

[54] STATIONARY HEAT EXCHANGER

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[51] Int. Cl. F23I 15/02

[58] Field of Search 165/4-10;
60/39.51 R

[56]

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[57]

ABSTRACT

A stationary heat exchanger in which a plurality of corrugated heat radiating plates are radially arranged in juxtaposed relation to form independent radial fluid passages between each other, and fluid is passed in the every other ones of said fluid passage in one direction, while another fluid is passed in the rest of said fluid passages in the opposite direction, whereby heat is exchanged between said two fluids.

4 Claims, 18 Drawing Figures

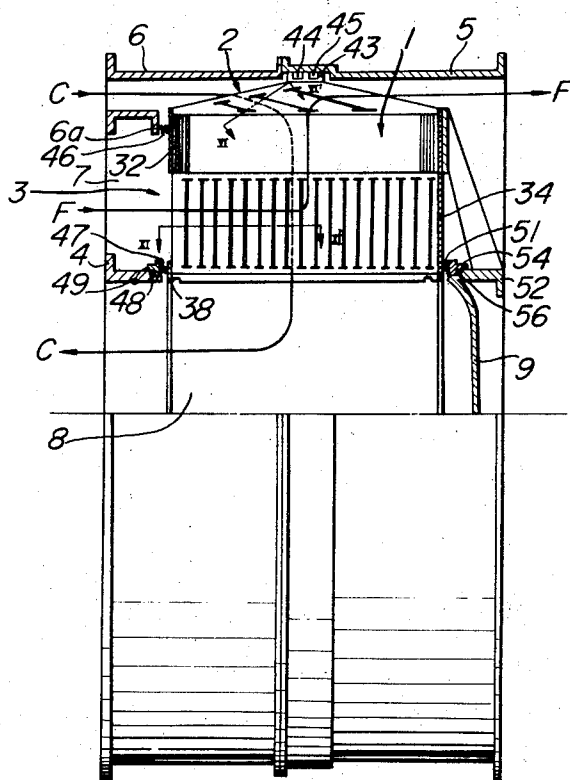


FIG. 1

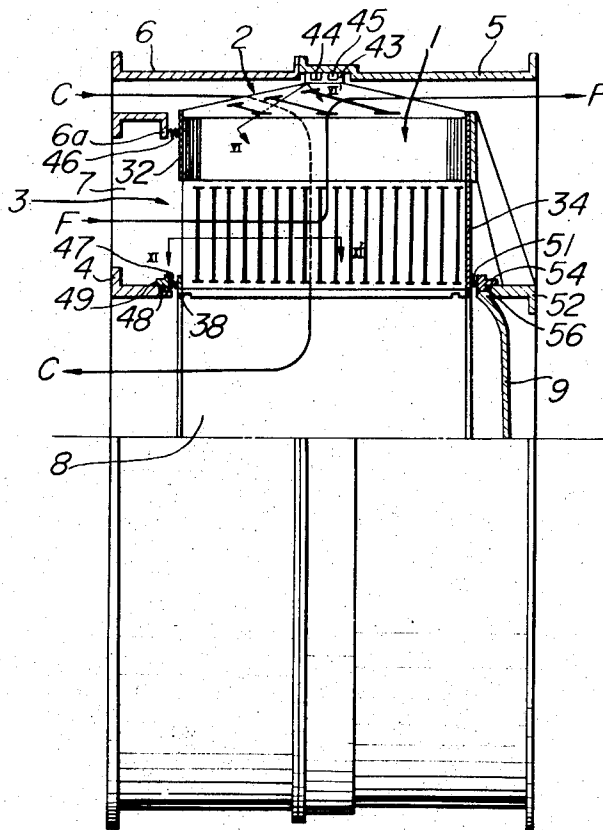


FIG. 2

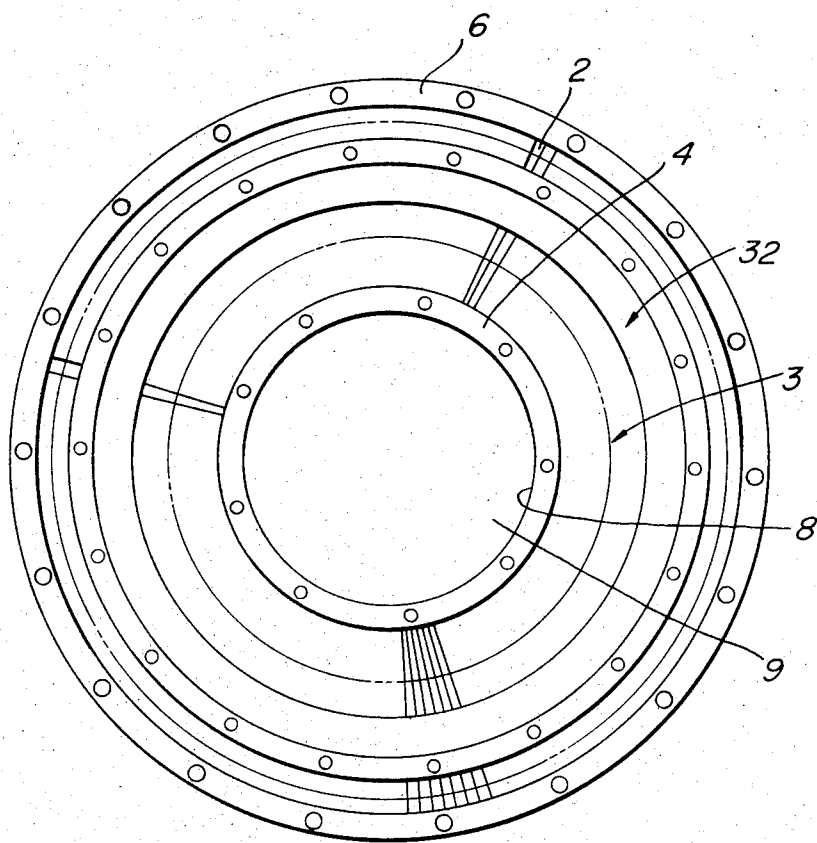
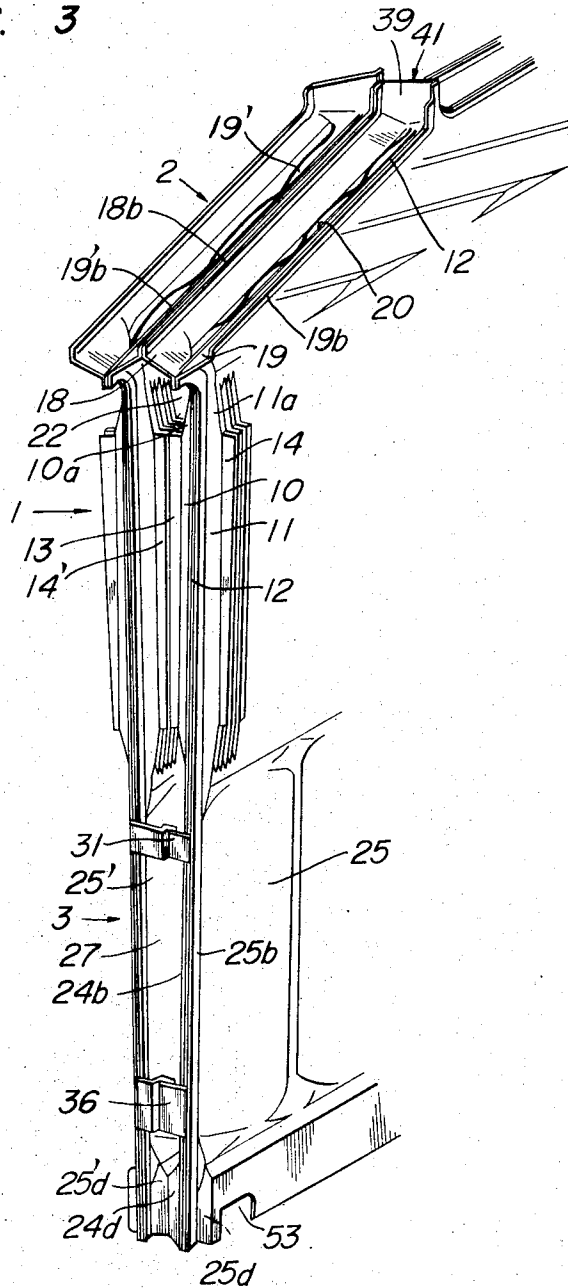


FIG. 3



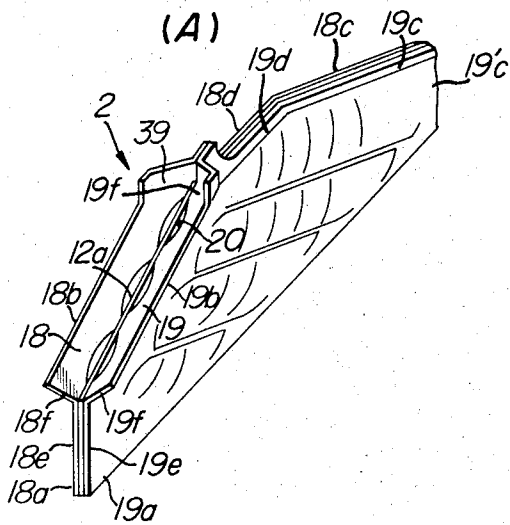
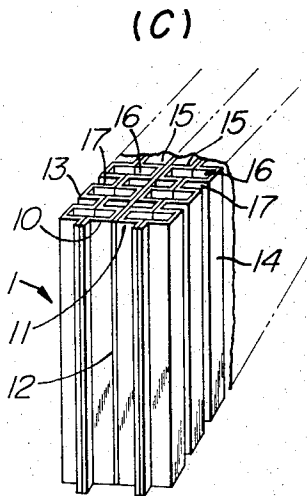
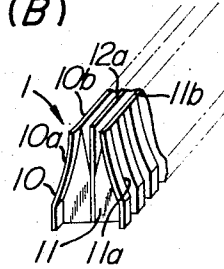
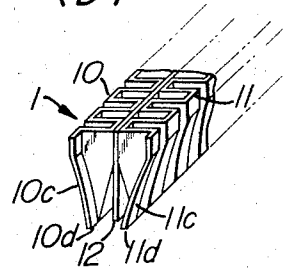


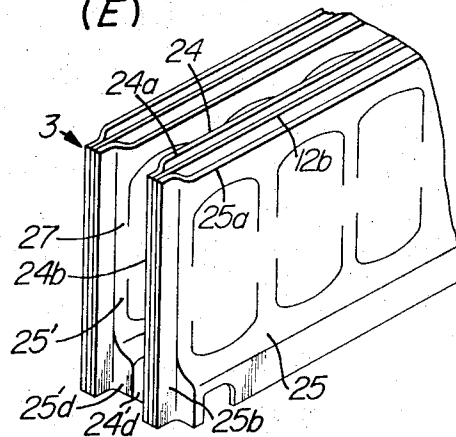
FIG. 4
(B)



(D)



(E)



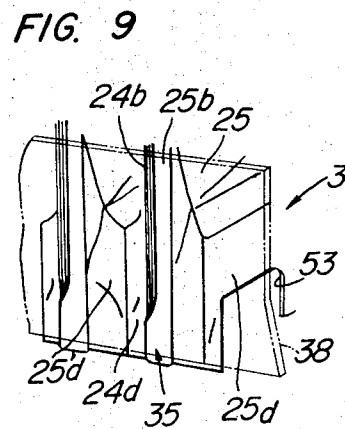
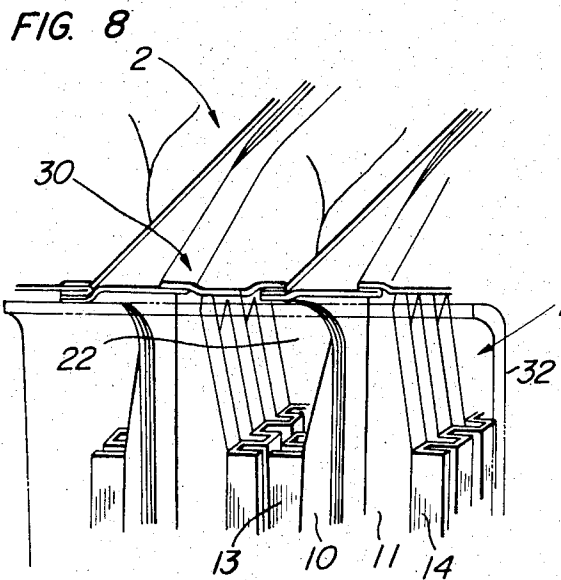
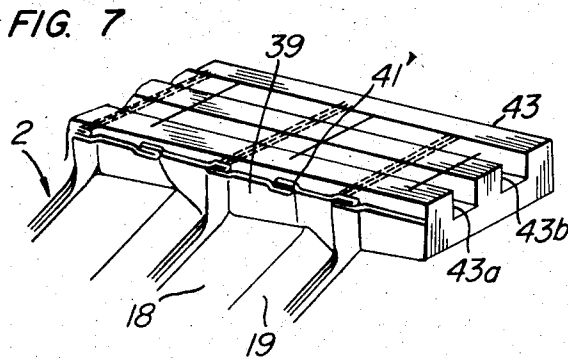
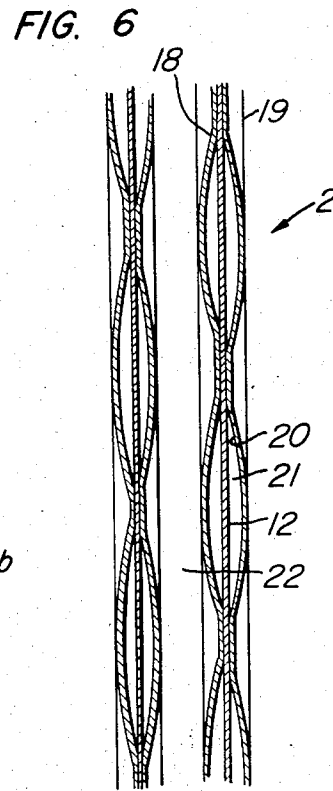
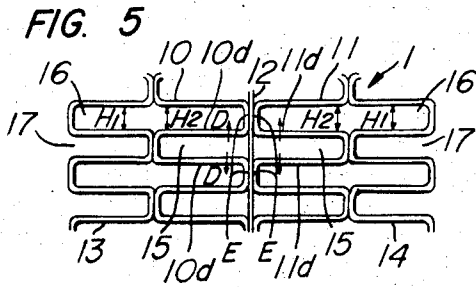


FIG. 10

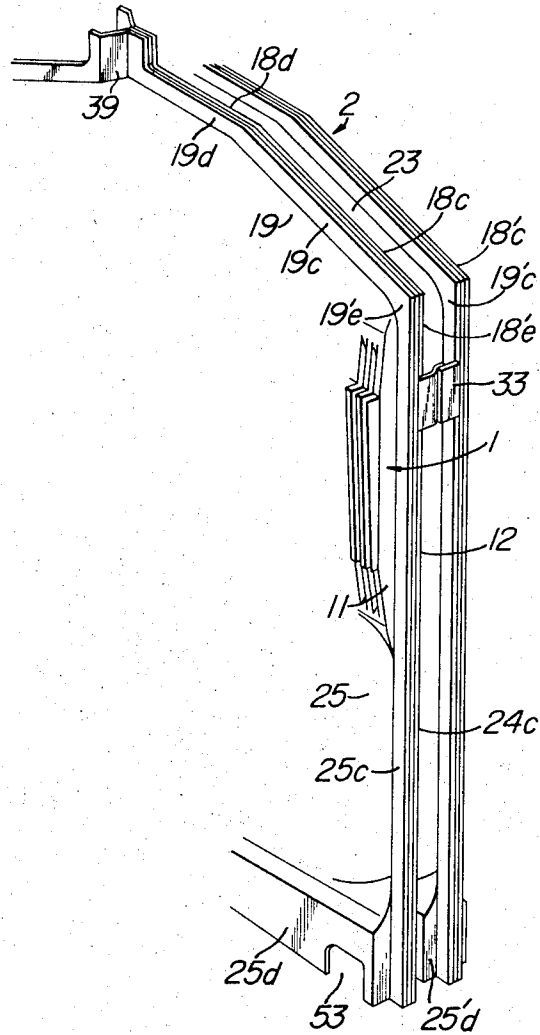


FIG. 13

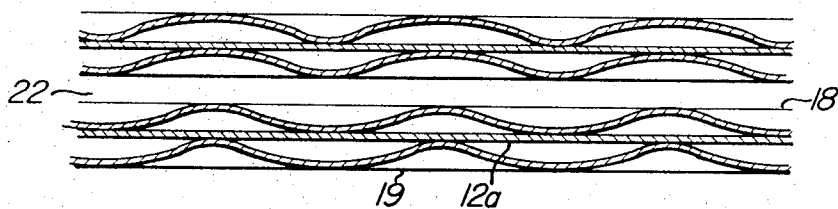


FIG. 14

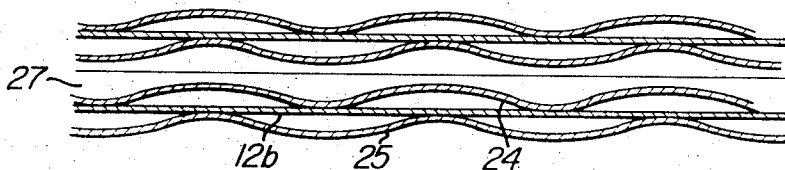


FIG. 11

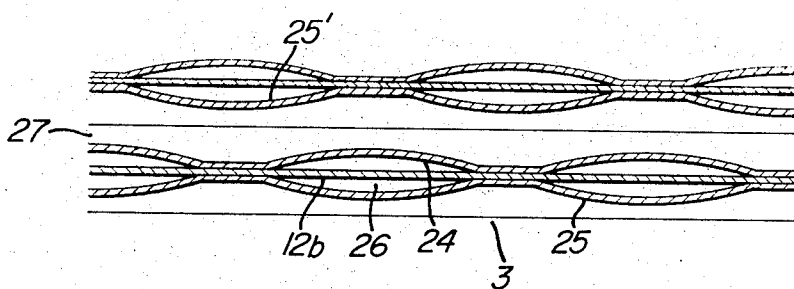
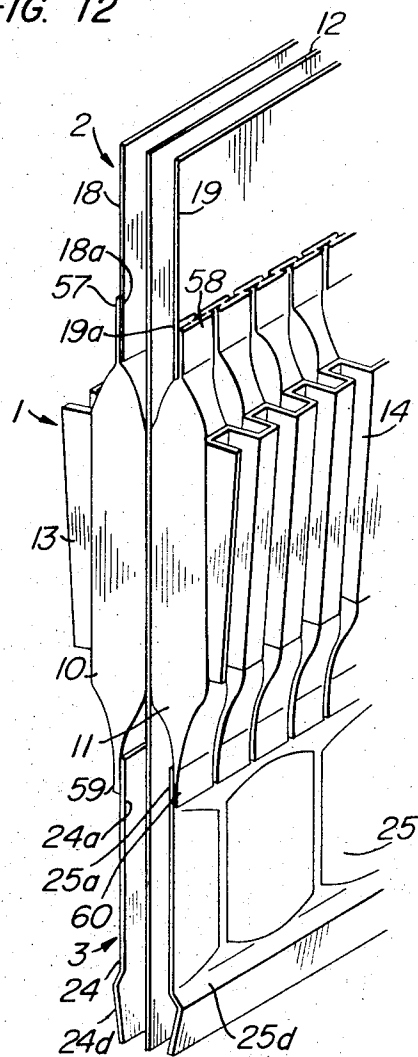


FIG. 12



STATIONARY HEAT EXCHANGER

This invention relates to a counterflow-type recuperative stationary heat exchanger in which fluids are passed in adjoining passages in opposite directions to each other, whereby heat is exchanged therebetween.

The recuperative stationary heat exchanges which have commonly been used heretofore are classified into a tube bank type consisting only of tubes and a tube-fin type consisting of a combination of tubes and fins. These types of heat exchangers are further classified into a parallel flow type, a perpendicular flow type and a counterflow type according to the flow directions of fluids. The tube bank type and tube-fine type heat exchangers have the disadvantage that, because of a large restriction imposed on the inner and outer heat transfer areas, the types of the inner and outer fluids are subjected to a limitation. The counterflow type heat exchanger has the disadvantage that, since different fluids are passed in opposite directions to each other, a complex and large-sized mechanism is required for preventing the fluids from mixing with each other and further much labor and time are required for manufacture.

In order to overcome the above disadvantages, the present invention has for its object the provision of a stationary heat exchanger which comprises an annular heat exchanger unit composed of a number of corrugated plates arranged radially in juxtaposed relation so as to define independent radial passages between each other, means for passing fluid in every other ones of said passages from the outer periphery toward the center of said annular heat exchanger unit and means for passing different fluid in the other every other ones of said passages from the center toward the outer periphery of said annular heat exchanger unit; and which, therefore, enables the heat transfer area of said corrugated plates to be freely adjusted, any combination of fluids to be used, the heat transfer capacity per unit area to be increased, and the incoming and outgoing fluids to be positively separated by a very simple mechanism, and can be easily manufactured.

The present invention will now be described in detail with reference to the accompanying drawings, in which:

FIG. 1 is an overall view of an embodiment of the stationary heat exchanger according to the present invention, with the half portion in vertical section briefly showing the construction thereof;

FIG. 2 is an elevational view as viewed from the left side of FIG. 1;

FIG. 3 is a fragmentary perspective view showing the front portions of the heat exchanger unit and gas guide unit;

FIGS. 4(A), 4(B), 4(C), 4(D) and 4(E) are fragmentary perspective views showing in explosion the heat exchanger unit and gas guide unit respectively;

FIG. 5 is a fragmentary transverse sectional view of the heat exchanger unit;

FIG. 6 is a fragmentary enlarged transverse sectional view of the gas guide unit taken along the line VI—VI' of FIG. 1;

FIG. 7 is a fragmentary perspective view of the protective ring member;

FIG. 8 is a fragmentary perspective view showing in detail the connection between the heat exchanger unit and the gas guide unit;

FIG. 9 is a fragmentary perspective view showing the sealed lower end portion of the gas guide unit;

FIG. 10 is a fragmentary perspective view of the rear portions of the heat exchanger unit and the gas guide unit;

FIG. 11 is a fragmentary enlarged transverse sectional view of the gas guide unit taken along the line XI—XI' of FIG. 1;

FIG. 12 is a fragmentary perspective view of another form of the connection between the heat exchanger unit and the gas guide unit;

FIGS. 13 and 14 are fragmentary vertical sectional views showing other forms of the gas guide unit respectively.

Referring first to FIGS. 1 and 2, the heat exchanger according to the invention comprises a heat exchanger unit 1 composed of a plurality of corrugated heat radiating plates having convexes and concaves of a rectangular sectional shape on both sides thereof and radially arranged in juxtaposed relation so as to define radial passages between each other, and a gas guide unit 2 for leading low temperature high pressure air into every other ones of said radial passages and leading to the outside high temperature low pressure gas emerging from the other every other ones of said passages. The low temperature high pressure air is, for example, air supplied from the blower to the combustor of a gas turbine engine, and the high temperature low pressure gas is, for example, the combustion gas generated in the combustor upon combustion of fuel with said low temperature high pressure air and discharged through the turbine. The heat exchanger further comprises a gas guide unit 3 for leading the high pressure air, heated during passage through the heat exchanger unit 1, to the outside and also leading the high temperature low pressure gas into said heat exchanger unit 1, a conduit 4 for collecting the high pressure air heated during passage through the heat exchanger unit 1, a conduit 5 for discharging the high temperature low pressure combustion gas, passing through the heat exchanger unit 1, to the outside therethrough, a conduit 6 for introducing the low temperature high pressure air into said gas guide unit 2, a gas inlet for leading the high temperature low pressure combustion gas, discharged from the gas turbine engine, into an inlet opening of said gas guide unit 3, and a hollow portion 8 formed centrally of said gas guide unit 3 and having one open end communicating with said conduit 4, with the other open end closed by a cover 9.

The detail constructions of the heat exchanger unit 1 and the gas guide units 2, 3 are respectively shown in FIGS. 3 and 4(A) - 4(E). Namely, the heat exchanger unit 1 is composed of a plurality of radial heat radiating elements radially arranged in juxtaposed relation as shown in FIG. 1. Each heat radiating element is composed of heat radiating plates 10, 11, 13 and 14. The heat radiating plates 10, 11 are corrugated by pressing so as to form convexes and concaves of a rectangular sectional shape on both sides thereof and welded together with a reinforcing plate 12 interposed therebetween, in such a manner that the convexes of the respective plates 10, 11 confronting each other. The heat radiating plates 10, 11 are respectively welded to the heat radiating plates 13, 14 of the adjoining heat radiat-

ing elements. The heat radiating plates 13, 14 are shaped in the same manner as the heat radiating plates 10, 11 and the pitch or the interval H_1 of the convexes thereof is equal to the interval H_2 of the convexes of the latter. The heat radiating plates 10, 11, 13 and 14 when connected together in the manner described above have the appearance and cross section as shown in FIGS. 4(C) and 5. As seen, the heat radiating plates 10, 11 and the reinforcing plate 12 define air passages 15, and the heat radiating plates 10, 11 and 13, 14 define gas passages 16. The heat radiating element thus constructed further define gas passages 17 between it and the adjoining heat radiating element. The radially outward ends 10a, 11a of the heat radiating plates 10, 11 are tapered as shown in FIG. 4(B), thereby to determine the flow directions of the low temperature high pressure air and the high temperature low pressure combustion gas passing through the heat exchanger unit as will be described later. Likewise, the radially inward ends 10c, 11c of the heat radiating plates 10, 11 are tapered as shown in FIG. 4(D), thereby to determine the flow directions of the low temperature high pressure air and the high temperature low pressure combustion gas passing through the heat exchanger unit as will be described later.

The gas guide unit 2 is composed of a plurality of gas guide elements, each for each heat radiating element, arranged circularly in juxtaposed relation around the heat exchanger unit 1. Each gas guide element is composed of a pair of trapezoidal guide plates 18, 19 welded at their lower edges 18a, 19a to the tapered edges 110b, 111b of the heat radiating plates 10, 11 by butt resistance welding. The oblique edges 18b, 19b of the guide plates 18, 19 are bent outwardly of each other with a small curvature by pressing, while the other oblique edges 18c, 19c (FIG. 10) are bent inwardly of each other with a small curvature. Further, the guide plates 18, 19 are gently corrugated such that each of them has a wavy sectional shape of a small curvature on the cross section taken on the line VI—VI' of FIG. 1. The guide plates 18, 19 are welded together at the oblique edges 18c, 19c, the flat edges 18d, 19d and the end edges 18e, 19e and 18'e, 19'e, concurrently with the welding of the heat radiating plates 10, 11, with an extension 12a of the reinforcing plate 12 interposed therebetween by butt resistance welding in such a manner that the recessed and projecting portions of the guide plate 18 register with the recessed and projecting portions of the guide plate 19 respectively as shown in FIGS. 3 and 4. Thus, air inlet openings 20 and air inlet passages 21 of an elliptical cross section are formed as shown in FIG. 6. The passages 21 extend obliquely downwardly toward the right as viewed in FIG. 3 and communicate with each other at their lower ends and also communicate with the air passage 15 of the heat exchanger unit 1. Thus, it will be understood that the low temperature high pressure air flowing into the air inlet openings 20 of the gas guide unit 2 passes in the passages 21 and then passes uniformly in the air passages 15 of the heat exchanger unit 1. On the other hand, the gas guide unit 2 is closed at the oblique edges 18c, 19c of the guide plates 18, 19 as shown in FIG. 10. FIGS. 3 and 10 show two of the heat radiating unit of the construction described previously. As seen, the heat radiating plate 13 of one element is slightly spaced from the heat radiating plate 14' of the adjacent element to form a passage 17, and the oblique edge 18c

of the guide plate 18 of the gas guide element corresponding to said one heat radiating element and the oblique edge 19'c of the guide plate 19' of the adjacent guide element are welded together, whereby a space 22 is formed between said two guide elements. The other end edges 18'e, 19'e of the guide elements are welded together. Therefore, the space 22 forms a discharge opening 23 between the guide plates 18, 19' of the two guide elements, and the gas passages 16, 17 located between the two guide elements are communicated with the discharge opening 23 through the space 22. This is the case for any adjoining heat radiating elements.

The gas guide unit 3 is composed of a plurality of adjoining guide elements. Each guide element, as shown in FIG. 4(E), is composed of a pair of guide plates 24, 25 embracing an extension of the reinforcing plate 12. One edges 24a, 25a of the guide plates 24, 25 are welded to the edges 10d, 11d of the heat radiating plates 10, 11 respectively and the opposite end edges 24b, 25b and 24c, 25c thereof are welded together respectively with the extension 12b of the reinforcing plate 12 interposed therebetween, by butt resistance welding (FIG. 10). The guide plates 24, 25 are corrugated such that a wavy sectional shape of a small curvature appears on the cross section taken on the line B—B' of FIG. 1. Therefore, it will be understood that elliptical spaces are formed between the guide plates 24, 25 as shown in FIGS. 4(E) and 11. The air passages 15 of the heat exchanger unit 1 communicate with the spaces 26. This is the case for any heat radiating element. With reference to the two guide elements shown in FIGS. 3 and 10, an outwardly bulged lower edge portion 24d of the guide plate 24 and an outwardly bulged lower edge portion 25'd of the adjacent guide plate 25' are welded together as shown in FIG. 9. Therefore, a space 27 is formed between the guide plates 24 and 25' as shown in FIGS. 3 and 4(E). This is the case for any adjacent heat radiating elements. The aforesaid spaces 26 communicate with the central hollow portion 8 of the heat exchanger and the spaces 27 communicate with the low pressure high temperature gas inlet opening 7 at one ends and with the gas passages 16, 17 of the heat exchanger unit 1 at the other ends thereof.

The heat exchanger unit 1 and the gas guide units 2, 3 are integrally connected together in the manner described above into a cylindrical body. The outwardly expanding edges 18f, 19f (FIG. 4(A)) of the guide plates 18, 19 of the gas guide unit 2 are partially pressed down to form a flange 30 as shown in FIG. 8, while flexed plates 31 (FIG. 3) are provided integrally on the gas guide unit 3, and an annular sealing plate 32 is secured to said flange and said flexed plates by butt resistance welding as indicated by the alternate long and two short dash line in FIGS. 1 and 8, to seal one of the heat exchanger unit 1. On the other hand, an annular sealing plate 34 is secured by butt resistance welding to plates 33 (FIG. 10) provided integrally on the heat exchanger unit 1 to seal the other end of the heat exchanger unit 1 and one end of the gas guide unit 3. Thus, an axial leakage of the low temperature high pressure air, supplied into the spaces 21 of the gas guide unit 3, from the opposite ends of the heat exchanger unit 1 is prevented and a leakage of the high temperature low pressure combustion gas, supplied into the spaces 27 of the gas guide unit 3, in the direction toward the sealing plate 34 is also prevented. Further, an annular sealing plate 38 is secured by resis-

tance welding to a flat portion 35 (FIG. 9) and plates 36 (FIG. 3) as indicated by the alternate long and two short dash line in FIGS. 1 and 9, said flat portion 35 being formed by partially bending the side edges of the welded lower portions of the guide plates 24, 25 by pressing and said plates 36 being provided integrally on the gas guide unit 3. Notches 53 (FIG. 3) formed in the lower edges of the guide plates 24, 25 are provided for the insertion of a lower die of a press and a welding electrode used in securing the sealing plate 38. A continuous flange 41 (FIG. 3) formed by projecting portions 39 (FIGS. 3 and 4) of the respective guide elements of the gas guide unit 2 is shaped by pressing into a flange 41' shown in FIG. 7 and an annular protective ring 43 is secured to said flange 41' by resistance welding. Further, O-rings 44, 45 (FIG. 1) are mounted in grooves 43a, 43b formed in the outer peripheral surface of the protective ring 43 respectively and the assembly of the heat exchanger unit 1 and the gas guide units 2, 3 is secured to the inner surface of the conduit 5 through said O-rings, which conduit 5 constitutes a housing (FIG. 1). Reference numeral 46 designates an annular bellows made from a sheet of a heat resisting material, e.g., a thin sheet of stainless steel, and having one end secured to the sealing plate 32 as by welding, with the other end secured to a flange 6a of the conduit 6 by means of bolts or welding. This bellows 46 serves to prevent a leakage of the low temperature high pressure air passing in the conduit 6 toward the gas guide unit 2. Reference numeral 47 designates another annular bellows also made from a thin sheet of stainless steel having one end secured to the sealing ring 38 as by welding, with the other end secured a flange member 49 which is connected to the conduit 4 through a packing 48. This annular bellows 47 serves to prevent a leakage of the high temperature low pressure combustion gas, passing in the gas inlet 7 toward the spaces 27 of the gas guide unit 3, into the conduits 4, 6 and the hollow portion 8. Reference numeral 51 designates still another annular bellows made, for example, from a thin sheet of stainless steel and having one end secured to the sealing plate 34 as by welding, with the other end secured to a flange member 54 as by welding, which flange member is connected to a conduit 52 through a packing 56. This annular bellows 51 serves to prevent a leakage of the heated high pressure air, flowing into the hollow portion 8, into the conduit 5 and a leakage of the low pressure high temperature combustion gas, discharged into the conduit 5, into the hollow portion 8.

The heat exchanger of the invention constructed as described above operates as follows: Namely, when the low temperature high pressure air generated by the compressor of the gas turbine engine is supplied into the conduit 6, it flows obliquely into the air inlet openings 20 from the outer periphery of the gas guide unit 2 and thence into the passages 21. The air inlet openings 20 are formed slantingly between the oblique edges 18b, 19b of the guide plates 18, 19 and said oblique edges 18b, 19b are expanded outwardly of each other as stated above. Therefore, the air inlet openings 20 have a relatively large area and the introduction of the high pressure air is facilitated. The guide plates 18, 19 respectively have a wavy cross section and are welded to the extension 12a of the reinforcing plate 12. Therefore, these guide plates have a large mechanical strength and will not be subjected to a deformation

under the pressure of the low temperature high pressure air. The low temperature high pressure air passing in the passages 21 flows into the air passages 15 in the heat exchange unit 1 while being guided by the tapered edges 10a, 11a of the heat radiating plates 10, 11 and, after passing through said air passages 15, flows into the spaces 26 in the gas guide unit 3 while being guided by the tapered edges 10c, 11c on the downstream side of the heat exchanger unit 1, and then flows into the central hollow portion 8 to be discharged axially in the direction opposite to the cover 9. Such flow of the low temperature high pressure air is indicated by the arrows C in FIG. 1. During passage of the low temperature high pressure air in the air passages 15 of the heat exchanger unit 1, the high temperature low pressure combustion gas passes in the gas passages 16, 17 of the heat exchanger unit 1 in the opposite direction to the flow direction of the air as described later, and gives the heat possessed thereby to said air. Thus, the so-called heat exchange takes place between the low temperature high pressure air and the high temperature low pressure combustion gas through the heat radiating plates 10, 11, 13, 14. The heat exchanging ratio in this case is extremely high because the low temperature high pressure air and the high temperature low pressure combustion gas flow adjacent each other and in opposite directions to each other. Because of the pressure differential between the low temperature high pressure air and the high temperature low pressure combustion gas, a force acts on the edge portions 10d, 11d of the heat radiating plates 10, 11, urging said edge portions to expand in the directions of the arrows D in FIG. 5. However, the bonding strength at the joints E between the heat radiating plates 10, 11 and the reinforcing plate 12 is large enough to overcome such force and the heat radiating plates 10, 11 will not be subjected to a deformation. The guide plates 24, 25 of the air guide unit 3 also have a wavy cross section and welded to the reinforcing plate 12. Therefore, these plates will not be deformed by the pressure of the heated high pressure air.

On the other hand, the high temperature low pressure combustion gas discharged from the gas turbine engine flows axially into the spaces 27 in the gas guide unit 3 as indicated by the arrow F in FIG. 1. Since one end of the gas guide unit 3 is closed by the annular plate 34, the combustion gas passing in the spaces 27 is directed into the gas passages 16, 17 in the heat exchanger unit 1 by being guided by the tapered edges 10c, 11c of the heat radiating plates 10, 11. The combustion gas thus passing in the gas passages 16, 17 gives the heat to the air passing in the air passages 15 as described above and then flows into the spaces 22 in the gas guide unit 2 by being guided by the tapered edges 10a, 11a of the heat radiating plates 10, 11, to be discharged to the outside from the discharge openings 23. Such flow of the high temperature low pressure combustion gas is indicated by the arrows F in FIG. 1.

It will be understood from the foregoing description that the high pressure air and the combustion gas respectively flow along independent paths completely isolated from each other and pass through the heat exchanger unit 1 in the opposite directions to each other and in adjacent relation to each other. Therefore, the low temperature high pressure air is heated very effectively and the heated air is supplied the combustor of

the gas turbine engine provided, for example, in the central hollow portion 8 of the heat exchanger.

In the embodiment described above, the tapered edges 10b, 11b of the heat radiating plates 10, 11 of the heat exchanger unit are connected with the edges 18a, 19a of the guide plates 18, 19 of the gas guide unit 2, and the tapered edges 10d, 11d of the former to the edges 24a, 25a of the guide plates 24, 25 of the gas guide unit 3 respectively, by butt resistance welding. It will be obviously understood, however, that these plates may be substituted by an integral member made from a single sheet of metal and shaped into the corresponding shape by pressing, or the longitudinal ends of the heat radiating plates 10, 11 may be smashed by pressing to form tapered portions and flat portions 57, 58, 59, 60 and said flat portions may be connected in plane contact with the edges 18a, 19a, 24a, 25a respectively by butt resistance welding, to obtain the same effect as described above.

It is also to be understood that the present invention is not restricted only to the embodiment described and illustrated herein, but many modifications are possible. For instance, the corrugation of the heat radiating plates 10, 11, 13, 14 is not necessarily restricted to a rectangular shape but an arcuate shape in cross section. The guide plates 18, 19 of the gas guide unit 2 may be combined with the extension 12a of the reinforcing plate interposed therebetween such that the convexes and concaves thereof are respectively parallel to each other as shown in FIG. 13, and obviously the guide plates 24, 25 of the gas guide unit 3 may be combined likewise as shown in FIG. 14. Further, instead of using a press for forming the guide plate 13, the heat radiating plate 10 and the guide plate 24, or the guide plate 19, the heat radiating plate 11 and the guide plate 25, as a unitary piece, a method may be employed which comprises preparing a die of a shape complementary to the unitary piece forming a metal layer on said die by electric casting which is a sort of plating method and removing the metal layer from said die when the thickness of said metal layer has reached a desired value. Still further, brazing or soldering may be used, instead of resistance welding, for mechanically coupling the gas guide unit 2, the heat exchanger unit 1 and the gas guide unit 3 with each other. The resistance welding is preferably carried out continuously, for example, by using the discharge current of a capacitor.

In the present invention, as described above, the heat exchanger unit is composed of a plurality of corrugated plates radially arranged in juxtaposed relation so as to form independent radial passages between each other, and fluid is passed in every other ones of said passages radially inwardly from the outer periphery of the heat exchanger unit, while different fluid is passed in the other every other ones of said passage radially outwardly from the center of the heat exchanger unit. By selecting the shape of corrugation of the corrugated heat radiating plates, the heat transfer area can be freely adjusted. Therefore, the heat exchanger of the invention can be used with any combination of fluids and particularly advantageously used for the heat exchange between air and air such, for example, as in a gas turbine engine, which requires a large heat transfer area on each side of a heat radiating plate. In the present invention, two kinds of fluid between which it is desired to exchange heat are passed counterflowwise on both sides of one corrugated heat radiating plate. This

plus the fact that the corrugated heat radiating plates are radially arranged in juxtaposed relation, enables such a remarkable advantage to be obtained that the heat transfer effect per unit area of the heat radiating plate can be increased far greater than in the conventional parallel flow type and perpendicular flow type ones of tube bank type and tubefin type heat exchangers, and consequently the heat exchanger of the invention can be very small in size with a minimum dead space therein, as compared with the conventional ones for the same heat exchanging capacity.

In the present invention, those corrugated heat radiating plates which are subjected to an internal pressure resulting from the pressure differential between two fluids passing on both sides thereof are coupled together through the intermediary of the reinforcing plate. Therefore, these corrugated heat radiating plates are well resistive against such internal pressure by virtue of the bonding strength between said heat radiating plates and said reinforcing plate. Owing to the presence of the reinforcing plate, it is unnecessary to register the pitch of corrugation of the corrugated heat radiating plates which are coupled together through the reinforcing plate. The heat radiating plates can be coupled with the reinforcing plate in an optional relative position, which greatly facilitates the production of the heat exchanger unit.

In the present invention, the radially opposite ends of the corrugated heat radiating plates are respectively tapered to form flat portions which define the radially opposite ends of the independent radial passages between each other. Therefore, the fluid flowing into one passage and the fluid flowing out of the adjacent passage can be separated positively and by a simple structure. Further, the aforesaid tapered flat portions give no resistance to the fluid flowing into or out of the passages, providing for a smooth uniform flow of fluid. The tapered flat portions at the radially opposite ends of the corrugated heat radiating plate can be shaped by a single pressing operation, which makes the fabrication of the plate very simple and easy.

What is claimed is:

1. A stationary heat exchanger comprising a heat exchanger unit mounted in a housing having means for passing fluids therethrough for a gas turbine engine, said heat exchanger unit including a plurality of heat radiating elements arranged in juxtaposed relation, each said element being composed of space corrugated heat radiating plates forming convexes and concaves of rectangular section and a reinforcing plate interposed therebetween, said heat radiating plates defining independent and adjacent passages between each other, means for leading fluid into every other ones of said passages from the outer periphery of said heat exchanger unit to pass it radially inwardly therein including a plurality of first guide plates, each attached to said heat radiating plates and means for leading another fluid into the rest of said passages from the central portion of said heat exchanger unit to pass it radially outwardly therein including a plurality of second guide plates, each attached to said heat radiating plates the opposite ends of said corrugated plates respectively being tapered to form flat portions for separating two kinds of fluids.

2. A stationary heat exchanger as defined in claim 1, wherein said heat radiating elements are continuously arranged to form a cylindrical body.

3. A stationary heat exchanger as defined in claim 1, wherein said heat radiating plates constituting the heat radiating elements are provided on their outer surfaces with means for increasing heat transferring surfaces so as to promote a heat efficiency.

4. A stationary heat exchanger as defined in claim 4, wherein gas guide means is provided adjacent the outer

end of the heat exchanger unit for guiding said one of the gases into said every other passage, said guide means being provided with passages for introducing said gas from the outside of the heat exchanger into the heat exchanger unit.

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