July 12, 1949. L. McT. CAMERON 2,476,179

HEAT EXCHANGER

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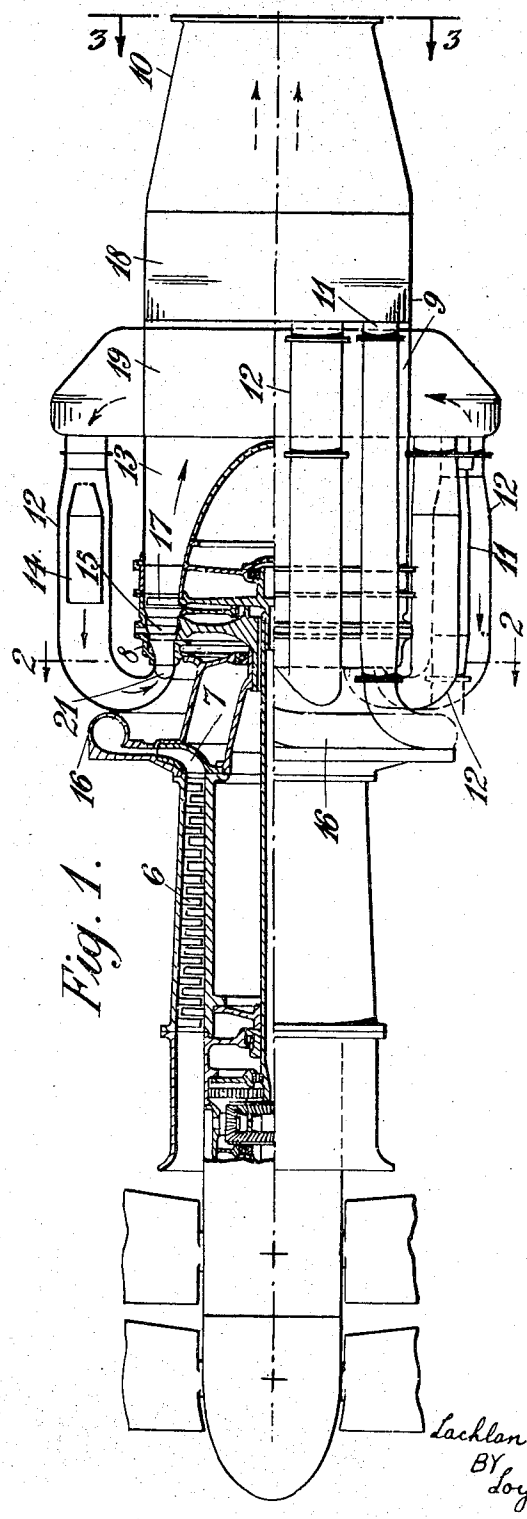



Fig. 1.

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Fig. 2.

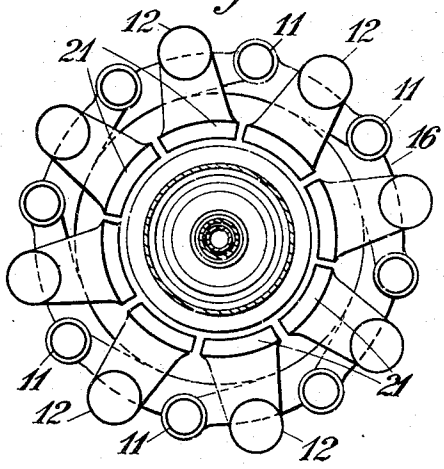



Fig. 4.

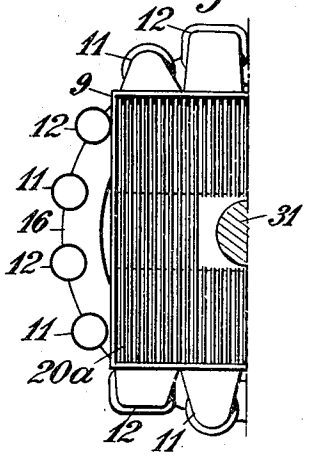



Fig. 5.

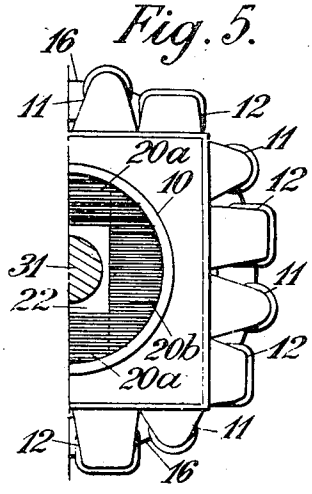
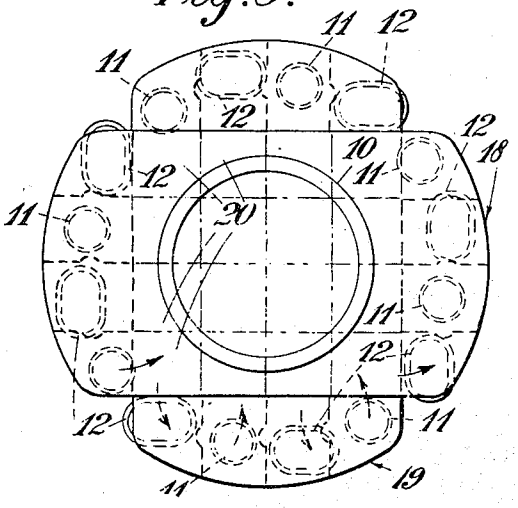



Fig. 3.



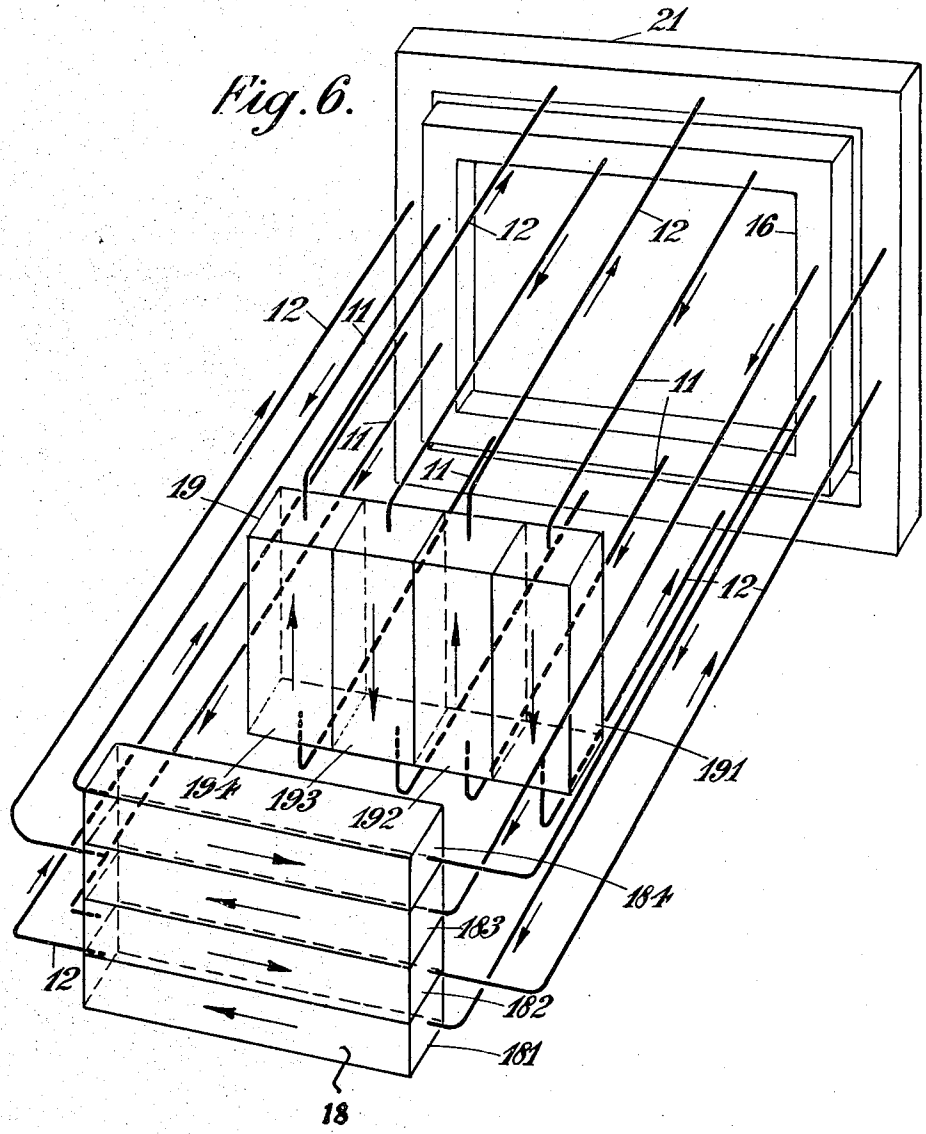

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Fig. 6.




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# UNITED STATES PATENT OFFICE

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## HEAT EXCHANGER

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Section 1, Public Law 690, August 8, 1946
Patent expires August 12, 1962

4 Claims. (Cl. 257—235)

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This invention concerns improvements in or relating to heat-exchangers and has for its object to provide a construction of heat-exchanger in which one of the two fluids passing therethrough is enabled to enter and leave the heat-exchanger in a number of different directions.

To this end a heat-exchanger in accordance with the present invention comprises a plurality, for example, two, heat-exchange compartments which are disposed side-by-side and ducts leading fluid to and from said compartments, the arrangement being that one of the two fluids passing through the heat-exchanger is divided into two streams one for each compartment, the streams passing through the compartments in dissimilar directions.

According to another feature of the invention each compartment is divided into a plurality of heat-exchange cells and one of said fluids is adapted to be divided into as many currents as there are cells, the arrangement being that for each compartment, the currents pass through adjacent cells in opposite directions.

Preferably the cells of one compartment are normal to the cells of the adjacent compartment so that the paths followed by the currents passing through the compartments are mutually at right angles.

Whilst the invention is concerned with heat-exchangers in general, the heat-exchanger in accordance with the present invention is particularly suitable for use in conjunction with jet-propulsion and gas-turbine units for aircraft. Accordingly two embodiments of the present invention as applied to a gas-turbine unit will now be described with reference to the accompanying drawings in which:

Figure 1 is a longitudinal elevation partly in section of a gas-turbine unit for an aircraft in which a heat-exchanger in accordance with the present invention is incorporated as one of the members of the unit,

Figure 2 is a section on the line 2—2 of Figure 1,

Figure 3 is a view in the direction of arrow 3 of Figure 1,

Figures 4 and 5 are views respectively corresponding to Figures 2 and 3 and showing a construction of heat-exchanger for use with a gas-turbine unit in which the power is transmitted to a pusher airscrew by a shaft passing through the heat-exchanger, and

Figure 6 is an explanatory diagram.

The general disposition of the elements of the gas-turbine unit, which is intended to drive a tractor airscrew, is as shown in Figure 1. To reduce the overall diameter of the unit to a minimum the various components are placed as far as practicable one behind the other. Thus the air-compressor (which is constituted by an axial-flow compressor 6 in series with a centrifugal compressor 7) is disposed at the front of the unit, i. e. facing the direction of motion of the aircraft, the turbine unit which is generally indicated at 8, is placed behind the compressor, the heat-exchanger 9 is placed behind the turbine unit and finally the discharge nozzle 10 is placed behind the heat-exchanger. The diametral dimension of the heat-exchanger 9 and turbine unit 8 is less than that of the centrifugal compressor 7 and the advantage is taken of this to place ducts 11, 12 outside these components without their extending materially beyond the periphery of the compressor in a radial direction. A trunk 13 extends from the discharge side of the turbine-unit to the heat-exchanger and is adapted to convey the exhaust gases from the former to the latter. The ducts 11 (Figure 2) are provided to convey air from the compressor to the heat-exchanger and the ducts 12 to convey the pre-heated air from the exchanger to the turbine unit 8. The turbine unit described operates as follows:

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The compressors 6, 7 which are driven by the turbine 15 supply air to an annular expansion chamber 16. This air is led by the cold-air ducts 11 to the heat-exchanger 9 which it traverses and is then led back by the pre-heated-air-ducts 12 to the turbine unit 8. Disposed within each pre-heated-air duct is a combustion chamber 14 in which the fuel is burnt and through which the whole or a part of the pre-heated air passes. The combustion products perform work in passing through the turbine unit 8, of which the turbine 15 is coupled to and drives the compressor 6, 7 whilst the turbine 17 is coupled to and drives the airscrew, illustrated as contra-rotating co-axial airscrews. The exhaust gases from the turbine unit 8 flow along the exhaust gas trunk 13 and through the exchanger 9 to the discharge nozzle 10.

The exhaust gases in flowing through the exchanger give up part of their heat-content to the cold air circulating therethrough so that the latter is preheated before it approaches the combustion chambers.

In the particular application of the invention referred to two factors are of special importance. Firstly the pressure drop entailed across the "cold" side of the exchanger is of relatively little importance whilst the pressure drop encountered in the "hot" side is material. The latter pressure drop must therefore be kept at a minimum. To

this end, the exhaust gases from the turbine are constrained to follow a straight path to the discharge nozzle; however, the air passing from the compressor to the exchanger and thence to the turbine may without undue ill effect follow a circuitous path.

The second factor is that of ensuring uniformity of distribution by the compressor and of supply to the turbine. This requires that as great a number of outlets be spaced around the expansion chamber of the compressor as is practicable, and that a similar disposition of inlets to the turbine be provided. The construction of the heat-exchanger is such that a plurality of spaced outlets and inlets can be provided, and this is diagrammatically illustrated in Figure 6. For the sake of clarity the annular expansion chamber 16 of the compressor is shown as of rectangular form, and the inlet chamber 21 to the turbine nozzles is also shown as of rectangular form. The heat-exchanger comprises two compartments 18, 19 which, also for clarity, are spaced apart and the compartment 18 is constructed as four separate cells 181, 182, 183 and 184, these cells extending horizontally across the compartment. Similarly, the compartment 19 is made in four separate cells 191, 192, 193 and 194, but these extend vertically across the compartment.

The hot products of combustion flow through the central openings of the parts 16 and 21 by a straight course through the compartment 19 and then through the compartment 18 so as to have as little restriction as possible to the flow. The air from the expansion chamber 16 passes by a number of tubes 11 to the heat-exchanger, and two of such tubes are shown passing respectively from the top, bottom and two side sections of 16 representing a uniform distribution from the chamber 16. The two tubes 11 from the top horizontal section enter the cells 191 and 193 respectively, and the air passes downwards through these cells and then returns by the tubes 12 to the bottom horizontal section of the turbine inlet chamber 21. Similarly air from the bottom horizontal section of the chamber 16 enters the cells 192 and 194 and passes upwards therethrough returning by the tubes 12 to the top horizontal section of the chamber 21. All the air passing through the compartment 19 travels in a vertical direction, being upwards and downwards respectively in adjacent cells.

A similar arrangement is provided for the sides of the chambers 16 and 21, and in this case the air passes through the compartment 18. From the right-hand vertical section of the chamber 16 the air passes to the cells 181 and 183 and passes horizontally therethrough, and is returned to the left-hand vertical section of the chamber 21; the air from the left-hand vertical section of the chamber 16 passes through the cells 182 and 184 from left to right and returns to the right-hand vertical section of the chamber 21. All the air passing through the compartment 18 therefore, moves in a horizontal direction, alternately towards the right and towards the left in adjacent cells. It will be seen, therefore, that a uniform distribution of air from the chamber 16 is obtained by the pipes 11 with a uniformly distributed supply by the pipes 12 to the chamber 21 and this uniform distribution is associated with an arrangement of cells which provides oppositely directed currents of air in adjacent cells, whilst the streams of air in the two compartments 18 and 19 respectively are mutually at right angles to one another; this arrangement provides for the highest efficiency of heat transfer.



In practice, the chambers 16 and 21 will usually be of circular form as shown in Figures 2 and 3, and the heat-exchanger 9 is a cubiform structure built in normal manner from a multitude of heat-exchanger elements contained within a frame.

The exchanger is mounted behind the exhaust gas conduit with one face of the exchanger directed toward the turbine so that the gases approach normally to one face of the exchanger, pass through the exchanger and leave the opposite face thereof. In this way the exhaust gases may be discharged from around the whole of the periphery of the gas turbine and follow a comparatively free path to the discharge nozzle. The cold air side of the heat-exchanger is divided equally into two compartments 18, 19 (see Figure 1) and each such compartment is further subdivided into a plurality of cells 20 which extend across the compartments. The cells in the compartments 18 and 19 are respectively disposed so that the cold air will travel through the compartment 18 in a horizontal direction as shown in Figure 3, whilst the cold air will travel through the cells of the compartment 19 in a vertical direction i. e. the air in adjacent compartments follows paths which are mutually at right angles.

The flow of air and gases through the chambers is as follows:

Cold air is led by ducts 11 from a plurality of outlets which are equally spaced around the periphery of the expansion chamber 16 of the compressor. The number of outlets corresponds to the total number of cells contained in both compartments. In the embodiment shown in Figure 3 there are a total of four cells for each of the two compartments, so that the total number of cells and thus the total number of outlets from the compressor is 8.

For compartment 18 the air from the compressor is led into a cell 20 flows across it in a horizontal direction as seen in Figure 3 and in so doing gains heat from the exhaust gases which are passing successively through the two compartments 18, 19. The pre-heated air leaves the cell by the opposite face from which it entered and passes to a pre-heated air duct 12 and combustion chamber 14 and thence to one of the gas turbine nozzles 21 which are equal in number to the outlets from the compressor. The air in the next adjacent cell of the compartment 18 follows a similar path except that it flows through the cell in an opposite direction from that for the cell already referred to. Thus the air in the bottom cell of the compartment 18 (see Figure 3) flows from left to right whilst the air in the next adjacent cell from right to left. Similarly with the flow of air through the other cells.

The flow of air through the compartment 19 is similar to that described for compartment 18, in this case however, the air flows through the cells and crosses the compartment in a vertical direction. Here again air in adjacent cells flows in opposite directions. For instance, in the right-hand cell shown in Figure 3 the flow of air is from the bottom towards the top whereas in the next adjacent cell it is from the top towards the bottom.

It will be noted from Figures 2 and 3 that the cold air ducts 11 and pre-heated air ducts 12 (which are grouped around the periphery of the exchanger 9, exhaust gas trunk 13 and turbine unit 8) are intercalated.

The embodiment shown in Figures 4 and 5 is for incorporation in a gas turbine unit of similar construction to that shown in Figure 1 and described above, with the exception that the turbine 17 instead of driving a tractor airscrew disposed at the front of the compressor, transmits its drive to a pusher airscrew disposed behind the unit. This necessitates that the airscrew-shaft passes from the turbine 17 through the heat-exchanger 9 and discharge nozzle 10. To meet the requirements of this construction the heat-exchanger has been modified as shown in Figures 4 and 5, in which like parts as are shown in Figures 2 and 3 are indicated by the same numerals.

Thus cells 20*a* which are located around the outer surface of the heat-exchanger 9 convey the air from its associated cold air ducts 11 to their associated preheated air ducts 12 without interruption. Passing through those cells 20*b* which are located at the middle of the heat-exchanger is the airscrew shaft 31. In order to maintain continuity of flow through the cells the shaft 31 is enveloped by a collector 22 which extends for the length of the heat-exchanger. The cold air moving through the cells 20*b* then discharges into the collector, passes round the shaft and continues its path through the other part of the cell towards the pre-heated air ducts 12.

The distribution of cold air from the compressor and pre-heated air to the turbine unit can be rendered very uniform by the provision of a sufficient number of such compartments and cells.

It will be appreciated that the matrix of the heat-exchanger can be built up from finned tubes, embossed plates and the like.

I claim:

1. A heat exchanger comprising two compartments, a plurality of cells for each compartment, a plurality of passages for each cell to convey fluid in one direction only therethrough, the passages of the cells of one compartment being disposed normal to the passages of the cells of the other compartment, an inlet duct for each cell by which fluid is admitted to the heat exchanger and an outlet duct for each cell by which fluid is discharged from the heat exchanger after having passed through one cell only, said inlet and outlet ducts being intercalated around the periphery of the heat exchanger.

2. A heat exchanger comprising a duct for conveying a first heat-exchange fluid, a pair of matrices lying side by side within the duct each



for conveying a second heat-exchange fluid once only across the duct along straight parallel paths, the paths traversed by the second fluid along one matrix being normal to the paths traversed by said fluid through the other matrix, a plurality of inlet ducts to convey the second fluid to each matrix, a plurality of ducts to convey the second fluid from each matrix, said inlet and outlet ducts being disposed wholly around the first fluid duct and the inlet ducts being intercalated with the outlet ducts.

3. A heat exchanger comprising a straight duct of rectangular cross-section for conveying a first heat-exchange fluid, a plurality of straight parallel tubes extending across one pair of opposite sides of the rectangular duct and forming a first matrix to convey a part of a second heat-exchange fluid through the exchanger once only, a plurality of straight parallel tubes extending across the other pair of opposite sides of the rectangular duct and forming a second matrix to convey the remainder of sid second heat-exchange fluid through the exchanger once only, said matrices lying side by side, a plurality of inlet ducts for each matrix, and a plurality of outlet ducts for each matrix, said inlet and oulet ducts being spaced wholly around the rectangular duct and being intercalated.

4. A heat exchanger according to claim 1 wherein a collector extends lengthwise of the heat exchanger through certain of the cells of both compartments and the passages of said cells communicate with said collector so that the fluid in travelling from an inlet to an outlet through said cells passes through the collector.

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