A gas turbine regenerator for passing high pressure compressor discharge air in a heat exchange relation with hot turbine exhaust gases. An air inlet plenum and an air outlet plenum are disposed in a cross-flow relation with respect to the exhaust gas flow, within the exhaust gas flow, whereas a plurality of heat exchange unit pressure tubes fluidly interconnect said air plenums and are disposed in a generally parallel flow relation with respect to said exhaust gas, within the exhaust gas flow. Opposite ends of each unit pressure tube are received into either the air inlet plenum or the air outlet plenum whereby fluid communication between plenums is established and separation at each unit pressure tube opposite end is prevented. Thermal expansion of the heat exchange unit is substantially uniform since both the heat exchange pressure unit tubes and the air plenums are disposed within the hot gas flow.
GAS TURBINE REGENERATOR

BACKGROUND OF THE INVENTION

This invention was made under contract with the United States Government under Contract 0-35510 with the United States Maritime Administration of the Department of Commerce. The U.S. Government is licensed in accordance with the terms of the aforesaid contract and has reserved the rights set forth in Sections 1 and 1 of the Oct. 10, 1963 Presidential Statement of Government Patent Policy.

The invention relates, in general, to heat exchangers; and, in particular, this invention relates to gas turbine regenerators (recuperators). A regenerator (recuperator) is used in a gas turbine power plant to heat compressor discharge air prior to its entry into the combustion chambers thereby reducing the amount of fuel necessary to bring the combustion gases to the required operating temperatures. Heat is transferred to the compressor discharge air from hot turbine exhaust gases which pass through the regenerator in heat transfer relation with the compressor discharge air. The regenerator includes alternating air and gas channels to effect the heat transfer.

Prior art gas turbine regenerators have included box-like structures having plate-fin tube banks with the entire regenerator banded together by tie straps interconnecting massive structural end frames. Compressor discharge air, at relatively high pressure (about 130 psia) tends to push apart the tube banks as well as tending to warp or bow the end frame structure. In the prior art, bowing of the end frame structure was prevented by using a plurality of relatively thick structural ribs incorporated into the massive end frame. The aforesaid construction is disadvantageous in that a thermal mass mismatch is created between the end frames and tube banks in that the tube banks expand more quickly than the end frames creating undesirable stressing in the regenerator.

An attempt to solve this problem is set forth in U.S. Pat. Application Ser. No. 383,705, for Tramuta et al. filed July 30, 1973, and assigned to the assignee of the present invention. The application entitled "Pressurized Strongback Regenerator" minimizes thermal mismatch by replacing the heavy structural ribs by a pressurized air chamber at the ends of each tube bank.

It is therefore one object of the present invention to reduce the overall weight of a gas turbine regenerator.

It is another object of the present invention to minimize thermal mismatch between the tube bundle and its support structure.

It is another object of the present invention to obviate massive structural end frames and tie-strap in regenerator construction.

Other objects and advantages will become apparent from the following description of one embodiment of the present invention, and the novel features will be particularly pointed out hereinafter in the claims.

BRIEF DESCRIPTION OF THE INVENTION

According to the present invention, a regenerator may include one or several heat exchange modules, or sections each section comprising an air inlet plenum and an air outlet plenum mounted in a cross-flow relation with respect to said exhaust gas flow. A heat exchange tube bank is positioned between the air inlet and outlet plenums in a generally parallel flow relation to said exhaust gas flow, the tube bank including a number of unit pressure tubes. Each unit tube includes an air passageway defined by a pair of spaced apart parallel plates attached together at their peripheral edges. There is a slotted opening at each opposite end of each pressure tube. Each air plenum is formed with circumferential slots, along its axial length which receive therein respective opposite end unit pressure tube slotted openings whereby the air inlet and air outlet plenums are in fluid communication and opposite ends of each unit pressure tube are held together by the slotted air plenums. Gas passageways are defined between each pair of air passageways. The air inlet and outlet plenums are in the hot gas flow and thus tend to expand uniformly with the heat exchange tube bank.

FIG. 1 is a partially cut-away perspective view of a gas turbine regenerator according to the present invention.

FIG. 2 is an exploded perspective view of a regenerator section including a heat exchange tube bank and air inlet and outlet plenums.

FIG. 3 is a partially cut-away perspective view of a unit tube structure.

FIG. 4 is a partial end view of a unit tube structure.

DETAILED DESCRIPTION OF THE INVENTION

A regenerative cycle for a gas turbine is well known and is, in particular, shown in FIG. 1 of U.S. Pat. application Ser. No. 383,705, filed July 30, 1973, for Tramuta, Miller and Knox and assigned to the assignee of the present invention. Generally described, the regenerative cycle consists in passing compressor discharge air in a heat exchange relation with hot turbine exhaust gases through a regenerator (recuperator) to raise the temperature of the air prior to the combustion cycle. However, the present invention is applicable to any heat exchange device and the present preferred embodiment is illustrative of one particular use.

Referring to the drawings of the present invention, FIG. 1 shows a regenerator 11 including an outer frame 13 of minimal construction and end flanges 15 for attaching the regenerator into an exhaust gas duct (not shown). The regenerator may be comprised of one or more heat exchange sections 17 each comprising a heat exchange tube bank 19 and an air inlet plenum 21 and an air outlet plenum 23. Flow arrows indicate the exhaust gas flow direction and the compressor discharge air flow direction. The air plenums are each formed with end flanges 25 for connecting the air inlet plenum to the compressor discharge and the air outlet plenum to the combustion chamber inlet respectively (not shown).

Each heat exchange section includes a heat exchange tube bank 19 comprising a plurality of unit pressure tubes as shown in FIGS. 2, 3 and 4. Each unit tube includes a pair of parallel, spaced apart plates 35a and 35b defining an air passageway 37 therebetween. Each air passageway may further include a number of staggered strip-fin means 39 interposed between the parallel plates providing alternating brazing surfaces S. The peripheral edges of each pair of parallel plates are joined to provide a closed seam 43 forming a sealed perimeter about the unit tube air passageway.

The unit pressure tube may be formed with a substantially rectangular section including gas strip-fin means
49 on each air passageway outer surface. Moreover, the air passageways are extended beyond each rectangular portion to form trapezoidal end portions each terminating in an open semi-circular slot 45 which permits air flow through the unit tube air passageway. The gas strip-fin means may be attached to the outer surfaces of the rectangular section by brazing. Obviously, this is only one of several possible configurations since the rectangular section including gas strip-fin means may be extended to obviate the trapezoidal end sections.

The air inlet and outlet plenums are formed with semi-circular slotted openings 55 which are disposed along the longitudinal axis of each air plenum. The slotted openings in the air inlet plenum are substantially aligned with and directed toward the slotted openings in the air outlet plenum. Each unit pressure tube is disposed between the air plenums so that the slot at one end is received into an air inlet plenum slotted opening and the slot at the opposite unit tube structure end is received into an air outlet plenum slotted opening thereby fluidly communicating the air inlet plenum with the air outlet plenum through the plurality of unit pressure tubes. Moreover, separation of the joined parallel plates is prevented at each end of the unit tube structure by the restraint imposed by the slotted pipes comprising the air inlet plenum and the air outlet plenum respectively.

The operation of the regenerator is as follows. Hot turbine exhaust gas flows through the regenerator as indicated in FIG. 1. The air inlet plenums and the air outlet plenums are disposed in a generally cross-flow relation with respect to the hot exhaust path as well as positioned in the hot exhaust flow path. The plenums are interconnected by heat exchange tube banks disposed in a parallel flow relation with respect to the exhaust gas flow and positioned in the hot gas flow. Because the plenums and heat exchange tube banks are both positioned in the exhaust gas flow heating of component parts is more uniform. Moreover, the hotter air outlet plenum is positioned at the hot exhaust gas inlet, where the gas temperature is highest; whereas, the cooler air inlet plenum is positioned downstream, where the gas temperature is cooler, further contributing to more uniform heating and hence thermal expansion.

The unique slotted plenum construction equalizes thermal mass by obviating massive end structures. The unit pressure tube, high pressure, air passageways are each held together by the slotted air plenum pipes, internal and peripheral brazing thereby providing a more uniform construction rather than relatively light heat exchange tube banks and a massive end structure associated with the prior art.

An additional advantage of the unit pressure tube construction is realized in that individual tubes may be removed from the regenerator for maintenance and replacement.

While there is shown what is considered to be, at present, the preferred embodiment of the invention, it is, of course, understood that various other modifications may be made therein; and, it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A heat exchange section for passing a high pressure air flow in a heat exchange relation with a high temperature gas flow comprising:
   a tubular inlet and outlet plenum disposed in said housing, said tubular plenums having at least one open end for receiving and discharging said high pressure air flow, a plurality of axially spaced, circumferentially elongated slots formed in said inlet and outlet plenums, said plenums disposed in spaced, generally parallel relationship with the slots of one plenum generally facing and axially aligned with the slots of the other plenum;
   a plurality of discrete high pressure air passage means for directing high pressure air flow from said inlet plenum to said outlet plenum and for transferring heat thereto from said high temperature gas flow passing through said housing, said means extending between and interconnecting said inlet and outlet plenums and arranged in generally spaced parallel relationship and in generally parallel flow relationship to said gas flow with each said means comprising a pair of closely spaced generally parallel plates joined together at their peripheral edges so as to define an air passageway therebetween and formed with an open slot at opposite ends for flow into and out of said air passageway, each said passage means having one open end inserted into a slot of one plenum and joined thereto and the other open end inserted into the corresponding axial slot of the other plenum and joined thereto so as to form a gas passageway between each pair of high pressure passage means, whereby said passage means are connected to each other through and supported exclusively by said tubular plenums so as to permit removal and replacement of an individual one of said passage means and to reduce thermal stressing of said passage means.

2. The heat exchange section recited in claim 1 wherein the air inlet plenum is downstream from the air outlet plenum with respect to said gas flow.

3. The heat exchange section recited in claim 1 wherein strip-fin means are disposed between each pair of parallel plates having alternating surfaces in metal joined abutment to the interior surfaces of said unit pressure tube.

* * * * *
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,866,674
DATED : February 18, 1975
INVENTOR(S) : Salvatore S. Tramuta et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In column 4, claim 1, insert the following line between lines 12 and 13:

-- a housing; --

Signed and Sealed this second Day of September 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks