal energy thereto to preheat the compressor air.

15 Claims, 18 Drawing Figures



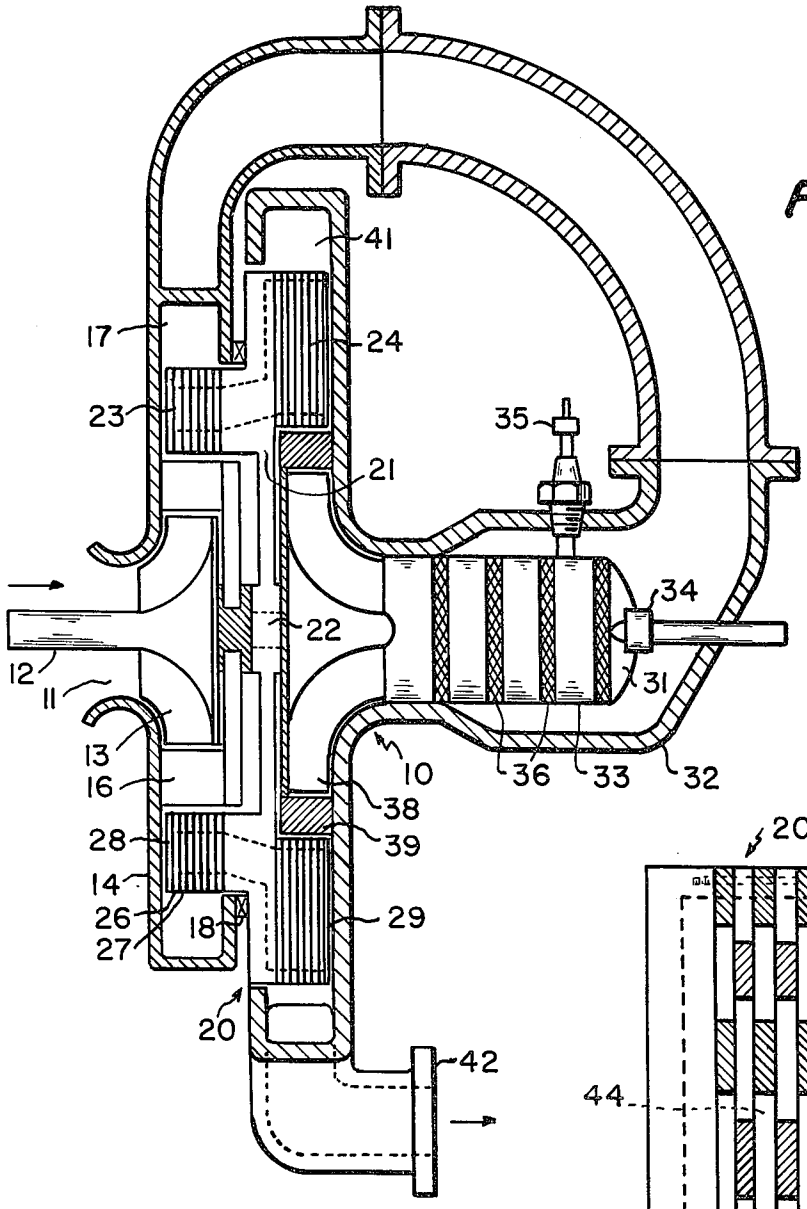

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Fig. 1

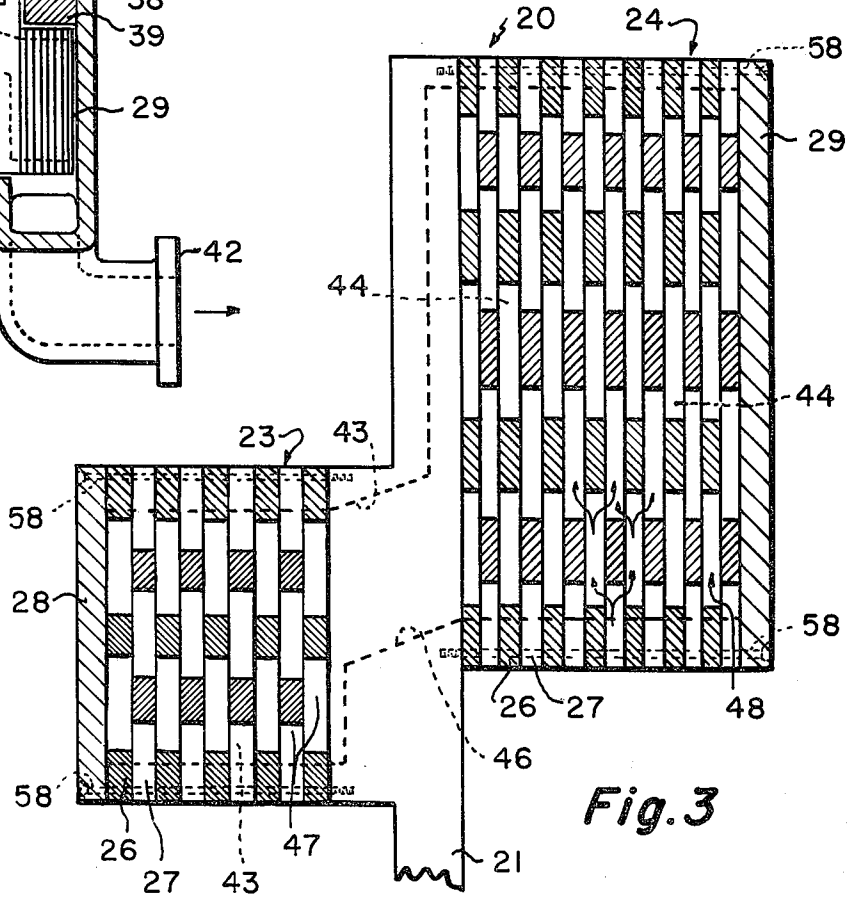

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Fig. 3

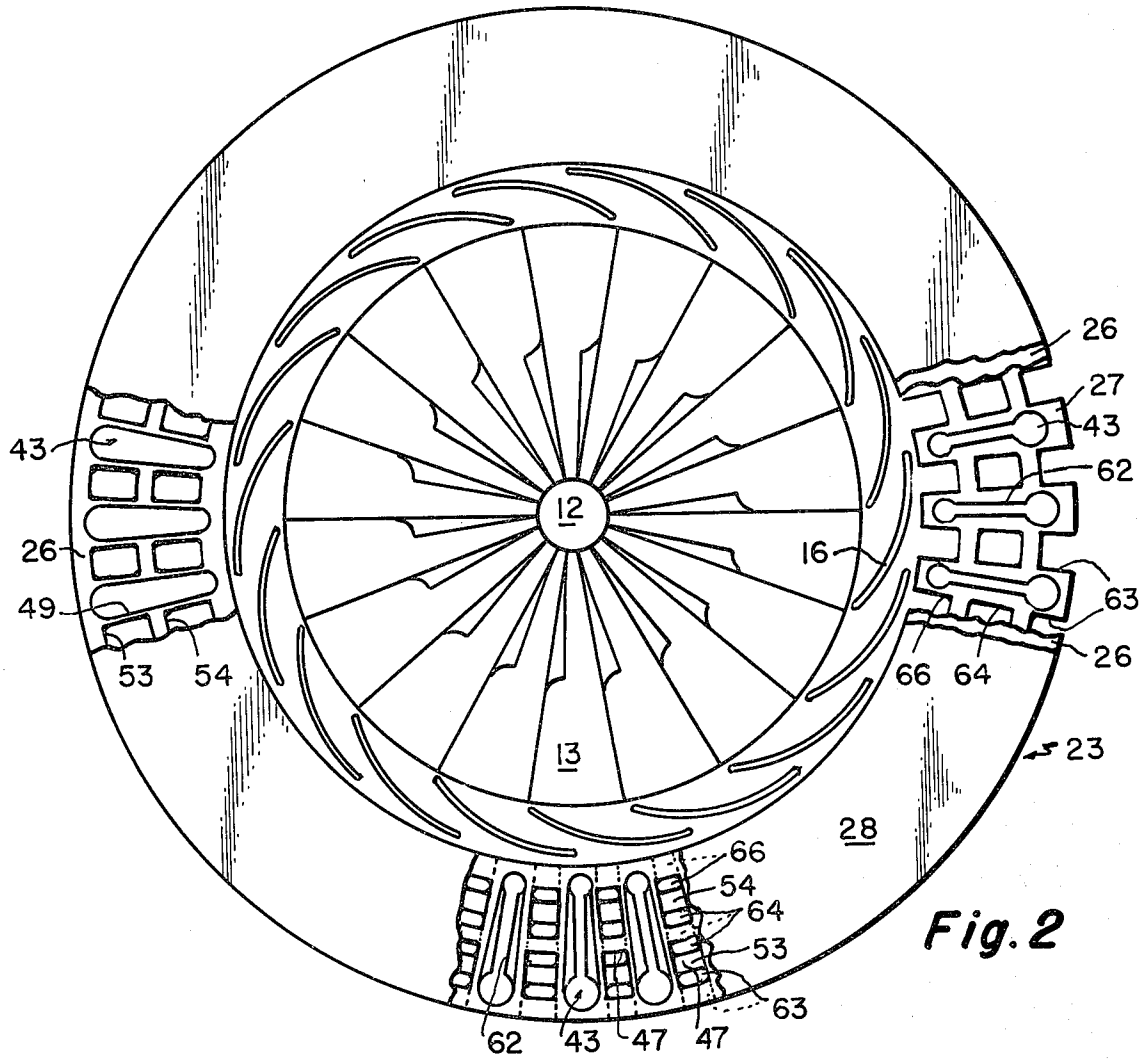

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Fig. 2

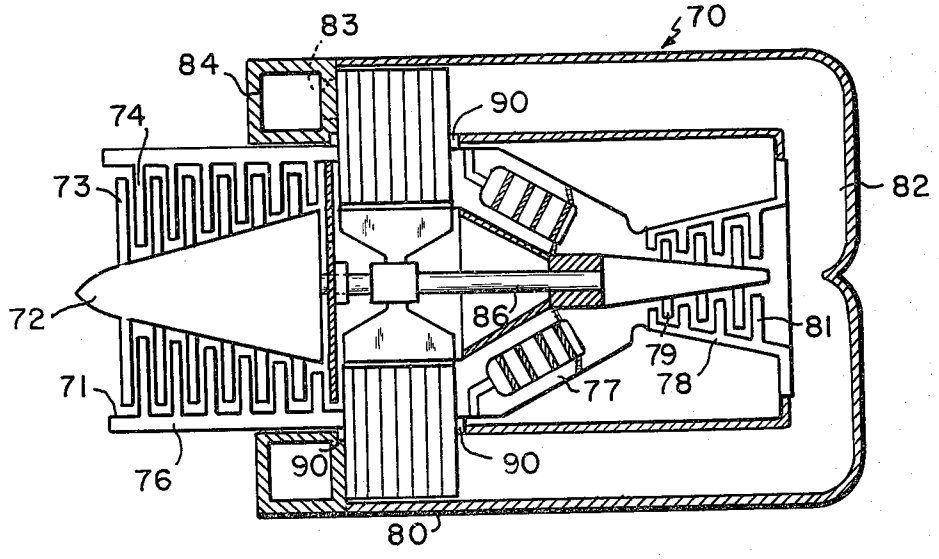

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Fig. 7

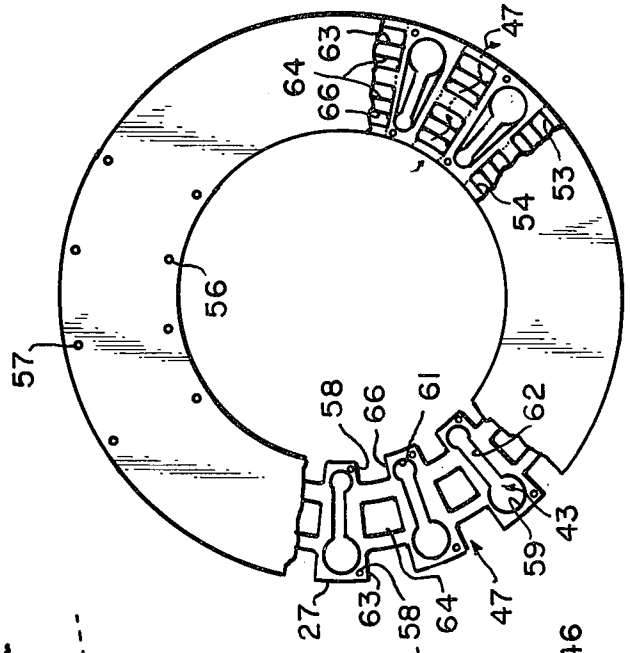


Fig. 5

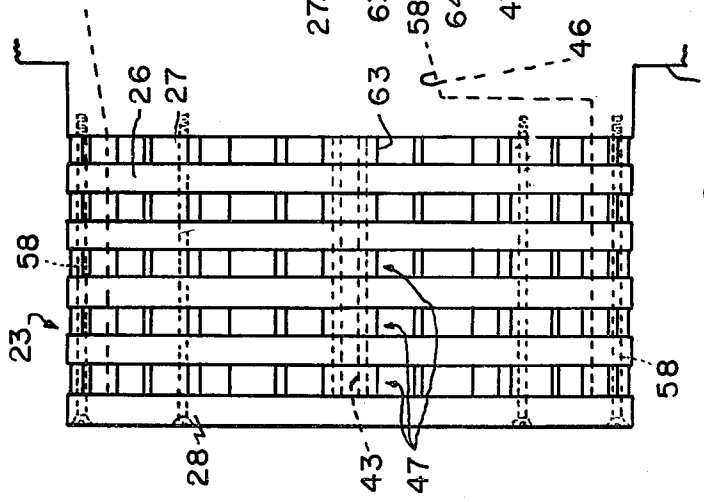


Fig. 6

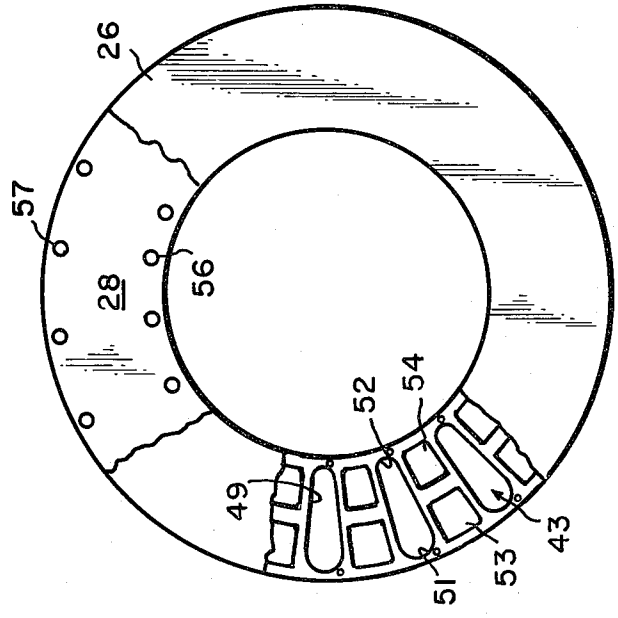


Fig. 4

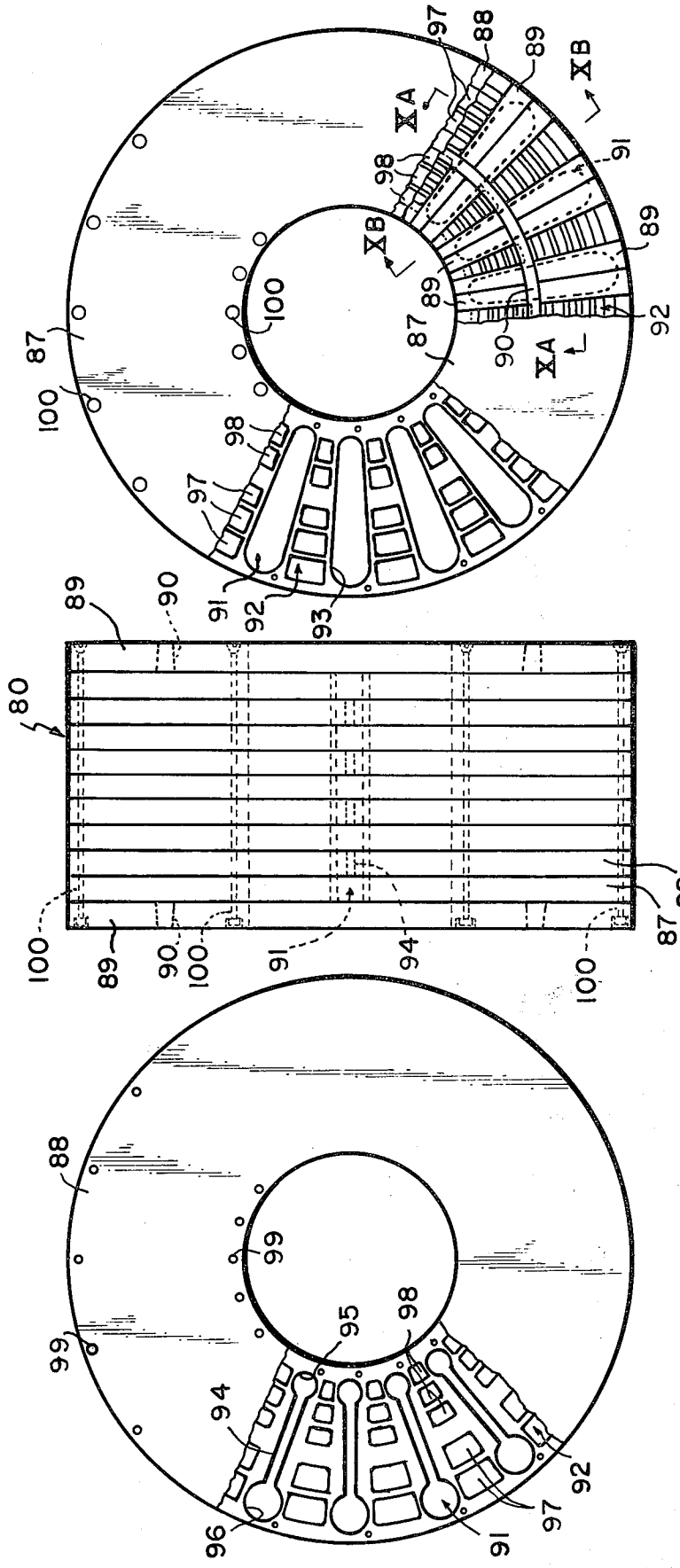


Fig. 10

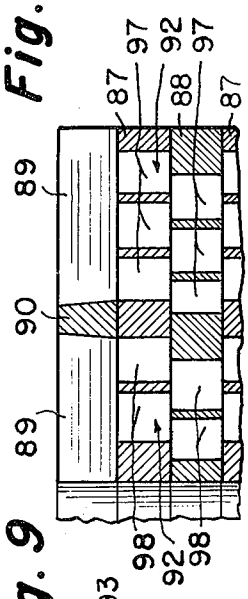


Fig. 10B

Fig. 9

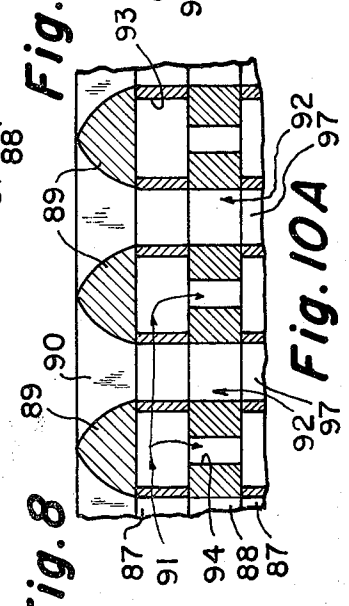


Fig. 10A

Fig. 8

Fig. 11

Fig. 12

Fig. 13A

Fig. 13B

Fig. 13C

Fig. 14

HEAT EXCHANGER FOR GAS TURBINE ENGINES

FIELD OF THE INVENTION

The present invention relates to a heat exchanger for use in gas turbine engines, and, in particular, to a high efficiency, low bulk heat exchanger utilizing a working fluid to transfer thermal energy from exhaust gases to compressed gas of a turbine engine.

BACKGROUND OF THE INVENTION

Gas turbine engines have been known and utilized for many years. Applications to which the gas turbines have been adapted have been limited because of their high specific fuel consumption compared to other types of engine and power sources which were or are available.

The efficiency and specific fuel consumption of a gas turbine can be improved by at least two fairly well known thermodynamic means. One method is to increase the combustion temperature, but this method is limited by the practical limitation of the materials available as well as their cost. The other method is recovering thermal energy which would otherwise be lost in the exhaust gases and transferring it to the compressed air prior to entry into the combustion chamber. The principle advantage of the latter method is that less fuel is required to reach the turbine limiting temperatures resulting in a higher thermal efficiency, lower specific fuel consumption, and lower exhaust gas temperatures.

Generally, two types of heat exchangers are used in gas turbines, the recuperative type where there is a continuous flow of exchange fluids and the regenerative type where exchange is by periodic flow. In practice, the recuperator comprises a fixed matrix of tubes which carries one of the exchange fluids and about which the other fluid is circulated either in parallel or at an angle thereto. In the regenerator a fixed or movable matrix is utilized. In the movable regenerator, the matrix is alternatively subjected to the hot and cold exchange fluids. In the fixed or stationary regenerator, a working fluid, e.g. liquid metal, is alternatively subjected to the hot and cold exchange fluids.

In one example of a movable regenerator, a porous matrix is rotated about an aixs permitting air which is to be preheated to enter through the matrix and absorb heat. At the same time exhaust air is passing through the matrix, usually in an opposite direction, giving up thermal energy to the matrix. This type of regenerator requires elaborate sealing means to separate the incoming air from the exhaust gases.

In a stationary regenerator, the working fluid, usually a liquid metal, must be pumped from the matrix portion in contact with the exhaust gases to the matrix portion in contact with incoming air. The requirements for pumping the working fluid between the two exchange areas necessitates complicated piping as well as pumps thereby adding to the weight of the turbine. Liquid metal heat exchangers also entail very complicated design precautions in addition to the power loses caused by the pump. Moreover, there exists no satisfactory working fluid for the entire temperature range of the gas turbine.

Accordingly, it is an object of the present invention to provide a heat exchanger for use in gas turbine engines which overcomes the inherent limitations and disadvantages of recuperators and regenerators of the prior art. It is a further object of the present invention

to provide a heat exchanger which is adaptable to both centrifugal and axial gas turbine engines.

SUMMARY OF THE INVENTION

The present invention provides a heat exchanger for use in gas turbine engines which efficiently transfers thermal energy from the exhaust gases to the compressed air prior to its entry into the combustion chamber. The heat exchanger of the present invention neither requires elaborate and expensive sealing means as in movable regenerators nor expensive and heavy pumping means as required in fixed regenerators. The size of the heat exchanger of the present invention is comparable to prior art regenerators and recuperators.

Generally, the heat exchanger of the present invention comprises a first and second matrix rotatably mounted within the gas turbine. Preferably, the first and second matrix are mounted as a single unit for free rotation. The first matrix is in contact with air from the compressor of the turbine and the second matrix is in contact with the hot exhaust gases. Each matrix comprises a plurality of passageways extending therethrough and at least one fluid chamber positioned at an angle to the passageways. Preferably, a plurality of fluid chambers are provided in each matrix which may be interconnected to define a single chamber in each matrix of which are independent of each of the other chambers within that matrix. The passageways are preferably labyrinth in nature to provide a high surface contact area to the respective contacting gas of each matrix. Each fluid chamber is in communication with an associated chamber of the other matrix where the chambers are independent and in communication with an associated common defining chamber of the other matrix where interconnected.

Each of the fluid chambers contains a quantity of continuously circulating fluid which absorbs heat from the second matrix in contact with the exhaust gases passing therethrough. The fluid vaporizes in the chambers of the second matrix and condenses to release the thermal energy in the chambers of the first matrix which is in contact with the cool compressed air of the turbine compressor. The continuous circulation of the fluid is caused by the forces acting on the two phases of the fluid. Gas diffusion forces act upon the vapor to transport it to the first chamber for condensing. An external force, preferably the centrifugal force of the rotating heat exchanger, acts upon the condensate to force it to the second matrix chamber where it is vaporized. The fluid must have a boiling point within the temperature range to which the heat exchanger is subjected.

Preferably the heat exchanger of the present invention comprises a plurality of first and second annular discs mounted alternatively face-to-face to form the first and second matrices. Each of the first and second discs includes a plurality of fluid chambers and gas passageway openings of different dimensions so as to form when bonded together high surface area fluid chambers and labyrinth path passageways. For a centrifugal gas turbine the outer diameter of the first and second annular discs of the first matrix is slightly larger than the inner diameter of the first and second annular discs of the second matrix to provide a centrifugal force gradient that maintains substantially all of the liquid in the second matrix. The first and second matrices in a centrifugal turbine are preferably mounted to a mounting

plate adapted for free rotation about the drive shaft. The fluid chambers are radially spaced apart and extend axially about each matrix and the gas passageways extend from the inner to outer diameter of each matrix.

In an axial gas turbine, the air passageways are axially positioned within the matrices and the fluid chambers are positioned radially. In both heat exchangers, the fluid chambers are preferably staged to increase the heat transfer efficiency of the unit.

Accordingly, the present invention provides an efficient means for thermodynamically increasing the efficiency of a gas turbine engine. Other advantages of the invention will become apparent from a perusal of the following detailed description of presently preferred embodiments taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional elevation of a generalized centrifugal gas turbine utilizing the heat exchanger of the present invention;

FIG. 2 is an elevation in partial cutaway of the heat exchanger of FIG. 1 mounted cencentrically about the diffuser and impeller members;

FIG. 3 is an enlarged view, in partial section, of the first and second matrices of the heat exchanger;

FIG. 4 is an elevation partially showing the fluid chamber and air passageway openings formed therethrough;

FIG. 5 is an elevation in partial detail of a second annular disc and a partial cutaway elevation of the first and second annular discs, respectively;

FIG. 6 is a front elevation of the first matrix;

FIG. 7 is an elevation in partial section of a generalized axial gas turbine utilizing the heat exchanger of the present invention;

FIG. 8 is an elevation of a second annular disc of the heat exchanger of FIG. 7 showing in partial view the fluid chamber and air passageway opening formed therethrough;

FIG. 9 is a side elevation of the heat exchanger shown in FIG. 7;

FIG. 10 is an elevation in partial view of a first annular disc and a partial elevation of the matrix shown in FIG. 9;

FIG. 10A is an enlarged section of the cover plate and discs taken along line XA—XA of FIG. 10;

FIG. 10B is an enlarged section of the cover plate and discs taken along line XB—XB of FIG. 10;

FIG. 11 is a partial elevation of a first annular disc for a two stage heat exchanger for use in a centrifugal gas turbine;

FIG. 12 is a partial elevation of a second annular disc for a two stage heat exchanger;

FIG. 13A, B and C are partial elevations of a mounting plate for a two stage heat exchanger comprising the first and second annular discs of FIGS. 11 and 12; and

FIG. 14 is a partial cutaway of the assembled discs and mounting plates shown in FIGS. 11A–13C.

PRESENTLY PREFERRED EMBODIMENT

With reference to FIG. 1, a single stage heat exchanger 20 of the present invention is shown for use in a single stage centrifugal compressor gas turbine 10. Generally, gas turbine 10 includes an inlet port 11 of a size and configuration to supply proper air flow to the front of the compressor with an even pressure distribution. Gas turbine 10 includes a drive shaft 12 to which is mounted impeller 13 of the compressor unit. Mounted to outer casing 14 of turbine 10 is diffuser manifold 16 positioned circumferentially around impeller 13. By means of impeller 13 and diffuser 16, the inlet air to the turbine is increased in pressure and discharged into compressor manifold 17 where it is thereafter heated. Seal 18 prevents the escape of compressed air from around heat exchanger 20.

Heat exchanger 20 of the present invention is positioned adjacent to the impleller/diffuser assembly. Heat exchanger 20 includes an annular mounting plate 21 having axial bearing mounts 22 adapted to provide free rotation of the heat exchanger about shaft 12. Heat exchanger 20 includes a first matrix 23 for preheating incoming air and a second matrix 24 for extracting thermal energy from exhaust gases mounted to the respective sides of mounting plate 21. Each matrix comprises a plurality of first annular discs 26 and second annular discs 27 alternatively bonded to each other and end plates 28 and 29, respectively. Compressed air from diffuser 16 is directed through first matrix 23 of heat exchanger 20 with a tangential velocity sufficient to cause heat exchanger 20 to freely rotate. As the compressed air passes through first matrix 23 the air absorbs thermal energy in a manner set forth in more detail hereinafter.

The preheated compressed air is discharged from heat exchanger 20 into compressor manifold 17 which is in communication with burner 31. Generally, burner 31 comprises an outer combustion liner 32 and an inner combustion liner 33 having at least one fuel nozzle 34 extending into inner combustion chamber 33 for introduction of fuel. A spark plug 35 is provided for ignition of the incoming fuel. The average temperature of the gases entering the turbine is usually as close to the temperature limit of the burner material as possible to obtain maximum engine performance. Since inner combustion liner walls 33 must be protected from high temperatures of combustion, a plurality of openings or corrugations 36 are provided therethrough for the introduction of cooling air at several stations therealong and to provide an insulating layer or film between the hot gases and the metal wall of the outer combustion liner 32. The hot combustion gases are directed out of the combustion chamber to radial outflow turbine 38 and exhaust diffuser 39. The hot turbine exhaust gases outflow is directed through second matrix 24 of heat exchanger 20 for discharge into exhaust manifold 41 through exhaust ports 42.

Referring to FIG. 2, first matrix 23 of heat exchanger 20 is radially positioned from impeller 13 and diffuser manifolds 16. Thus, the inner diameter of first matrix 23 is slightly larger than the outer diameter of diffuser member 16. As shown in FIG. 3, the outer diameter of first matrix 23 is slightly larger than the inner diameter of second matrix 24 to provide a centrifugal force gradient between the two matrices for proper maintenance of thermal transfer fluid circulation.

With reference to FIGS. 2 and 3, matrices 23 and 24 include a plurality of axial fluid chambers 43 and 44, respectively. Fluid chambers 43 and 44 are interconnected through opening 46 is mounting plate 21. Because of the relative positioning of matrices 23 and 24, fluid chamber 44 of second matrix 24 is radially offset from fluid chamber 43 of matrix 23 providing the centrifugal force gradient. Opening 46 of mounting plate

21 is of a size coextensive with the overlap of fluid chamber 43 and fluid chamber 44.

Matrices 23 and 24 comprise a plurality of labyrinth gas passageways 47 and 48 respectively. Air enters passageways 47 from diffuser 16 and exhaust gas enters passageways 48 from turbone 38 and exits to the respective compressor and exhaust manifolds. A tangential velocity component at the air leaving diffuser 16 of the compressor unit causes the heat exchanger 20 to freely rotate about shaft 12 at about 600–1100 RPM. While plate 21 could be mounted for direct rotation with shaft 12, it is not preferred because the high RPM developed by the engine would disrupt the gas flow through the matrices and would place high centrifugal loads on the heat exchanger. Accordingly, it is preferred that plate 21 be free to rotate to match the tangential velocity of the gas leaving diffuser 16 and turbine 38.

A transfer fluid such as water is contained within fluid chambers 44 at the outer peripheral inner surface by means of centrifugal force. Fluid condensate circulates from chambers 43 into fluid chamber 44 where it is vaporized as it contacts the surfaces which are at an elevated temperature due to the exhaust gases passing through passageways 48. Chambers 43 may include a slight draft angle which extends from end plate 28 to mounting plate 21 such that outer peripheral portions of the fluid chambers increase in size slightly from the end plate to the mounting plate.

Referring to FIGS. 4 through 6, first and second matrices 23 and 24 respectively, comprise a plurality of first and second annular discs 26 and 27, respectively. Discs 26 and 27 may be made from any suitable high temperature metal preferably stainless steel. The first and second discs of first matrix 23 are substantially the same as those of second matrix 24, except the size of the discs are larger and, thus, the relative proportions of fluid chambers 44 and air passageways 48 are larger for matrix 24 than matrix 23. Accordingly, it is necessary to describe in detail only one of the matrices.

Fluid chambers 43 of matrix 23 preferably comprise a plurality of individual chambers formed in each of the discs. In first disc 26, fluid chambers 43 comprise a plurality of radially extending oblong openings 49 cut in annular disc 26. Openings 49, shown in partial detail in FIG. 4, radially extend around the entirety of disc 26 and preferably include rounded end portions or outer end portions 51 having a radius larger than inner end portions 52. Annular disc 26 also includes a plurality of air passageways 47 formed therethrough between each of the fluid chamber openings 49. Air passages 47 of annular disc 26 include two radially spaced apart openings 53 and 54. Whereas two large openings are shown, any number of variously sized openings can be used, provided, however, that a large surface area for thermal transfer is provided while at the same time not creating such a restricted or constricted passage as to provide a large pressure drop between diffuser 16 and compression manifold 17. Located around the inner and outer periphery of annular disc 26 are a plurality of recessed openings 56 and 57 for bolts 58 used to mount matrices 23 and 24 to plate 21.

With reference to FIG. 5, second annular disc 27 includes a plurality of fluid chambers 43, identical in number with disc 26 and around the entirety of the disc. Fluid chambers 43 of the second annular disc 27 are formed to include bulbular end portions 59 and 61. Outer bulbular portions 59 have a radius substantially the same as end portions 51 of elongated openings 49 in first annular disc 26. The inner bulbular portion 61 has a radius substantially identical to the inner end portion 52 of openings 49 in first annular disc 26 to provide a substantially unrestricted passage along the upper and lower portions of fluid chambers 43. Between outer and inner bulbular portions 59 and 61 is a connecting neck member 62 having a width less than the corresponding width along longitudinal radial opening 49 of discs 26.

Air passageways 47 of second annular disc 27 include radially located openings 63, 64 and 66 positioned between each of the fluid chambers 43. Outer openings 63 provide a discharge for each passageway 47 and 48 from matrices 23 and 24, respectively. Openings 66 provide for ingress from diffuser 16 and turbine 38 into matrices 23 and 24, respectively. As shown in FIG. 5, openings 66 overlap openings 54 of first annular disc 26. Center openings 64 are adapted to overlay both openings 53 and 54 of first annular disc 26 and openings 63 of discs 27 are adapted to overlie openings 53 of disc 26. Thus, when first and second annular discs 26 and 27 are brought together to form a matrix, air passageway 47 of matrix 23 and passageways 48 of matrix 24 are formed as a cooperative labyrinth between openings 63, 53, 64, 54 and 66 of the first and second annular discs, respectively. By means of these labyrinth passageways, good heat exchange properties are attained without substantial energy losses or pressure differentials between ingress openings 66 and egress openings 63. Fluid chamber 43 provides high surface contact area because of the constriction formed by neck 62 in second annular disc 27 as shown in FIG. 5. There is, however, a substantially unrestricted passage at the outer radial end portions because of the substantial radial conformity between bulbular portions 59 and end portions 51 of second and first annular discs, respectively. This is also the case with inner bulbular portion 61 and radial end portions 52. With respect to first matrix 23, outer bulbular end portions 59 and end portions 51 are of increasing diameter from end plate 28 to mounting plate 21 to provide a slight draft angle, if desired, to facilitate the flow of condensate into matrix 24. So as not to require the separate manufacture of each disc for matrix 23, the angle could be made after fabrication or bonding of the discs. Transfer fluid is of an amount sufficient to fill outer bulbular portions 59 and necks 62, thereby leaving unrestricted lower bulbular portions for the free flow of vaporized fluid.

Alternatively, the fluid chambers of both matrices, but preferably only fluid chambers 44, can be defined as a single chamber by interconnecting the inner portions of each of the discs by including an annular channel in either or both mounting plate 21 and/or end plates 28 and 29. Any imbalance in the heat exchanger during start-up is corrected before combustion is fully initiated and without any adverse wear on the bearings.

Referring to FIG. 7, another embodiment of the heat exchanger of the present invention is disclosed for use in an axial compressor gas turbine 70. Generalized axial gas turbine 70 includes an inlet 71 and an axial compressor 72. Axial compressor 72 includes rotor blades 73 and stator 74 mounted on casing 76. Compressed air from axial compressor 72 passes through the first matrix of heat exchanger 80 into combustion chamber 77. Combustion gases from combustion

chamber 77 are directed into axial turbine 78 having rotors 79 mounted thereto and stators 81 positioned on turbine casing. Exhaust gases from the turbine are ducted into manifold 82 and directed to second matrix of heat exchanger 80 to exhaust ports 83 and exhaust manifold 84. Axial compressor 72 and axial turbine 78 are both mounted on shaft 86. Heat exchanger 80 is rotatably mounted on shaft 86 and adapted to freely rotate independently thereof.

Referring more particularly to FIGS. 8 through 10, heat exchanger 80 comprises alternately mounting first and second annular discs 87 and 88, and end covers 89. Heat exchanger 80 comprises a plurality of fluid chambers 91 and air passageways 92. Fluid chambers 91 are similar in nature to those of heat exchanger 20 for the centrifugal compressor type of gas turbine. They include a plurality of elongated openings 93 radially positioned around first annular disc 87, and openings 94 radially positioned around second annular disc 88 having inner and outer bulbular portions 95 and 96, respectively. Air passageways 92 comprise a plurality of radially spaced openings 97 between chamber openings 93 and 94 and positioned about the outer radial half of each annular disc 87 and 88. Radially spaced openings 98 are positioned about the inner radial half of the respective annular discs between the fluid chamber openings. Preferably, openings 97 in first annular disc 87 are radially offset from openings 97 in second annular disc 88 to provide a labyrinth path as shown in FIG. 10 and 10B for high heat exchange surface area as well as gas turbulence. This is also the case with respect of openings 98 of the second matrix. Openings 97 through the outer radial half of the annular discs provides a heat transfer area for hot exhaust gases passing therethrough. Openings 98 through the inner radial half of the annular discs provide passage for axially compressed intake air. The axially compresses air has a radial component or a radial tangential force which causes heat exchanger 80 to freely rotate upon shaft 86 as the air passes therethrough.

With reference to FIGS. 10, 10A and 10B, the end covers positioned on both sides of heat exchanger 80 comprise a plurality of aerodynamically shaped members 89 which overlie only the fluid chamber and aid in forcing air or gas into passageways 97 and 98. Cover 89 includes an annular seal 90 to prevent the escape of compressed air or exhaust air into the exhaust manifold or combustion chamber. Fluid chambers 91 can be defined as a single chamber by providing an annular channel at the base of each disc which is in communication with each chamber opening.

Annular discs 87 and 88 include a plurality of recessed openings 99 for securing bolts 100. Thermal transfer fluid condensate in fluid chamber 91 is maintained at the hot end of the chamber by means of centrifugal force which displaces the vaporized fluid for condensation in the lower portion of the chamber. In the construction of regenerators 20 to 80, it is preferable that no seals between the respective annular discs be utilized. It is therefore preferable that the discs be diffusion or fusion bonded to each other to provide effective sealing and an integral assembly.

The embodiments previously described with respect to the centrifugal and axial gas turbines were both addressed to one stage heat exchangers. In practice, however, a multi-stage heat exchanger may be desired to achieve maximum thermal energy transfer. Essentially the same design parameters are utilized and the only practical difference is twice the number of fluid chambers are used for a two stage heat exchanger, for example, or 3 times as many for a three stage exchanger.

For the purpose of explaining the nature of the changes needed to adapt the heat exchanger of the present invention to a multi-stage unit, FIGS. 11 through 14 are directed to the second matrix of a two stage heat exchanger. The principles involved in a two stage heat exchanger are, however, applicable to any multiple stage heat exchanger. Referring in particular to FIG. 11, a first annular disc 101 of a second matrix (in contact with hot exhaust gases) comprises a plurality of first and second fluid chambers 102 and 103. Fluid chambers 102 are positioned about the outer radial half of disc 101 while second chambers 103 are positioned about the inner radial half of the disc The first and second chamber are radially positioned about disc 101 so as to be radially "out-of-phase" with each other. Fluid chambers 102 and 103 of the first annular disc 101 are of the same configuration as fluid chamber openings 49 of first annular disc 26 of the single stage heat exchanger 20 described above.

Positioned between each of the fluid chambers 102 and 103 are openings 104 and 105, respectively, for the passage of hot exhaust gases. A plurality of intermediate openings 106 are positioned so as to be coextensive with openings 104 and 105. Intermediate openings 106 provide passage bridges between the radially offset array of openings 104 and 105. Alternatively, the radial inner and outer portions of discs 101 can be separately made and spaced apart to define an annular opening in place of intermediate openings 106. While this method creates additional assembly steps, a less restricted air passageway is provided.

Referring to FIG. 12, second annular disc 107 comprises a plurality of first and second fluid chambers 108 and 109 positioned about the outer radial half and inner radial half of the disc, respectively. Fluid chambers 108 and 109 of the second annular disc 107 have the same configuration as chambers 43 of second annular disc 27, that is, they include inner and outer bulbular portions connected by a constricted neck portion. First and second fluid chambers 108 and 109 are radially offset from each other.

Positioned between each of the fluid chambers 108 and 109 are openings 111 and 112, respectively. Openings 111 and 112 are positioned to overlie at least two associated openings 104 and 105 respectively of first disc 101. Intercommunication between openings 111 and 112 of disc 107 is provided by means of intermediate openings 106 of disc 101, as shown more clearly in FIG. 14. Each radial array of openings 111 includes a partial opening encompassing the outer periphery of disc 107 and each radial array of openings 112 includes a partial opening encompassing the inner periphery of disc 107 for egress and ingress, respectively, of exhaust gases.

The primary differences between a multiple stage, e.g. two stage, heat exchanger and a single stage heat exchanger is the nature of the connections between the associated fluid chambers of the first and second matrices. To achieve the advantage of a two stage heat exchanger, the fluid chambers positioned about the outer radial half of the first matrix formed by openings 102 and 108 are connected to the fluid chambers positioned about the inner radial half of the second matrix

formed by the respective openings **103** and **109.** And the inner fluid chambers of the first matrix are connected to the outer fluid chambers of the second matrix.

In order to effect the desired inner-outer connection, a mounting plate comprising at least three annular discs is required. Referring to FIG. **13A**, a first plate **113** of the mounting plate comprises openings **114** and **116** adapted for associated communication with fluid chambers of the second matrix formed by openings **102** and **108** and **103** and **109,** respectively, of the second matrix. An intermediate disc **117** having radial openings **118** and **119,** FIG. **13B**. Openings **118** and **119** are in communication with openings **114** and **116** of first plate **113,** respectively. A third plate **121** is positioned adjacent intermediate plate **117** and includes openings **122** and **123.** Openings **122** are in communication with opening **118** of plate **117** and fluid chambers formed by openings **103** and **109** of the first and second annular discs of the first matrix. Openings **123** are in communication with openings **119** of plate **117** and the fluid chambers of the first matrix formed by openings **102** and **108.** Thus, inner fluid chambers of one matrix are connected to the outer chambers of the other as shown in FIG. **14.**

Preferably, the mounting plates **113, 117** and **121** are of thickness greater than the first and second annular discs to provide fluid openings of sufficient size for efficient thermal fluid circulation. Alternatively, these plates could comprise a plurality of thin plates bonded together as in the case of the first and second matrices.

Alternatively, the plurality of fluid chambers of a multi-stage heat exchanger can be defined as a single inner and single outer fluid chamber by providing a first plate similar to plate **113** except that a pair of concentric annular channels would be formed each having at least four equally spaced openings in communication with the channels formed therethrough. Chambers **102** and **103** would be positioned in communication with the outer and inner channels, respectively. A second plate similar to plate **121** would be provided comprising a pair of concentric annular channels each having at least four openings therein. The inner and outer channels would be in communication with the inner and outer fluid chambers of the cold side matrix. A third plate similar to plate **117** would be provided between the first and second plates and would include radial openings similar to openings **118** and **119** for connecting and in communication with the openings in the outer annular channel of one matrix and openings in the inner annular channel of the other matrix. The number of radial openings in the same number of openings formed in the annular channels. By defining a single fluid chamber, greater fluid circulation can be achieved and simpler assembly techniques employed.

Moreover, it is clear that the shape, size and relative placement, as well as the number of fluid chambers and air passageway openings are considerations which are determined for each particular turbine application. Other openings configurations can be used to achieve higher surface contact area of less flow restrictions. Accordingly, the invention may otherwise be embodied within the scope of the appended claims.

What is claimed is:

1. A heat exchanger for gas turbine engines comprising:

a first and second matrix mounted for rotation about a main shaft of said turbine, said first matrix being in contact with gas from the compressor of said turbine and said second matrix in contact with exhaust gas, each of said matrices including a plurality of passageways for passage therethrough of the respective contacting gases, and at least one fluid chamber, said fluid chamber being in communication with an associated chamber of the other matrix and having a thermal transfer fluid contained therein vaporizable at below exhaust gas temperature.

2. A heat exchanger as set forth in claim **1** wherein: said first and second matrices are radially offset from each other and mounted to a mounting plate for said first and second matrices and adapted for rotation about said shaft, said fluid chamber of each matrix being axially aligned with said shaft and said passageways being radially aligned with said shaft.

3. A heat exchanger as set forth in claim **1** wherein each matrix includes a plurality of fluid chambers, each fluid chamber being in communication with an associated chamber of the other matrix.

4. A heat exchanger as set forth in claim **2** wherein said fluid chambers of each matrix are interconnected.

5. A heat exchanger as set forth in claim **2** wherein: first and second matrices comprise a plurality of alternately mounted first and second annular discs, said first and second discs including a plurality of radially extending elongated openings adapted to cooperatively form a plurality of fluid chambers when mounted together, and a plurality of openings radially aligned between alternate elongated openings, the openings of one of said discs adapted to overlie at least two openings of said other disc to form upon mounting passageways extending from the inner circumference to the outer circumference of the matrices.

6. A heat exchanger as set forth in claim **2** wherein said mounting plate includes at least one opening to provide associated communication between the fluid chambers of the respective matrices.

7. A heat exchanger as set forth in claim **1** wherein: said first and second matrices are of an annular configuration and wherein said fluid chambers are radially aligned to said shaft and said passageways are axially aligned with said shaft.

8. A heat exchanger as set forth in claim **7** comprising: a plurality of first and second annular discs, said first matrix comprising an inner radial portion of said discs and said second matrix comprising an outer radial portion of said discs.

9. A fluid chamber as set forth in claim **7** wherein said air passageways are axially positioned to provide a counterflow of the respective gases.

10. A gas turbine heat exchanger comprising:

a first and second matrix mounted for rotation within said turbine, said first matrix being in contact with gas from a compressor of said turbine and said second matrix in contact with exhaust gas, each of said matrices including a plurality of passageways for passage therethrough of the respective contacting gases, and at least first and second fluid chambers, each of said fluid chambers being in communication with an associated chamber of the other matrix and having contained therein a thermal transfer fluid.

11. A gas turbine heat exchanger as set forth in claim 10 wherein each matrix includes a plurality of at least first and second fluid chambers.

12. A gas turbine heat exchanger as set forth in claim 10 wherein said first fluid chamber of one matrix is in communication with said second fluid chamber of said other matrix.

13. A gas turbine heat exchanger as set forth in claim 10 including a mounting plate for mounting said first and second matrices and having at least first and second openings for connecting said first fluid chamber of one matrix with said second fluid chamber of said other matrix.

14. A gas turbine heat exchanger as set forth in claim 11 including a mounting plate for mounting said first and second matrices and having a plurality of at least first and second radial openings for connecting said first fluid chambers of one matrix with associated second fluid chambers of said other matrix.

15. A gas turbine heat exchanger as set forth in claim 14 wherein said mounting plate includes at least two annular channels on each side for interconnecting each of the first fluid chambers and for interconnecting each of the second fluid chambers, said first radial opening connecting said first annular channel of one matrix with said second annular channel of said other matrix.

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