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# (54) Plate heat exchangers

(57) In a heat exchanger having a core consisting of plates 12 together defining passages (e.g. 14, Fig. 6) for compressed air alternating with passages (16) for hot exhaust gases, a manifold 22*a* or 22*b* interconnects adjacent air passages and comprises a hoop 52 positioned to extend between one plate and the next and to overlap a common juncture of said pair of plates, in particular a joint between short tubular interconnections spanning the gas passages, and formed by annular plate portions e.g. 54*a* displaced from the general plane of the plates and brazed together. The hoop 52 is brazed around each tubular interconnection, overlapping and reinforcing the brazed joint between the annular portions. The manifold can be reinforced against deformation by bars (32, Figs. 9—11) which extend along edge regions of the plates.

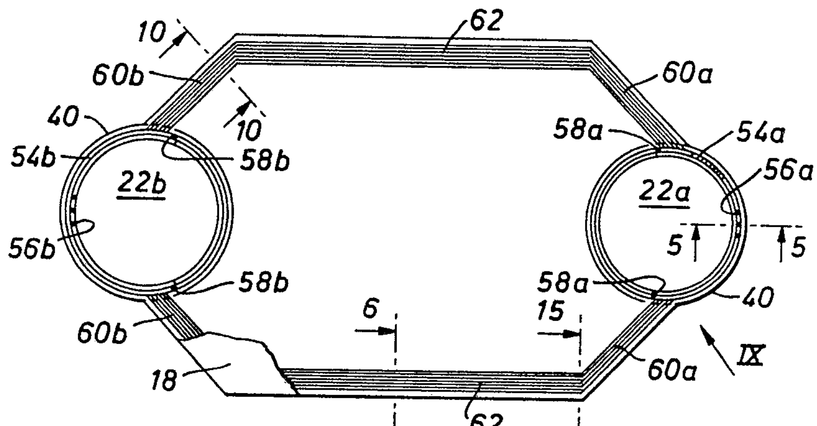

FIG. 4.

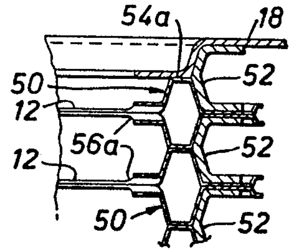

FIG. 5.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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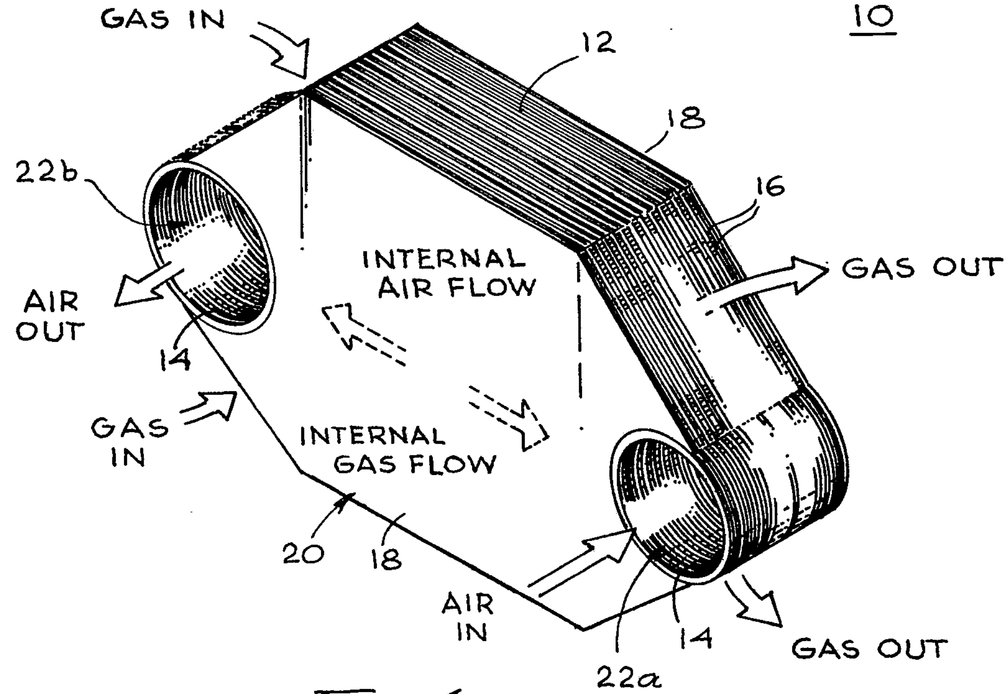


Fig. 1

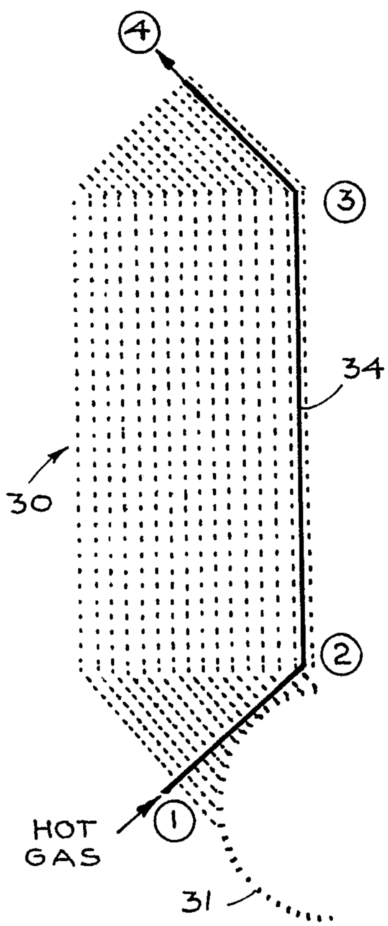


Fig. 2

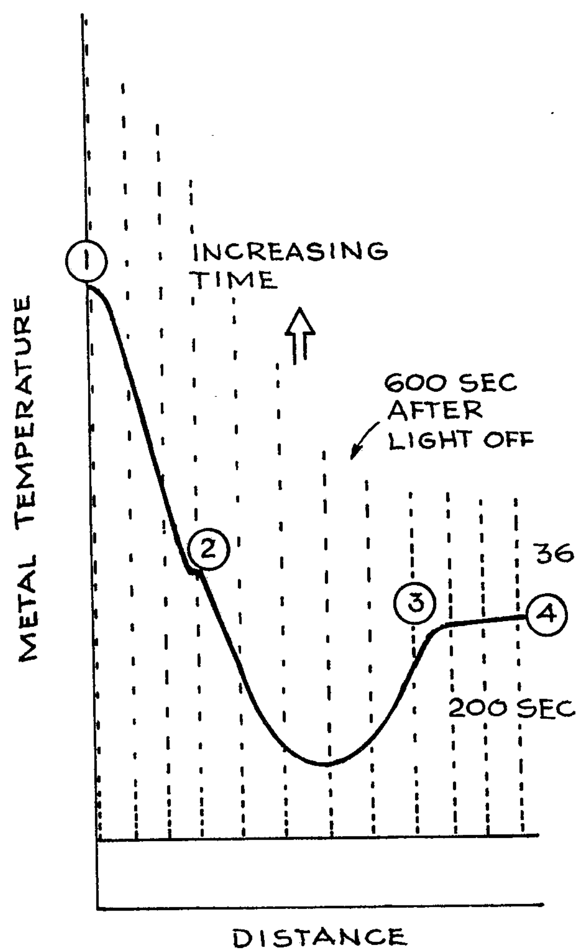


Fig. 3

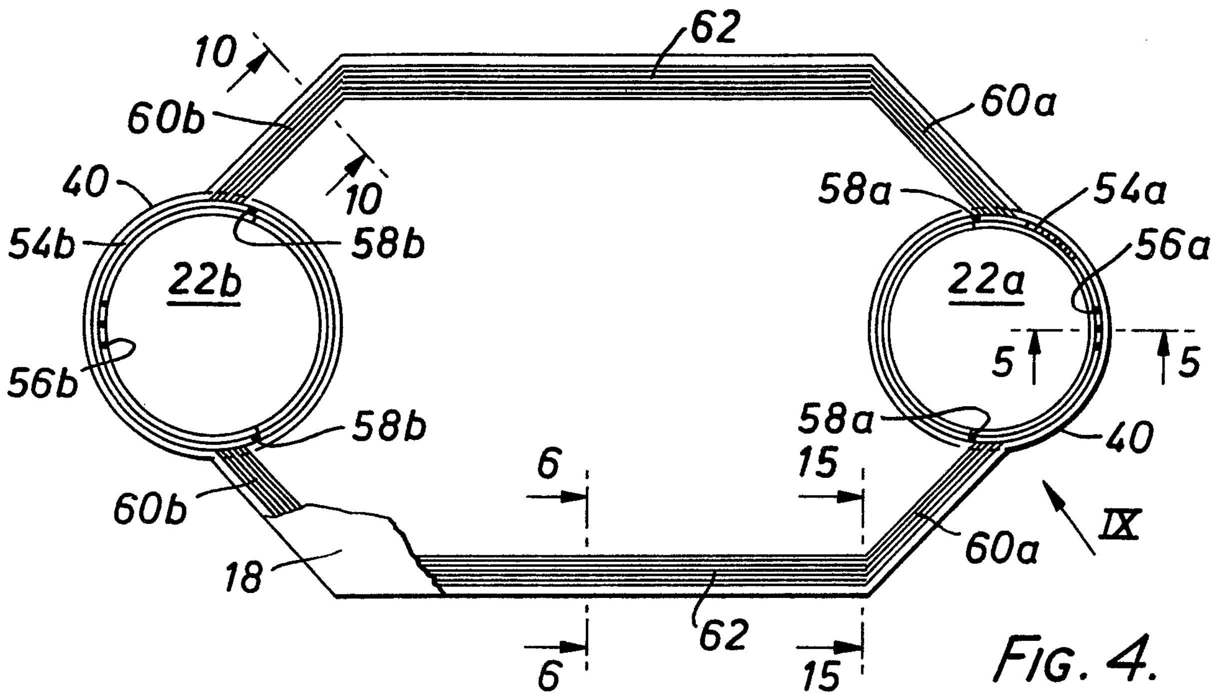


FIG. 4.

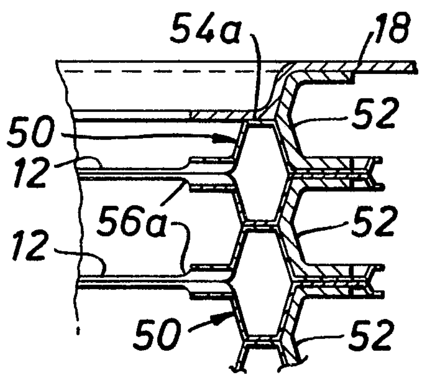


FIG. 5.

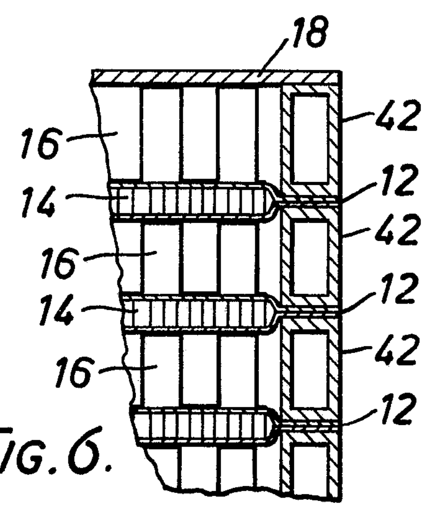


FIG. 6.

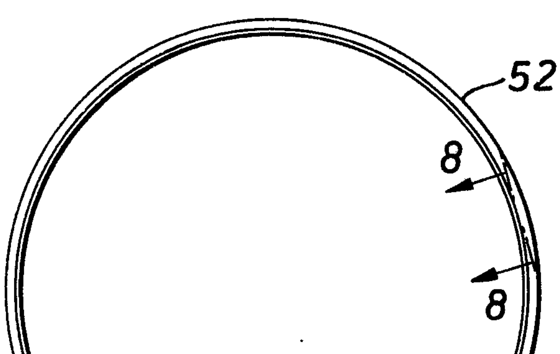


FIG. 7.

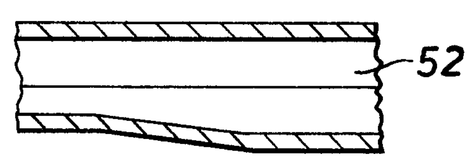


FIG. 8.

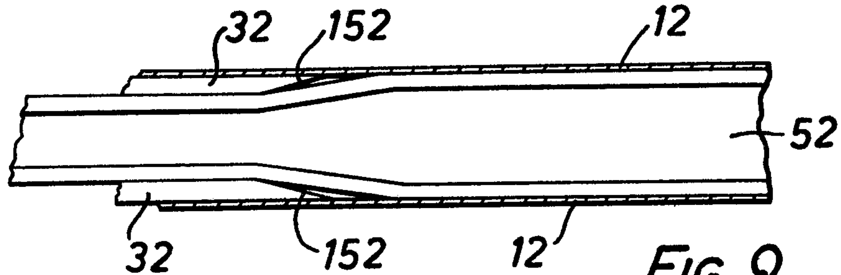


FIG. 9.

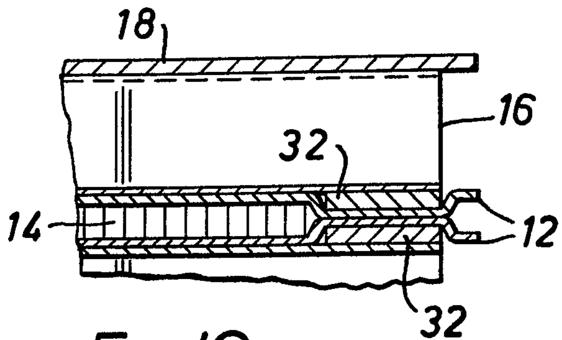


FIG. 10.

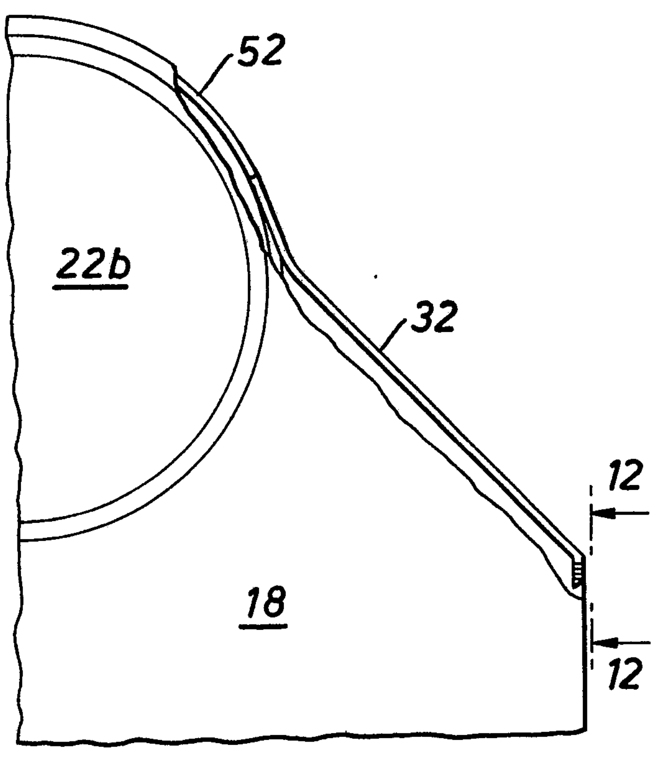


FIG. 11.

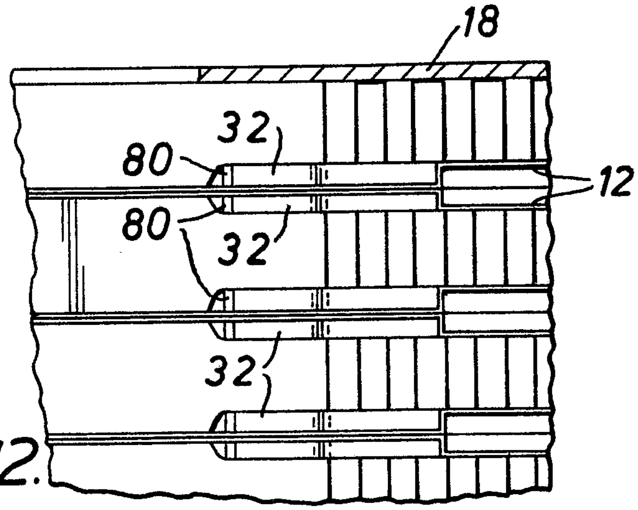


FIG. 12.

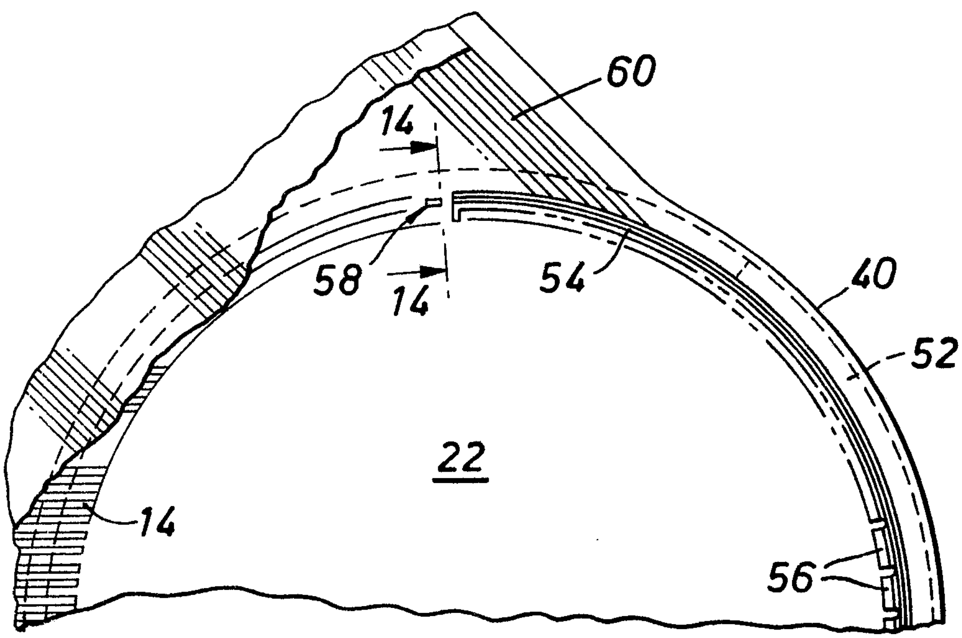


FIG. 13.

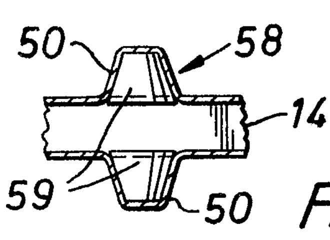


FIG. 14.

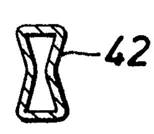


FIG. 15.

SPECIFICATION

**Heat exchangers for high pressure fluids**

This invention relates to heat exchangers for applications in which one of the heat exchange fluids is at a relatively high pressure. It is particularly but not exclusively applicable to heat exchangers for use as regenerators in gas turbine engine systems; such heat exchangers transfer heat from turbine exhaust gases, which are at relatively low pressure, to compressed air supplied by a compressor at relatively high pressure, to serve as combustion air.

Many of the regenerators in previous gas turbine engines have been a plate-and-fin type of construction incorporated in a compression-fin design.

The previously used compression-fin design developed unbalanced internal pressure forces of substantial magnitude, often of several hundred thousand kgf in a regenerator of suitable size. Such unbalanced forces, tending to split the regenerator core structure apart, were contained by an exterior frame known as a structural or pressurized strongback. There are advantages in arranging for the heat exchanger core structure to bear these pressure forces, so that the strongback can be eliminated, and there are no unbalanced pressure forces outside the core. However, certain parts of the heat exchanger core may require extra reinforcement to ensure that they carry these pressure forces.

According to one aspect of the invention, a heat exchanger comprises a series of plates defining, between them, passages for, alternatively, a heating fluid and a fluid to be heated, and one or more manifolds which extend through the plates, to interconnect the various passages carrying one of the said fluids, the or each manifold being formed by integral annular poritions of the plates which are displaced from the respective general planes of the plates to form tubular interconnections between the plates, and the heat exchanger also includes a plurality of reinforcing hoops, each of which extends around one of the said tubular interconnections, and overlaps the joint between the two integral annular portions of the two plates which form the respective tubular interconnection, and the hoop being structurally connected to both these plates.

In a preferred form of the heat exchanger, the integral annular portions of the plates are brazed together to form the tubular interconnections. Nornally, the said one fluid will be the fluid which is at the higher pressure, so these brazed joints are placed in tension. Brazed joints between flat surfaces are relatively weak in tension, but these joints are straddled by the reinforcing hoops, which are preferably also connected to the plates by brazing. In this way, the tubular interconnection is enabled to withstand the tension forces which result from being pressurized to, say, 7 to 11 bars, and which may amount to several thousand kgf.

The remaining parts of the plates are preferably interconnected by fins which prevent separation of the plates under the pressure forces.

Reinforcing bars may be provided which extend from the reinforcing hoops, along the surfaces of the plates. These bars preferably extend along edge regions of the plates, and are connected to side bars which join the plates along further parts of their edge regions. In the gas turbine engine application, the hot exhaust gas may be directed to flow over these reinforcing bars before reaching the rest of the heat exchanger plates and therefore the reinforcing bars can also act as heat sinks, reducing the effect of sudden gas temperature changes on the heat exchanger.

The invention may be carried into practice in various ways, but one specific example will now be described by way of example, with reference to the accompanying drawings, of which:

Figure 1 is a diagrammatic view, in perspective of a heat exchanger core section embodying the present invention;

Figure 2 is a diagrammatic representation of a portion of the heat exchanger of Figure 1, as it is represented for the purposes of computer modelling;

Figure 3 is a chart showing the temperature of the metal at different points in the heat exchanger, as calculated by the computer model, over a period of time following turbine light-off;

Figure 4 is somewhat diagrammatic elevation of the heat exchanger core, sectioned so that the air flow side of one of its plates is visible;

Figure 5 is a section taken on the line 5—5 of Figure 4;

Figure 6 is a section taken on the line 6—6 of Figure 4;

Figure 7 is a section taken on the line 6—6 of Figure 4;

Figure 7 is an elevation of a reinforcing hoop which is incorporated in the heat exchanger;

Figure 8 is a section taken on the line 8—8 of Figure 7;

Figure 9 is an elevation taken in the direction of the arrow IX of Figure 4, and shows a joint between a reinforcing hoop and a pair of reinforcing straps;

Figure 10 is a section taken on the line 10—10 of Figure 4;

Figure 11 is a view, similar to part of Figure 4, but enlarged, and with part of the structure broken away;

Figure 12 is a partial elevation, taken on the line 12—12 of Figure 11;

Figure 13 is a view, similar to part of Figure 4, but enlarged, and with part of the structure broken away;

Figure 14 is a section taken on the line 14—14 of Figure 13; and

Figure 15 is an enlarged section taken on the line 15—15 of Figure 4.

Figure 1 illustrates a brazed regenerator core as utilized in heat exchangers of the type discussed hereinabove. The unit 10 of Figure 1 is but one section of a plurality (for example, six) designed to be assembled in an overall heat exchanger module. The core section 10 comprises a plurality of formed plates 12 interleaved with air fins 14 and gas fins 16, which serve to direct the air and exhaust gas in alternating adjacent counterflow passages for heat transfer. Side plates 18, similar to the inner plates 12 except that they are formed of thicker sheets, are provided at opposite sides of the core section 10. When assembled and brazed together to form an integral unit, the formed plates define respective manifold passages 22*a* and 22*b* at opposite ends of the central counterflow heat exchanging section 20, which manifold passages communicate with the air passages in the central section 20.

As indicated by the respective arrows in Figures 1, heated exhaust gas from an associated turbine enters the far end of the section 10, flowing around the manifold passage 22*b*, then through the gas flow passages in the central section 20 and out of the section 10 on the near side of Figure 1, flowing around the manifold 22*a*. At the same time, compressed air from an inlet air compressor associated with the turbine enters the heat exchanger section 10 through the manifold 22*a*, flows through internal air flow passages connected with the manifolds 22*a*, 22*b* through the central heat exchanging section 20, and then flows out of the manifold 22*b* from whence it is directed to the burner and associated turbine (not shown). In the process the exhaust gas gives up substantial heat to the compressed air which is fed to the associated turbine, thereby considerably improving the efficiency of operation of the turbine system.

Heat exchangers made up of core sections such as the unit 10 of Figure 1 may be provided in various sizes for regenerated gas turbine systems, which may, for example, produce outputs in the range of 4 MW to 80 MW. In the operation of a typical system employing a regenerating heat exchanger of this type, ambient air enters through an inlet filter and is compressed to from 8 to 12 bars absolute pressure, reaching a temperature of approximately 315°C in the compressor section of the gas turbine. It is then piped to the heat exchanger core where the air is heated to about 480°C by the exhaust gas from the turbine. The heated air is then returned to the combustor and turbine sections of the associated engine via suitable piping. The exhaust gas from the turbine is at approximately 600°C and essentially ambient pressure. The exhaust gas drops in temperature to about 315°C in passing through the core section 10 and is then discharged to ambient through an exhaust stack. In effect, the heat that would otherwise be lost is transferred to the turbine inlet air, thereby decreasing the amount of fuel that must be consumed to operate the turbine.

The regenerator is designed to operate for 120,000 hours and 5,000 cycles without scheduled repairs, a lifetime of 15 to 20 years in conventional operation. This requires a capability of the equipment to operate at gas turbine exhaust temperatures of 600°C and to start as fast as the associated gas turbine so that the heat exchanger does not impose any delays which result in wasting fuel while the system is brought up to a stabilized operating temperature. Instead, the starting-up and shut-down times are limited by certain regimes which must be followed during the start-up and shut-down of the turbine to accommodate the limitations of the turbine structure during these transitional phases. Thus, when a turbine is being started, it is first brought to approximately 20% of operating speed, at which time the combustor is lit off. Thereafter, under a controlled program, the turbine is eventually brought up to speed. A similar program is followed during shutdown. It is important from the operating standpoint of the overall regenerated turbine system that the heat exchanger included therein be capable of accommodating to the regime dictated by the limitations of the turbine structure. As will become clear from the following description, the heat exchanger 10 has certain design features which assist in fulfilling these requirements. These design features are concerned with certain portions of the heat exchanger core section where thermal stresses may be concentrated or where the structure may be weaker than at others.

Figures 2 and 3 are presented to illustrate the temperatures and thermal gradients encountered in heat exchangers of the type described herein. Figure 2 shows a nodal system used in one specific regenerator computer model. This represents a portion 30 of the core section 10 of Figure 1. Since the core is symmetrical, only half of the core is modeled. The circular section 31 is the hot end manifold; the cold manifold was not modeled because it is not in a region of potential thermal fatigue.

Figure 3 is a graph corresponding to the computer print-out of temperatures along the heavy line 34 of Figure 2 from turbine lightoff to 600 seconds after lightoff. The heavy line 36 in Figure 3 shows temperatures along the heavy line 34 of Figure 2 at 200 seconds after lightoff, the ordinates 1, 2, 3 and 4 along the line 36 corresponding to the points 1, 2, 3 and 4 along the line 34 of Figure 2.

The structure of the heat exchanger will now be described in greater detail. Referring first to Figure 4, this shows one of the formed plates 12, from the side which is contacted by the compressed air. The central area of the plate is flat, but a raised flange portion is provided all around the plate. When the heat exchanger is assembled, this raised flanged portion is brazed to the corresponding portion of a similar formed plate which is placed, in inverted position, on top of the formed plate 12. Thus, as can be seen from Figure 6, the two plates together form a shallow box, within which the compressed air is contained. The air fins 14 can also be seen in Figure 6; these fins are positioned within the box, and extend from one plate 12 to the other, being brazed to both these plates. In this way, the fins 14 strengthen the air flow box against the internal pressure of the compressed air, and also define a plurality of passages, between the fins, for directing the flow of the compressed air. The pattern of flow established by the fins 14 can be seen from Figure 4; some of the passages between the fins are shown at 60*a* near the air inlet manifold 22*a*, at 62 in the central portion 20, and at 60*b* near the air outlet manifold 22*b*.

In the assembled heat exchanger, the shallow boxes formed by the pairs of formed plates 12 are assembled with a small spacing between adjacent boxes, as can be seen from Figure 6, to allow the exhaust gases to flow over the outer surfaces of the boxes. This spacing is maintained by various components, including the gas fins 16, which are brazed to the plates 12 in the same way as the air fins 14. Figure 2 illustrates one of the gas flow paths defined by the fins 16 as the heavy line 34. The spacing between adjacent boxes is also maintained by side bars 42, which can be seen in Figure 6. These bars are hollow and rectangular, and extend along the length of the central portion 20 only of the heat exchanger, so that the exhaust gases can enter and leave the spaces between the air flow boxes along the oblique parts of the periphery of the plates 12. The side bars 42 are received between the raised, flanged edge portions of the plates 12, rather than between their central flat portions, and therefore the depth of the bars 42 is somewhat greater than that of the gas fins 16.

Finally, the structure of the air manifolds 22*a* and 22*b* also maintains the spacing between adjacent air flow boxes. Each manifold consists, essentially, of a series of short tubular portions bridging the spaces between adjacent air flow boxes, and thereby providing a tube which passes right through the heat exchanger, communicating with each of the air flow boxes. Thus, referring again to Figure 4, each formed plate 12 has a circular hole at each end, to accommodate the air flow in the manifold, and an annular area 54*a* or 54*b* around this hole is depressed away from the general plane of the central portion of the plate. As Figure 5 shows, this depressed annular portion is brazed to the corresponding portion of the formed plate 12 forming part of the adjacent air flow box, so that the two depressed portions together form a short tube linking the two air flow boxes.

The side plates 18 are completely flat, except for depressed annular portions corresponding to the portions 54*a* and 54*b* of the formed plates 12. Thus, as can be seen from Figures 5 and 6, there is a gas flow space between each side plate 18 and the adjacent air flow box.

The structure as so far described provides complete separation of the air and gas flows, but some parts of the structure may not be sufficiently strong to withstand the internal pressure forces to which they are subjected during operation. For this reason, various reinforcing components are incorporated in the heat exchanger, and will now be described.

Firstly, as Figure 5 shows, a reinforcing hoop 52 is positioned around each of the short tubular portions which form the manifolds 22*a* and 22*b*, and is brazed to the two adjacent formed plates 12. The hoop 52 bridges the annular brazed joint between the plates 12, providing added strength. Around almost the whole circumference of the manifold, the hoop is of such a depth (in the axial direction) that it fills completely the space between the plates 12; this means in general that, around that part of the periphery of the manifold which lies on the outside of the heat exchanger, each hoop 52 has the same depth as the side bars 42, while the rest of the hoop is rather shallower, being of the same depth as the gas fins 16. This variation in depth can be seen in Figure 9.

Figure 8 shows a slightly modified form of reinforcing hoop, which is fitted between each side plate 18 and the adjacent air flow box. Because the side plates 18 are completely flat, apart from the annular depressions around the manifolds, this modified hoop needs only half the variation in depth of the hoop shown in Figure 9; the side of the hoop against the side plate 18 is completely flat.

Secondly, reinforcing straps 32 extend from each manifold 22*a* and 22*b* to the ends of the side bars 42. These reinforcing straps are best seen in Figures 9 to 12. Each of the reinforcing straps is brazed to the outside of one of the air flow boxes, along the flanged edge portion of the formed plates 12; as Figure 10 shows, the depth of the flanged edge portions plus the thickness of the two reinforcing straps 32, one on each side of the air flow box, is equal to the depth of the main part of the air flow box. The gas fins 16 can therefore extend right to the outboard edge of the reinforcing straps 32, being brazed to these straps. At their ends adjacent the manifold 22*a* and 22*b*, the reinforcing straps 32 are brazed between the flanged peripheral portion of the formed plate 12 and the reduced depth portion of the reinforcing hoop 52, which for this reason continues a little way along the part of the periphery of the manifold 22*a* or 22*b* which is on the outside of the heat exchanger; this arrangement is shown in Figure 10, from which it will be seen that the end of the strap is tapered, as shown at 152, to match roughly the shape of the hoop 52 where the depth of the hoop changes.

At the ends 80 of the straps 32 adjacent the side bars 42, each strap is brazed between the side bar 42 and the plate 12; for each reinforcing strap, a rebate is formed in the end of the side bar 42, to accommodate the thickness of the reinforcing strap 32.

Thus, the ends of the straps, overlapping with the side bars 42 and the hoops 52 are brazed into a solid reinforcing structure to accomplish the desired reinforcement and containment of the air passages between the plates 12 and the region of the straps 32. The reinforcement of the respective manifold sections 22, as described hereinabove, is effected by the supporting arrangements of the hoops 52 which are also brazed to the plates 12 and the side plates 18. The straps 32 also serve to reinforce the manifold sections against deformation from thermal expansion since the outer portions of the manifolds, being in the form of an arch, have a greater tendency toward thermal deformation than the inner portions where the fins provide support.

Provisions are also made in the design of the heat exchanger to ensure that the heat exchanger is not subjected to excessive thermal stressing if the associated gas turbine plant is started up or shut down as fast as is permitted by the design of the turbine. In other words, the starting-up or shutting down speed should be limited by the turbine, not the regenerator. To achieve this result, arrangements are provided to direct air or exhaust gases to selected parts of the heat exchanger, to minimise thermal stressing during starting-up or shutdown, and these arrangements will now be described.

As described above, the manifolds 22*a* and 22*b* are formed by depressed annular portions of the formed plates 12. Radially inwards of these annular portions, the plates 12 have a further semi-annular portion which extends around the half of the circumference of the manifold on the outside of the heat exchanger, and lies in the centre plane of the air flow box, that is to say, in the same plane as the flanged edge portions of the plate 12, so that a semi-annular trough 50 is formed in the plate 12. This is best seen in Figure 5; as can be seen from this figure, a passage 54 is thus formed between the two plates 12 which form each air flow box, and this passage extends around 180° of the manifold. Taking the air inlet manifold 22*a* as an example, communication is provided from the manifold 22*a* to the semi-annular passage 54*a* by a number of openings 56*a*, which are formed by making portions of the inner semi-annular boundary of the trough spaced away from the centre plane of the air flow box; these openings are also visible in Figure 5. The ends of the semi-annular passages 54 are closed by plugs 58*a* and 58*b* (Figure 4), shown generally as 58 in Figures 13 and 14. As Figure 14 shows, each plug 58 has upper and lower portions 59, separated by the depth of one of the air fins 14.

The air entering the semi-annular passage 54 is therefore prevented from flowing straight out of the ends of the passage; instead, along the part of the passage near the plugs 58, the passage 54 is open on its outer side to the passages formed by the outermost air fins 14, so that the air is forced to follow these passages. This air then has to follow a similar path, but in reverse, when it reaches the air outlet manifold 22*b*.

Around the remaining 180° of the two manifolds, the edges of the plates bordering the manifold do not obstruct the passage of air directly between the manifold and the passages formed by the air fins 14.

By causing a portion of the compressed air to flow through the semi-annular passages, the temperature of the outer parts 40 of the manifolds 22*a* and 22*b* can be kept more or less in step with the temperatures of adjacent parts. It will be appreciated that, especially because of the extra thermal capacity presented by the reinforcing hoops 52, there would, without this extra air flow, be a tendency for the temperature of the outer parts 40 of the manifold to lag behind changes in temperature of the other parts.

During start-up operation, for example, compressed air at elevated temperature is introduced to the heat exchanger core via the inlet manifold 22*a*. This air passes along the passages defined by the fins 14 to the central part of the core and raises the temperature of the core in accordance with the temperature of the air. A portion of the air is bled off automatically through the openings 56 where it is caused to flow about the outer manifold portions 40 to heat these portions also as the central core section is being heated, thereby limiting the thermal gradients and related thermal stress between the respective portions of the heat exchanger core. When the turbine is lit off, after the core has been elevated in temperature from the heat of the compressed air as described, the exhaust gases bring the temperature of the core up further to steady state operating temperatures as the turbine is brought up to speed. During this period of the start-up phase, the outer portions of the manifolds are in the exhaust gas stream so they receive some heating directly from the exhaust gas, but those in the outlet manifold side also continue to receive heat from the continued flow of air through the passages 54 as this air is heated in the finned air passages 60, 62. During the shutdown phase of turbine operation, the turbine is throttled down to reduced speed and the air passing through the heat exchanger also cools down, the flow of this air through the passages 54 at the periphery of the manifold 22 serving to cool the manifold in accordance with the temperature of the remainder of the heat exchanger core.

The side bars 42 are hollow, as mentioned above. Their ends are open, and therefore the exhaust gas can flow through these bars as well as through the passages formed by the gas fins 16. Because there is only a limited heat conduction path between these side bars and the air fins 14, there may be a tendency for the side bars 42 to reach a a higher temperature than the rest of the structure, notwithstanding their greater thermal capacity; at any rate, the side bars 42 will not normally lag behind temperature changes in the rest of the structure. To control the amount of exhaust gas flowing through the side bars 42, the ends of the bars are crimped to reduce their flow cross-section, as is illustrated by Figure 15. In this way, it should be possible to avoid excessive thermal stresses. The side bars 42 adjacent the side plate 18 will probably not require any restriction of the exhaust gas flow, because heat is conducted away by the side plate 18.

A heat exchanger core section 10 is assembled by stacking the various inner plates 12, air fins 14 and gas fins 16, in repetitive sequence with the hoops 52, straps 32 and side bars 42 between outer plates 18, after which the entire assembly is brazed into a rigid integral unit. In assembling the heat exchanger components, an outer plate 18 is first laid down with its offset annular portions facing upward. An outer hoop is then placed about each manifold opening in the outer plate and a layer of gas fins and outer side bars is placed thereon in the manner shown in Figures 5, 6, 10 and 12, but inverted. Straps 32 are placed in position on the outer hoops 52 and side bars 42 and extending across adjacent portions of the gas fins 16. An inner plate 12 is next laid down with the manifold ring portion side down, bearing against the offset portion of the outer plate, and the peripheral flange side up. A layer of air fins 14 is then placed in position, together with a set of plugs 58, after which another inner plate 12 is laid on top of the assembly, but inverted from the attitude of the previously-placed inner plate 12 so that its flanges abut with the flanges of the adjacent plate. Next a layer of edge straps, gas fins, inner hoops, and side bars is placed in position, followed by the next inner plate of the next segment, etc., with the sequence being repeated until the assembly is completed and the outer hoops, side bars and plate on the upper side are applied to complete the stacked assembly. The assembly is then placed in a brazing oven to braze the entire assembly as a complete unit, brazing compound having been placed prior to assembly on all adjacent surfaces which are to be brazed. During assembly, spot welding is used to affix the various elements in place.

The arrangement of the reinforcing hoops and straps as separate elements which are integrally brazed and tied together with the central section side bars within the heat exchanger core advantageously permits the separate design of these elements for optimum strength and other desirable properties. The materials employed for these elements and the increased thickness relative to the thin tube plates which are afforded by this design serve to provide additional strength where needed in the heat exchanger. The reinforcing straps form beam sections bridging the portion between the manifold hoops and the central core section side bars and, at least on the gas inlet side of the heat exchanger, beneficially function as heat sinks which assist in reducing the thermal shock which otherwise might be encountered by the tube plate leading edges during light-off and shutdown of the associated turbine.

CLAIMS

1. A heat exchanger comprising a series of plates defining, between them, passages for, alternately, a heating fluid and a fluid to be heated, and one or more manifolds which extend through the plates, to interconnect the various passages carrying one of the said fluids, the or each manifold being formed by integral annular portions of the plates which are displaced from the respective general planes of the plates to form tubular interconnections between the plates, and the heat exchanger also including a plurality of reinforcing hoops, each of which extends around one of the said tubular interconnections, and overlaps the joint between the two integral annular portions of the two plates which form the respective tubular interconnection, and the hoop being structurally connected to both these plates.

2. A heat exchanger as claimed in Claim 1, in which each hoop is structurally connected to the two adjacent plates by brazing.

3. A heat exchanger as claimed in Claim 1 or Claim 2, in which each hoop is generally U-shaped in radial cross-section, with the base of the U radially innermost, and both the base and the sides of the U are structurally connected to the adjacent plates.

4. A heat exchanger as claimed in Claim 1 or Claim 2 or Claim 3 in which each hoop is formed of material thicker than at least some of the series of plates.

5. A heat exchanger as claimed in any of the preceding claims in which each pair of plates defining a passage for the said one fluid are spaced apart around a first part of the periphery of the manifold, to provide communication between the manifold and the said passages, and the two plates of each such pair are sealed together around a second part of the periphery of the manifold, each reinforcing hoop having a lesser axial thickness around the first part of the manifold periphery, and a greater axial thickness around the second part of the manifold periphery, to conform to the shape of the plates.

6. A heat exchanger as claimed in Claim 5, in which the variation of the axial thickness of reinforcing hoops received between adjacent plates is distributed symmetrically about a plane of symmetry of the hoop, normal to the axis of the hoop.

7. A heat exchanger as claimed in Claim 5 or Claim 6, which also includes a side plate which completes the series of plates, one of the reinforcing hoops being received between the side plate and the next plate, and the said one reinforcing hoop and the side plate have planar surfaces facing one another, by which surfaces they are structurally connected, the variation in axial thickness of the hoop being provided on the side of the hoop away from the side plate.

8. A heat exchanger as claimed in Claim 5 or Claim 6 or Claim 7, in which the axial thickness of each reinforcing hoop varies from the lesser thickness to the greater thickness in such a manner that the hoop conforms to the shape of each adjacent plate, apart from leaving a space which is occupied by an end of a reinforcing bar, which extends along the surface of the plate, away from the manifold.

9. A heat exchanger as claimed in Claim 8, in which each reinforcing bar extends along an edge region of one of the plates.

10. A heat exchanger as claimed in Claim 9, in which each pair of plates between which a reinforcing hoop is positioned are also joined, along an edge of the heat exchanger, by a side bar, the reinforcing bars each being connected to, at one end, one of the reinforcing hoops, and at the other end, one of the side bars.

11. A heat exchanger as claimed in Claim 10 in

which the ends of the side bars are rebated to receive the ends of the side bars.

12. A heat exchanger as claimed in any of Claims 8 to 11, in which each reinforcing bar extends along a region of the plates along which the two plates defining a passage for the said one fluid are sealed together, each reinforcing bar having a thickness approximately equal to half the spacing between the general planes of the said two plates.

13. A heat exchanger as claimed in any of the preceding claims, in which the passages between the plates of the series each contain fins interconnecting the plates.

14. A heat exchanger as claimed in Claims 12 and 13 in which the fins on the same side of each plate as one of the reinforcing bars are connected both to the plate and to the surface of the reinforcing bar remote from the plate.

15. A gas turbine engine system including a heat exchanger as claimed in any of the preceding claims, the engine system having a compressor which supplies compressed air to the heat exchanger as the said one fluid, to be heated by exhaust gases from a turbine of the engine system, and then to serve as combustion air.

16. Apparatus for the reinforcement of thin plate heat exchangers fabricated of stacked tube plates defining fluid passages and having manifold sections integrally formed with the heat exchanging sections thereof comprising:

a plurality of hoops positioned respectively between pairs of adjacent plates which are joined together in sealing relationship, each hoop being configured to extend from one adjacent plate to the next and overlap a common juncture of said plates, said hoop being joined in structural reinforcing relationship to the adjacent surfaces of said plates.

17. The method of providing reinforcement for integral manifold sections located at opposite ends of a heat exchanger fabricated of stacked formed plates and fins comprising the steps of:

forming a plurality of hoops to conform in configuration and dimension to the outer surfaces of offset ring portions surrounding manifold openings in respective plates; and

inserting during the stacking of the plates said plurality of hoops respectively between adjacent pairs of plates on the ring portion sides of the plates in positions surrounding said ring portions and in surface contact therewith.

18. The method of assembling a heat exchanger core comprised of a plurality of formed plates and fins, wherein each plate includes integral manifold sections at opposite ends thereof, comprising the steps of:

laying down a first tube plate formed with ring portions offset from the plane of the plate, the ring portions surrounding manifold openings in the plate, and edge flanges extending along opposite ends of the plate;

placing a plurality of air fins on said plate in positions to define air flow passages between opposite manifold sections;

placing a second tube plate inverted relative to the first tube plate over the first tube plate and the air fins;

placing a plurality of reinforcing hoops and gas fins over the second tube plate, the gas fins being positioned to define gas flow passages from one end of the heat exchanger core to the other around the manifold sections, the hoops being positioned to surround the respective manifold openings and surrounding ring portions and in surface contact with adjacent ring portion and flange surfaces;

repeating the cycle of steps to develop a stacked assembly of heat exchanger core elements; and

brazing the entire assembly to form an integral unit.

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