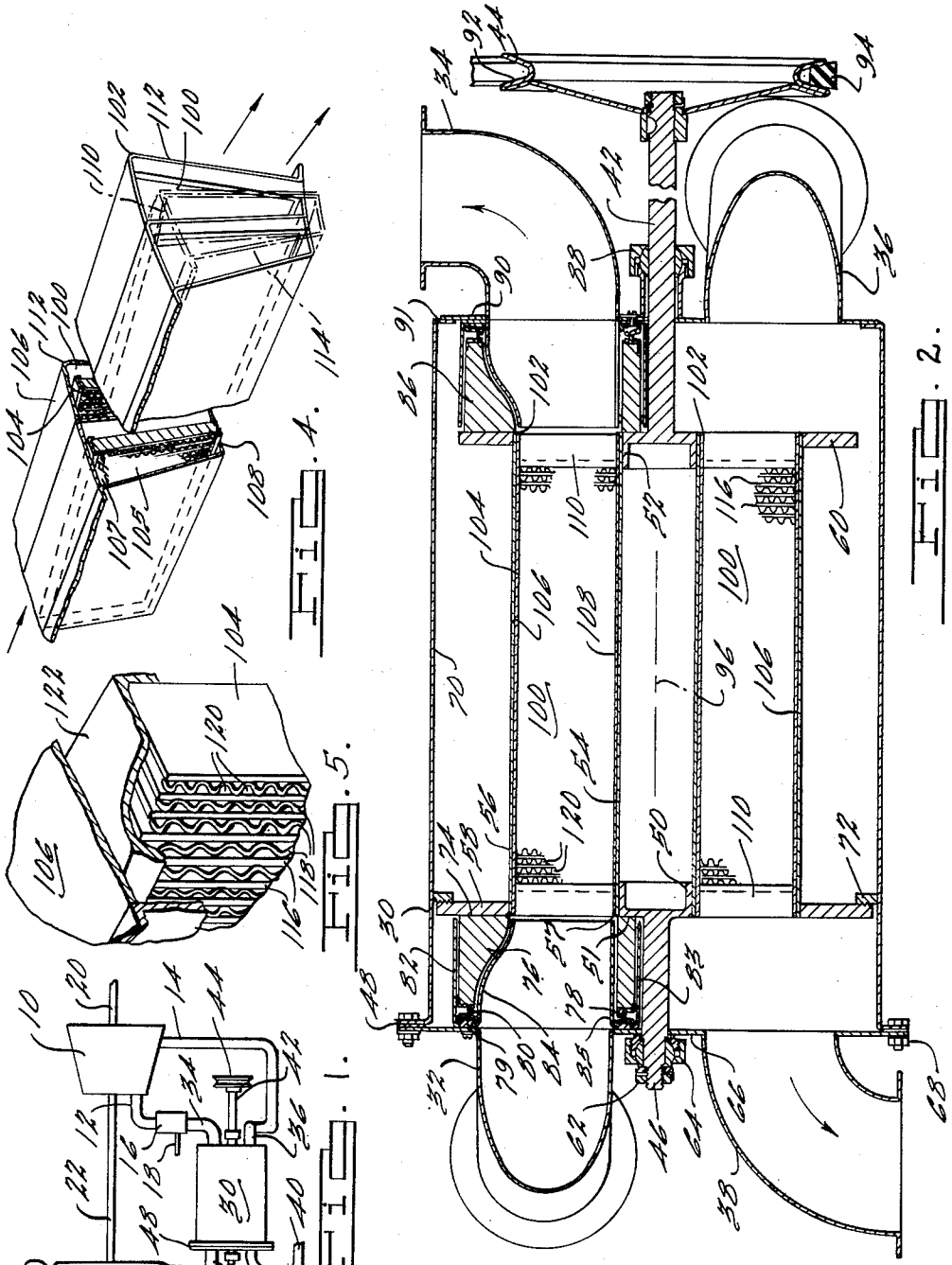
Aug. 7, 1956 S. B. WILLIAMS 2,757,907

HEAT EXCHANGER

Filed Nov. 9, 1950

2 Sheets-Sheet 1



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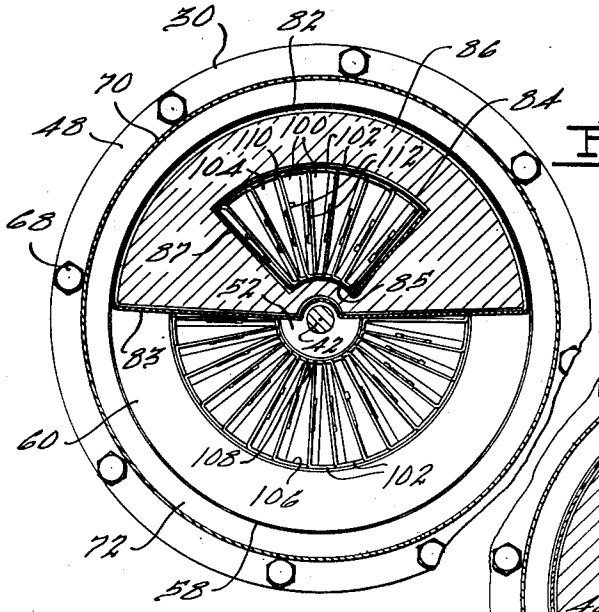


Fig. 3.

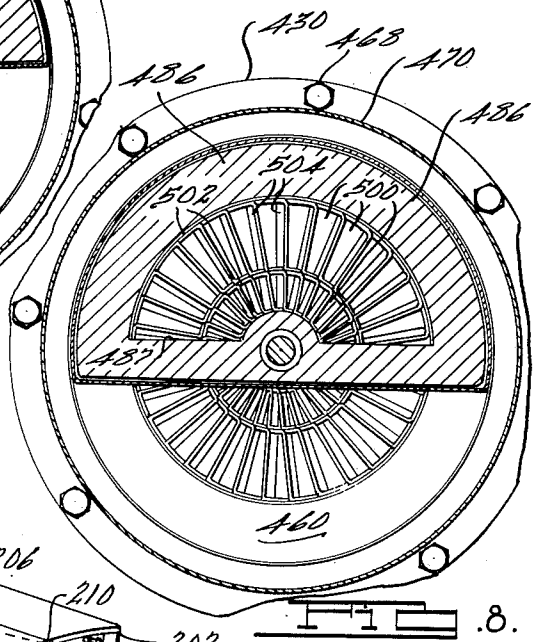


Fig. 8.

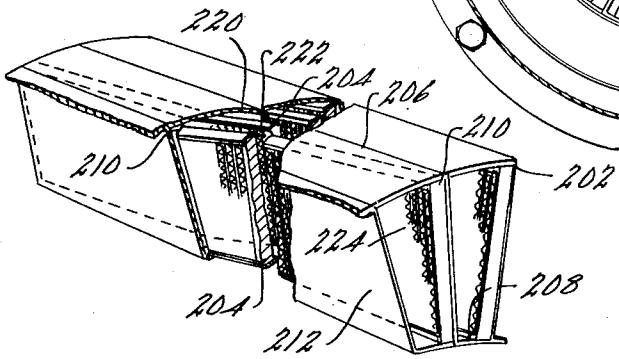


Fig. 6.

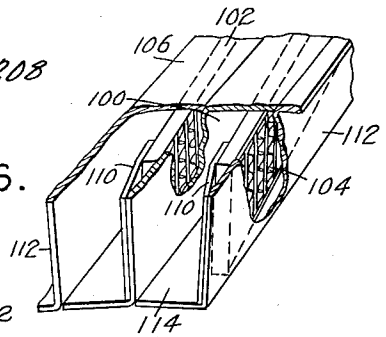


Fig. 4A.

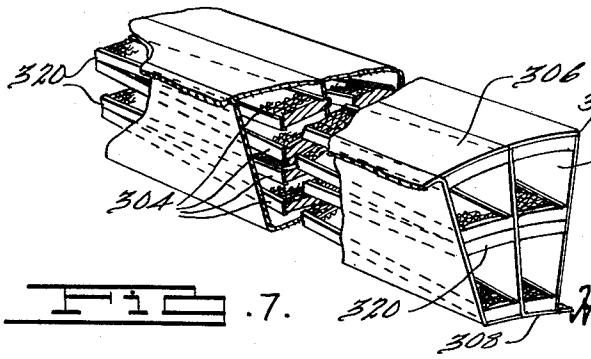


Fig. 7.

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United States Patent Office

2,757,907

Patented Aug. 7, 1956

2,757,907

HEAT EXCHANGER

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Application November 9, 1950, Serial No. 194,850

7 Claims. (Cl. 257—6)

The present invention relates to heat exchangers and more particularly to heat exchangers of the regenerative type in which there is a rotatable element subdivided into cells which contain heat absorptive material and which are traversed by two fluid streams caused to flow alternately through the core material. One of these streams imparts heat to the heat transfer material while the other fluid stream abstracts heat therefrom, the rotation of the element positioning each celled portion thereof in succession in order that it will be traversed alternately by the two fluid streams.

Hitherto, a rotative type regenerator has been used in cases where the pressure of the two fluid streams differs little if at all, and consequently it has been fairly easy to minimize leakage from one stream to the other as, for instance, by employing relatively simple means for sealing the structure, the seal length thereof being of substantial magnitude in comparison to the face area of the absorptive material. In a gas turbine plant, however, where the exhaust gases are used to heat the gas delivered by the compressor and also in other apparatus such as an oxygen producing plant, the pressures of the fluids in the two streams passed through the heat exchanger may be very different and more effective methods of sealing and of reducing the comparative seal length become necessary.

An object of the present invention is to provide such sealing that a heat exchanger of this type may be used for these purposes especially where proportionately large face entrance area for the heat transfer material is required.

According to a feature of the invention is the provision of cell passages of extended length which can accommodate long walls of pervious heat transfer material which are disposed obliquely to the entrance and discharge directions of flow of fluid with respect to the cell passages.

According to a further feature a heat exchanger is provided in which the core face entrance area is relatively large in comparison to the effective length of the seal around the high pressure fluid ports.

According to yet a further feature of the present improvement, when the core angle of disposition is about 8°, then approximately five times as much fluid can be handled under conditions of laminar flow than can be handled by a conventional heat exchanger of the same seal length having the core face entrance area disposed normal or transverse to the passage entrance and discharge direction. If turbulent flow is contemplated, an attempt to flow five times as much fluid through the conventional transversely disposed core face entrance area will result in a pressure drop of the factor five squared times as much as the pressure drop for the improved heat exchanger having a core angularity of about 8° and roughly the same seal length. If the core angularity is decreased to approximately 5° in the improved heat exchanger, the multiplication factor for the improved behavior and effectiveness as compared to a transversely disposed core exchanger is ten times under circumstances of laminar flow; under circumstances of turbulent flow then, a flow of ten times the fluid through the transversely disposed cores

will result in the same total heat transfer through both exchangers but ten squared times the pressure drop will result across transverse cores in comparison to the improved cores as set at approximately 5° angularity. The above figures are submitted as representative for particular designs considered, due allowance having already been taken into account for dead length in the cell passages devoted to space occupied by necessary ramps and fairing for the angled cores.

According to still a further feature of the invention, a rotating element is provided of which the rotating ends of the metallic cells are in contact with the rubbing seal and the core material is not itself subject to frictional wear. Hence the core material may be of fine texture and fragility if desired and may be free from the burden of wear.

According to another feature, provision is made to seal the end of the rotating element of a heat exchanger by a resiliently urged face seal which can adjust itself for optimum sealing effect.

According to still another feature is the provision of an easily fabricated structure which may be constructed of sheet metal as one chief material, the structure thereby lending itself to certain economies of manufacture.

Other features, objects, and advantages will either be specifically pointed out or will become apparent as reference is made to the following detailed description taken in conjunction with the accompanying drawings wherein:

Figure 1 is a layout of a typical power plant in which the heat exchanger of the instant invention finds application;

Figures 2 and 3 are longitudinal and transverse sectional views respectively, of the heat exchanger;

Figure 4 is a perspective view of the cell passages and ramp-curved core material therein;

Figure 4A is a perspective view of the cell passage shown in Figure 4 as viewed in the opposite direction to show the structural relationship between the core and the other axial side of the cell passage walls;

Figure 5 represents an enlarged perspective of a portion of a core material found suitable for these applications;

Figures 6 and 7 show modified arrangements of the core material within the cell passages; and

Figure 8 is a transverse section through a heat exchanger element of slightly modified construction.

In respect to Figure 1 particularly, included in the turbine power plant layout is a gas turbine **10** having a gas inlet **12** and exhaust **14**. Inlet **12** is supplied with energy gases from a burner **16** having a fuel line **18** therefor. Turbine **10** may be provided with a main output shaft **20** and a compressor shaft **22** for driving a compressor and/or auxiliaries. Compressor **24** has an extension shaft **26** around which is disposed an air inlet bell **28** for passage of air to be compressed. The compressed air is delivered by the compressor through an outlet **29** to a heat exchanger **30** having a high pressure inlet **32** for the compressed air. Within exchanger **30**, heat is added to the compressed air and the air still under pressure is delivered in a preheated state through the regenerator outlet elbow **34** to burner **16**. Regenerator **30**, preferably of the counterflow type, has another inlet **36** for receiving exhaust gases from outlet **14** of turbine **10**. Regenerator **30**, after abstracting heat from these exhaust gases, delivers them through an elbow **38** into a discharge pipe **40**. Regenerator **30** is provided with a rotating element, later to be set forth in detail, which is keyed to a shaft portion **42** at one end of the regenerator mounting a drive device **44** for rotating the rotating element. At the opposite end of regenerator **30** is another shaft portion **46** in a flanged end **48** provided for access internally into the regenerator.

In regard to Figure 2, shaft portions **46** and **42** are provided respectively with wide rimmed parts **50** and **52**

which support inner and outer cylinders 54 and 56 constituting portions of a rotating heat exchanger element 57. Parts 50 and 52 are faced off to provide a radially extending flange such as indicated at 51 on part 50. At the ends of rotating element 57 may be provided radially extending circumferential flanges 58 and 60. Shaft portion 46 has a nut or other suitable fastener 62 at the end thereof and is journalled in a bearing 64. An end sheet 66 for the heat exchanger supports bearing 64 and is attached to the case 70 of the heat exchanger by suitable fasteners 68 through the flange 48 thereof. Casing 70 of heat exchanger 30 is provided with annularly grooved circumferential seal 72 of the labyrinth type, which cooperates with one side of the rotating flange 58. On the other side of flange 58 a rubbing seal 76 provides a seal along its sliding surface 74.

At the small end of seal 76, which may be circular, is provided a bellows 78 having one end attached to the circular portion seal and the other end firmly secured at 79 to end sheet 66 of the regenerator casing. Within bellows 78 is provided a resilient device 80 which resiliently urges seal 76 into contact with flange 58. Seal 76 is retained for axial motion in the chamber defined by sheet metal parts 82, 83 and 84, 85. Shaft portion 46 is connected for rotation through the parts such as 54 and 56 forming rotating element 57, with the shaft portion 42 at the similar opposite end of the regenerator. Extending to a point adjacent shaft portion 42, a seal 86 is resiliently urged into contact with flange 60 on the rotating element. As respects the seal material of Figure 2, seals 76 and 86 may be, without necessarily excluding other suitable materials, formed of metal impregnated graphite, sintered bronze impregnated with a dry lubricant such as molybdenum disulphide, or sintered iron impregnated with a dry lubricant. Shaft portion 42 is journalled in a bearing 88 supported by an end sheet 90 firmly secured as by welding 91 to case 70. Drive device 44 for shaft portion 42 may comprise a pulley having a V groove 92 over which is trained a V belt 94 appropriately driven through gearing which may find its source of power through either shaft 20, 22, or 26 as shown in Figure 1.

Extending longitudinally of the rotating element 57 and being generally disposed about the central axis 96 of the regenerator are provided a plurality of cell passages 100. Each cell 102 forming a cell passage 100 receives internally thereof pervious walls of a suitable core material 104 held between the respective top and bottom walls 106, 108 of the cell. The end of the core members 104 are secured as by brackets 110 to the opposite non-parallel walls later to be described in connection with individual cells 102.

With regard to Figure 3, the section shown of regenerator 30 is taken through one of the end seals thereof and will be observed to be in a direction such as to show flange 48 and fasteners 68. Centrally of flange 48 and extending toward the observer is the case 70, radially inwardly from which projects labyrinth seal 72. Between labyrinth seal 72 and end flange 60 of the rotating element appears a portion of end flange 58 of the rotating element. The sheet metal members 82, 83 and 84, 85 are shown to define a space in which is received the seal formed with a central opening 87 therein. Registering with central opening 87 are, a plurality at a time, cell passages 100 defined by their respective cells 102. The pervious walls provided by the core members 104 will be observed to be attached at their ends by suitable brackets or ramps 110 to the opposed non-parallel side walls 112 of the cells 102. The wedge-shaped portions of the seal 86 laterally of opening 87 will be observed to occlude the ends of certain passages whereas the passages between the widened rim portion 52 and flange 60 without the bounds of the seal 86 are completely exposed. The top and bottom walls 106 and 108 of cells 102 will be observed in Figure 3 to be generally adjacent respectively the flange 60 and the wide rim 52 shown exposed.

The operation of the device of Figures 1, 2, and 3 may be described as follows. High pressure gas from the compressor is passed from inlet 32 through the plurality of cell passages 100 which register with the sealed central opening 87. Seal 76, resiliently urged into sliding contact with flange 58 and with a faced off portion 51 of the widened rim 50, serves positively to seal the high pressure gas in the upper cell passages 100. Circular bellows 78 at the end of seal 76 prevents escape of any compressed gas past the securing fastener 79. Seal 86 likewise provides a sealed connection for the heated compressed gas leaving through elbow 34 of the regenerator for the burner. Inasmuch as element 57 is adapted to be rotatably driven during operation of the regenerator, the cells 102 are undergoing a continuous turning process such that the heat transfer cores 104 as they are cooled, are continually being replaced in the high pressure passages in rotation. The heat supplied the pervious walls of cores 104 is abstracted from the turbine exhaust gases led into the regenerator through inlet 36. This exhaust gas is of relatively low pressure compared to the relatively high pressure of the fluid in the high pressure side of the regenerator but no commingling of gas will result because of the effectiveness of the components cooperating with seals 76 and 86. The exhaust gas travels along the lower cell passages 100 through the pervious walls of the core material 104 and out the elbow 38. It is to be noted that labyrinth seal 72 in case 70 cooperates with flange 58 to prevent the low pressure exhaust gases from bypassing the lower cell passages 100.

In respect to Figures 4 and 4A, the cell passages 100 are shown as defined in isometric by the individual cells 102. Cells 102 have top and bottom walls 106 and 108 and non-parallel side walls or plates 112. Received in each cell is a core member 104 providing a wall of pervious material adapted to be alternately heated and cooled due to being subjected alternately to the flow of relatively hot and cold gases. Each core member 104 is along its top and bottom edge secured to the respective top and bottom walls 106 and 108 of cells 102. At either end of the core members 104 are secured to the generally radial, non-parallel opposed side walls 112 of cells 102. The end connections may suitably be effected by ramps 110 which are shown in full lines in Figures 2 and 4A, but which appear in phantom view in Figure 4 and which will be seen to be wall-attached to the radial walls 112 and to fit into the extended end portion 114 shown in full in Figure 2, but in phantom view in Figure 4 and provided for the cell structure 102. The extended end portion 114 while present in Figure 2, is designated by numeral and shown in phantom lines in Figure 4 for the reason of clarity in exposing the structure of the foreshortened ends of the cell structure 102 and also the end of the core member 104. The core member 104 presents a core face entrance area of considerable lateral extent generally indicated at 105. Inasmuch as the plane of the core 104 is disposed relative to the adjacent plate 112 so as to define an included angle A indicated at 107, the core face area is substantially greater than the cross sectional area of the individual cell passages 100. Since the cell passages 100 and the core members 104 have, in a transverse plane, one dimension in common, the total surface area afforded for a given cross sectional area of cell passage 100 bears a ratio to the latter said cross sectional area which is roughly equal to the numerical cosecant of the angle A. That is to say, the longest linear dimension of the core 104 corresponds to the hypotenuse of the right triangle which includes the angle A, and the cell linear width corresponds to the side of the right triangle opposite the included angle A; therefore, the ratio of the core face area to the cell cross section area is roughly equal to the cosecant of the angle A because these two areas bear substantially the same relationship to one another as do the linear dimensions just noted. If then the dead length of the ramp is taken into account, the multiplication factor of core face area to passage cross

section is considerably above unity for an angle A of 30° and for an angle of 8° is about the order of five times. The multiplication factor for an angle A of 5° is roughly ten times. As approached from another criterion, the situation is such that since the cross section passage area in overall combined form is roughly a function of the effective rubbing seal length, the effective core face entrance area by use of the improved heat exchanger under consideration exceeds in proportion the total seal length by a plurality of times. Hence a relatively smaller heat exchanger according to the improved version is able to present a relatively large core face entrance area in proportion to its radial size and length of seal.

Within the broader aspects of the invention, the individual cells **102** may each be formed from circular tubes which are shaped to assume the general configuration of the cells of Figures 4 and 4A. It is to be noted that the wall thickness of elements **104** is only a fractional part of the circumferential dimension of each cell passage **100**.

As regards Figure 5, a mode of locating the upper and lower edges of each core element **104** to the upper and lower walls of the cells is represented. Core elements **104** may be of an integrated structure formed of flat strips **116** which alternate with corrugated strips **118**. These strips may be of the order of thickness of 1½ thousandths inches and of a width corresponding to the thickness of the members **104** in Figures 4 and 4A. The corrugations of strips **118** cooperate with flat strips **116** to define passages **120** of a dimension roughly of the order to accommodate passage, say of a small needle. Strips **116** and **118** are held together in a channel member **122** between the opposed legs of the latter. Channel **122** is attached to upper wall **106** of the individual cell at the general angularity to side wall **112** as indicated by angle A in Figures 4 and 4A. The gas passes along the passage **100** in Figure 5 through the pervious wall provided by capillary openings **120** and continues along the passage **100** on the opposite side of the wall. Strips **116** and **118** may be formed of stainless steel, carbon steel, or a carbon steel coated with a suitable surfacing material such as aluminum. Within the broader aspects of the invention, the material for pervious walls **104** may be constituted by sheets of a porous ceramic extending substantially longitudinally of each cell, or mats of steel wool suitably retained between screening which runs generally longitudinally of the cells.

In Figure 6 each cell passage **200** is provided with a pair of core members **204**. The ends of each core member are secured to the non-parallel opposed side walls **212** of cells **202** by means of ramp brackets **210**. One core member **204** terminates about half way along the length of a passage **200** and the other core member **204** begins about half way along the passage **200** and terminates at the extreme end thereof. Gas entering the passage **200** in one direction progresses from the chamber **220** to the chamber **222** through one pervious wall provided by a core member and further progresses from the chamber **222** between the core members through the other core member to the chamber **224**. Then the gas is discharged through the opening at the end of the cell **202**. Oppositely directed gas of course takes a vice versa route.

In Figure 7, the cells **302** are of a modified type having four pervious wall members **304** per cell. The extreme core members **304** are attached respectively to the top and bottom walls **306** and **308** of cells **302**. At all other ends, core members **304** are joined to one another alternately at junction points such as **320**. In order to progress through each passage **300** the incoming gas must pass at least through one wall thickness of the pervious material of members **304**.

As respects Figure 8, a slightly modified form of heat exchanger **430** has flanged fasteners **468** and a case **470**. Internally of the case is a rotating element having an end flange **460** approximately half of which is free of the seal **486**. The central opening of seal **486** is indicated at **487** to expose the ends of a plurality of cell passages **500** arranged in two circumferential rows, one within and one without the other. The individual cells **502** in both rows contain each a core means as at **504** attached to the walls thereof by bonding or by suitable brackets.

The portions of the rubbing seals shown in Figures 3 and 8 will be observed to have a segmental central opening. The seal itself, however, undergoes a transition in cross section from one axial end to the other thereof and as described in connection with Figure 2, reduces to substantially a circular cross section adjacent the bellows **78** and the spring **80**.

Variations within the spirit and scope of the invention described are equally comprehended by the foregoing description.

I claim:

1. In a rotary regenerator unit for a gas turbine power plant adapted to be installed in the engine compartment of a wheeled vehicle, a circular housing comprising coaxially disposed inner and outer housing portions, said housing having an axis of rotation and spaced end surfaces disposed perpendicularly with respect to said axis, a plurality of circumferentially spaced baffles extending in a generally radial direction and interconnecting said inner and outer housing portions thereby defining a plurality of passages, and core structure interposed within each of said passages, the core structure for each passage comprising a pervious wall extending from one side of the passage to an opposite side thereof, one edge of said wall being located relatively close to one end surface of said unit and the opposite edge thereof being located relatively close to the other end surface of the unit thereby providing an effective gas passage area for each core structure which exceeds in magnitude the transverse cross sectional area of its associated passage, the thickness of said walls being substantially less than the spacing between two other juxtaposed passage sides.

2. In a rotary regenerator unit for a gas turbine power plant adapted to be installed in the engine compartment of a wheeled vehicle, a substantially cylindrical housing with concentric inner and outer housing portions, said housing having an axis of rotation and spaced end surfaces disposed perpendicularly with respect to said axis, a plurality of partitions extending in a generally radial direction between said housing portions and defining two sides of a plurality of passages for accommodating the passage of gasses through said unit, and a core structure interposed within each of said passages, each of said core structures comprising at least one flat pervious matrix element secured to one side of its associated passage, said matrix element forming an acute angle with said one passage side, one edge of said matrix element being located relatively close to one end surface of said unit thereby providing an effective gas passage area for each matrix element which exceeds in magnitude the transverse cross sectional area of its associated passage, said one passage side being circumferentially spaced from an opposed passage side, the thickness of said walls being substantially less than the radial spacing between said inner and outer housing portions.

3. In a rotary regenerator unit for a gas turbine power plant adapted to be installed in the engine compartment of a wheeled vehicle, a substantially cylindrical housing comprising concentric inner and outer housing portions, said housing having an axis of rotation and spaced end surfaces disposed perpendicularly with respect to said axis, a plurality of dividing plates extending in a generally radial direction between said concentric housing portions and defining a plurality of four-sided passageways for accommodating the passage of gases axially through the regenerator unit, at least one flat, pervious matrix element

mounted in each of said passageways with one edge thereof being located relatively close to one end surface of said unit and with the other edge thereof being located relatively close to the other end surface of said unit, each of said matrix elements forming an acute angle with one side of its associated passageways thereby providing an effective gas passage area for each matrix element which exceeds in magnitude the transverse cross sectional area of its associated passageway, said one passageway being radially spaced from its opposed side, the thickness of said matrix elements being substantially less than the circumferential spacing between said dividing plates.

4. In a rotary regenerator unit for a gas turbine power plant adapted to be installed in the engine compartment of a wheeled vehicle, a substantially cylindrical housing comprising concentric inner and outer housing portions, said housing having an axis of rotation and spaced end surfaces disposed perpendicularly with respect to said axis, a plurality of dividing plates disposed in a substantially radial position between said housing portions thereby defining a plurality of four-sided passageways for accommodating the passage of gasses axially through the regenerator unit, a pervious matrix wall mounted in each of said passageways and forming an acute angle with one of the sides of its associated passageway, one edge of said matrix wall being located relatively close to one end surface of said unit and the opposed edge of said matrix element being located relatively close to the other end surface of said unit thereby providing an effective gas passage area for said matrix element which exceeds in magnitude the transverse cross sectional area of its associated passageway, said one passageway side being circumferentially spaced from its opposed side, the thickness of said matrix element being substantially less than the radial spacing between said inner and outer housing portions, and means for mounting said unit for rotation about its central axis.

5. In a rotary regenerator unit for a gas turbine power plant adapted to be installed in the engine compartment of a wheeled vehicle, a substantially cylindrical housing having two end surfaces, a plurality of axially extending four-sided passages defined by said housing and situated in a circular row about the axis of said housing for accommodating the axial passage of gases therethrough, at least one pervious matrix wall interposed in each of said passages and forming an acute angle with two opposed circumferentially spaced sides of the same, one edge of each matrix wall being relatively close to one end surface of said unit and the opposed edge thereof being relatively close to the other end surface of said unit thereby providing an effective gas passage area for each matrix wall which exceeds in magnitude the transverse cross sectional area of its associated passage, the thickness of each matrix wall being less than the radial height of its associated passage and the width of each matrix wall being equal to the radial height of its associated passage.

6. In a rotary regenerator unit for a gas turbine power plant adapted to be installed in the engine compartment of a wheeled vehicle, a substantially cylindrical housing, said housing having an axis of rotation and spaced end surfaces disposed perpendicularly with respect to said axis, a plurality of passages formed within said housing in a circular row about the axis of said housing, at least one pervious matrix wall interposed in each of said passages, said walls forming an acute angle with two opposed sides of said passages, means for rotating said regenerator unit about its central axis, a pair of gas conduit means disposed at each spaced end surface of said housing, one of each of said pairs of conduit means being adapted to accommodate and to direct the flow of heated gases through a portion of said regenerator unit, the other of each of said pairs of conduit means being adapted to accommodate and to direct the flow of relatively cool gases through another portion of said regenerator unit, said pervious matrix walls being alternately heated and cooled by said gases upon rotation of said unit thereby effecting a thermal energy transfer from said heated gases to said cooled gases, the opposed edges of each matrix wall being located relatively close to one end surface and the other end surface of said unit respectively thereby providing an effective gas passage area for each matrix wall which exceeds the magnitude of the transverse cross sectional area of its associated passage, the thickness of each of said matrix walls being substantially less than the spacing between two other juxtaposed sides of its associated passage.

7. The combination as set forth in claim 6 wherein each of said passages includes a fairing ramp secured to separate one of the passage walls for each of said passages at either end thereof, said ramps comprising a surface inclined at an acute angle with respect to its associated passage side, one edge of each matrix wall being received under each ramp.

References Cited in the file of this patent

UNITED STATES PATENTS

1,781,303	Rydmark	Nov. 11, 1930
1,871,166	Fahrbach	Aug. 6, 1932
2,013,499	Meckenstock	Sept. 3, 1935
2,229,691	Boestad	Jan. 28, 1941
2,337,956	Yerrick et al.	Dec. 28, 1943
2,432,198	Karlsson et al.	Dec. 9, 1947
2,469,758	Alcock	May 10, 1949
2,480,248	Karlsson et al.	Aug. 30, 1949
2,485,088	Ellis	Oct. 18, 1949
2,503,651	Alcock	Apr. 11, 1950

FOREIGN PATENTS

116,544	Austria	Oct. 15, 1927
479,840	Great Britain	Feb. 10, 1938
636,839	Great Britain	May 10, 1950
957,953	France	Mar. 1, 1950