ABSTRACT

A tube and fin heat exchanger in which tube means is mounted in elongated slots in header plates for flow of a first fluid longitudinally through the tube means. The tube means is constructed to provide a broad and flat heat transfer surface on its sides, and strip fin material is mounted to such sides and provides for flow of a second fluid over such surfaces. According to a feature of the invention the interior of the tube means is partitioned and ends of the tube means and end applied manifold members uniquely cooperate for multi-pass flow of the first fluid through the tube means.

14 Claims, 7 Drawing Figures
TUBE AND FIN HEAT EXCHANGER

BACKGROUND OF THE INVENTION

Although not so limited, the invention has special reference to intercoolers, particularly those operating under relatively high pressure and temperature conditions.

Intercoolers commonly have a finned tube or tube and fin construction. A plurality of tubes is disposed between headers for a flow of first fluid therethrough. Intermediate the headers, and substantially parallel thereto, are sheet-like fins having pierced holes through which the tubes pass. A second fluid flows over the fins and over the tubes extending therethrough and as a result a transfer of heat between the fluids is effected. Usually, water or other liquid is passed through the tubes to have a cooling effect upon compressed air flowing over and between the fins externally of the tubes.

Improvements in air compressors have placed additional heat transfer burdens upon the intercooler which it has been sought to meet by adding tubes and fins and by otherwise increasing the heat transfer area. Space requirements do not allow for accumulation thereof. Heat exchange devices of more compact construction than the tube and fin design are not unknown but are for varying reasons unsuitable. For example, in an intercooler the water flow passages must be conveniently accessible for cleaning, and this is best achieved through use of a tubulous device in which the tubes are open and readily exposed at their ends.

SUMMARY OF THE INVENTION

The present invention introduces a generally new heat exchanger unit, useful as an intercooler or in other heat transfer work. The concept of a tube and fin construction is retained, as are cleanliness and other characterizing features. However, the new unit is a compact, high performance heat exchanger adapting ideally to stringent heat transfer requirements without the imposition of added size, weight and other penalties.

In structural terms, a disclosed embodiment of the invention utilizes tube means which by varying modes is elongated in a diametral sense. Broad, flat heat transfer surfaces are defined on its sides and interposed between the side surfaces of adjacent tubes is continuously corrugated fin strip material. The latter forms flow passages directing air or other fluid over the tube exteriors and provide secondary heat transfer surface. The fin structure may be made as compact as desired, a fin spacing for example double that possible in a conventional finned tube heat exchanger being readily achieved. Also, the fins are disposed to be metallurgically bonded to the tube side surfaces throughout their length with obvious advantages of reduced contact resistance, and greater structural integrity. The tube means provides flow passages for water or other fluid which is thus in heat transfer relation to the first mentioned exterior fluid. Header plates slotted in correspondence with the elongated tube means support such means, and the assembly so defined is united by means enabling a fixed compressive contact of the tubes with intermediately disposing fin strip material. A removable manifold member mounts on at least one end of the heat exchanger. A ribbed construction thereof, and cooperating slotted ends of the tube means, make possible a multi-pass flow path for the tube fluid, the tube means in this instance being appropriately internally partitioned.

An object of the invention is to provide a generally new heat exchanger unit which in a specific application introduces the advantages of compact, high performance heat transfer design to the field of intercoolers. Other objects and structural details of the invention will appear from the following description, when read in connection with the accompanying drawings, wherein:

FIG. 1 is a exploded view, in perspective, of a heat exchange unit in accordance with a first illustrated form of the invention;
FIG. 2 is a top plan view of the heat exchange unit of FIG. 1;
FIG. 3 is a view in longitudinal section, taken substantially along the line 3–3 of FIG. 2, a part of the tube assembly being broken away to show a portion of the strip fin material;
FIG. 4 is a fragmentary view, similar to FIG. 3 and enlarged with respect thereto, taken vertically through a row of stacked tube elements;
FIG. 5 is a view in cross section, taken substantially along the line 5–5 of FIG. 2, a gasket element being omitted;
FIG. 6 is a detail enlarged view in front elevation, showing tube elements mounted in a slot in a header plate; and
FIG. 7 is a view in perspective of a heat exchange unit in accordance with a second illustrated form of the invention, manifold members being omitted.

A tube and fin heat exchanger in accordance with the embodiment illustrated in FIGS. 1 through 6 utilizes tubes 10 as the "tube" part of the unit. The cooperating "fin" part is represented by strip fin material 11. End plates 12 and 13 are provided as required to complete a core assembly comprised of a plurality of rows of stacked tubes 10 and intermediate strip fin material 11.

Each tube 10 is an elongated member, square in cross section and open from end to end thereof. It is made of material capable of good heat conductivity and resistant to pressure deformation. A metal such as copper is suitable, especially since it is readily soldered or otherwise bonded to companion parts. In achieving a stacked row of tubes 10, opposing side walls of the tubes cooperate to define a relatively broad, flat expanse constituting a substantially single heat transfer surface on each side of the tube row.

The strip fin material 11 is positioned between adjacent rows of tubes 10 and between the end plates 12 and 13 and adjacent tube rows. The fin material in each location may be comprised of a single continuous strip or of a plurality of contiguous strips. In either event, it may assume a structural form common to known types of strip fin material. It is thus made of relatively thin sheet material relatively ductile in order that it may be crimped or gathered to a corrugated form, each corrugation defining a fin. The corrugations may assume various forms, as for example plain or ruffled, and may be left intact or may be variously lanced or slit, depending upon required heat transfer rates, pressure drop limits and other factors.

The fin strip is laterally compressed to bring about a desired spacing of individual fins and is mounted in sur-
face contact with the side of a row of tubes 10, the orientation of the strip being such that the strip corrugations extend in a desired direction relatively to the tubes, as for example at right angles to the tube lengths in the illustrated instance. The strip fin material 11 is compressed in a lateral sense to be under size in width as compared to the tube length. The several rows of tubes accordingly project at their ends relatively to side margins of the fin strips.

Header plates 14 and 15 support the core assembly between them. The header plates are identical in construction. Each is of rectangular configuration with flat, planar front and rear faces. Elongated in a longitudinal sense, but fully contained within the boundaries of the header plate is a lateral series of slots 20, one for each row of tubes 10. The slots 20 are rectangular in shape and correspond approximately to the end configurations of the tube rows which are accommodated therein. The slots are, however, slightly oversize relative to the dimensions of the ends of the tube rows to avoid the imposition of stresses which might tend to separate the rows of tubes from intermediate disposing fin strips. In thickness the header plates 14 and 15 are slightly exceeded by the distance by which the tubes 10 project relatively to the fin strips 11. Thus, a mounting of a header plate to an end of the core assembly may be continued until the inner face of the plate is presented as an abutment surface to the lateral margins of the fin strips at which time the ends of the tubes 10 are in slightly projecting relation to the front face of the plate. At vertically spaced apart locations projecting portions of the tubes 10 are cut by transverse notches or slots 16. Each row is cut by a slot 16 at common locations with the corresponding slots of the several rows transversely aligning with one another. The slots are in the illustrated instance cut at the joint between adjacent tubes 10 through mating walls thereof.

Adapted to mount to the front face of the header plate 14, in a closing relation thereto, is a manifold member 17. A similar member 18 mounts to the front face of header plate 15. The member 17 is formed with inwardly opening chambers 19 and 21 at its lower and upper ends respectively. Tubular bosses 22 and 23 open through a front wall of the manifold member 17 and respectively constitute a fluid inlet and fluid outlet as will hereinafter more clearly appear. Between the chambers 19 and 21 is a vertical series of spaced apart ribs 24 constructed to be in slightly projecting relation to the front or inner face of the manifold member and located to align with slots 16 in the tube rows. The ribs 24 define flow turnaround chambers 25 therebetween. The manifold member 18 is similarly constructed with a vertical series of projecting ribs 26 defining turnaround chambers 28. Ribs 26 are offset relatively to ribs 24, however, to place the turnaround chambers 28 similarly in an offset substantially alternating relation to the turnaround chambers 25.

Interposed between the front or inner face of each manifold member and the abutting face of a respective header plate is a marginal gasket 29. Bolts 31 extend through apertures 32 in the manifold member 17 and into tapped recesses 33 in the header plate 14 to provide a detachable mount for member 17. Like bolts 34 cooperate with like apertures 35 and tapped openings 36 to effect a similar mounting of the manifold member 18.

In the assembly of the heat exchanger unit, tubes 10 are laid one upon another to form a series of stacked rows as illustrated. Strip fin material is placed against the commonly formed tube wall on the sides of the assembly of rows and is placed also between adjacent rows to be in simultaneous contact with the opposing commonly formed walls of the adjacent rows. Core sheets 12, if required, are mounted to the sides of the assembly and the core so formed is subjected to a met- allurgical bonding or like operation uniting all of the parts into a single, integrated structure. The bonding may be done in any suitable manner, as for example by brazing of the parts. However, in the event of a use of copper tubes, the strip fin material may be formed of a like metal and the assembly thus lends itself to soldering with attendant advantages of simplicity and reliability. For example, between each row of tubes 10 and each pin strip 11 a layer of soldering paste or foil may be interposed. Thus, when the core has been assembled and while it is held within a jig or other fixture to assume a secure positioning of the parts and good contact between the tubes and fin strip material, it may be placed in a furnace and the temperature raised to a value to cause the interposed soldering material to flow and create sound, continuous joints between the fins of the fin strip material and the tubes with which they are in contact. The header plates 14 and 15 are mounted to the opposite ends of the core assembly either before or subsequent to the uniting of the core tubes with the core fin material. The slightly oversize slots 20 have solder material applied to the margins thereof in a manner, as shown in FIG. 6, simultaneously to join the tubes to the header plate and to seal the space around the tubes. Prior to effecting the soldered joint between the tube ends and the header plates, the plates are moved inwardly along the tubes to achieve a substantially compressive contact with the side margins of the fin strips 11. Flow passages between the header plates perpendicular to the tubes 10 and exterior thereto accordingly are defined. The fin strips 11 occupy such external flow passages and provide secondary heat transfer surface for a more rapid conduct of heat to and from the tube wall defined by the stacked tubes.

The manifold members 17 and 18 are subsequently applied to outwardly disposing faces of the header plates 14 and 15, with gaskets 29, if provided therein. The manifold members are advanced longitudinally upon their respective header plates with ribs 24 and 26 aligning with and being received in transverse tube slots 16. The advancing motion is continued until peripheral portions of the manifold members limit against peripheral portions of respective header plates whereupon bolts 31 and 34 are installed to tighten the manifold members against gaskets 29, effectively sealing the joint between each manifold member and its header plate. The gasket 29 provides a resiliently limiting means whereby a final tightening down of the bolts 31 and 34 may be utilized substantially fully to project ribs 24 and 26 into the slots 16, the need for establishing and holding fine tolerances in the relative lengths of the ribs and the relative depth of the slots being avoided. As noted, in the illustrated instance, the gaskets 29 are marginal only with respect to the manifold members. If desired, however, the gasket could be constructed substantially to match the inwardly facing side of the manifold member, that is, with cross pieces to align with and overlie the transverse ribs 24 and 26 and
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with openings to register with the chambers 25 or 28. In this instance, relative projection of the ribs 24 and 26 would be unnecessary, and a clamping of the manifold member to the header plate would result in a thrusting of the gasket material into the slots 16. In either event, the ribs 24 and 26 act as substantially sealed barriers denying fluid flow in a by-passing relation between adjacent chambers 25 or 28.

In use, the heat exchanger unit is suitably disposed for a ducted or ram flow of air or other fluid through the passages occupied by strip fin material 11 between the rows of tubes 10. At the same time, another fluid, which may be water, is admitted by way of boss 22 to manifold member 17. The fluid so admitted enters chamber 19 where it has simultaneous access to lower tubes of each row of tubes 10. The described fluid flows through such tubes through and beyond the opposite ends thereof where it reaches a first turnaround chamber 26 in manifold member 18. There it is compelled by an encounter rib 26 to move reverely through another series of tubes 10 back to the manifold 17. There the fluid enters a chamber 25 and, in encountering a rib 24, is compelled again to flow longitudinally through a next series of tubes back toward the manifold member 18. This serpentine flow path is continued until the flowing fluid reaches chamber 21 whereupon it communicates with outlet boss 23 and discharges from the unit. As will be understood, the fluid flowing through the tubes 10 is in heat transfer relation through the tube walls with the air or other first mentioned fluid flowing externally of the tubes along the paths defined by fin strips 11. The fluids being of different temperature, the fluid of higher temperature gives up some of its heat to the fluid of lower temperature by a convection-conduction process. The fluids are in the illustrated instance in an essentially cross-counterflow relation, the multi-pass travel of the manifold fluid bringing it into a substantially counterflow relation to the perpendicularly flowing fin fluid.

FIG. 7 discloses a core and header plate construction in accordance with a modified form of the invention. The FIG. 7 embodiment differs from that first considered principally in a different use of tube means for conducting the manifold fluid. In the second considered form of the invention the tube means takes the form of a plurality of single tubes 37, each of which corresponds to and in effect replaces a stacked row of the tubes 10. Each tube, 37 is a one-piece member, initially round in cross section, which has been compressed to the flattened configuration illustrated. Opposite side walls of the tube offer a continuous broad heat transfer surface which is contacted by strip fin material 38. Core sheets 39 and 41 are included if necessary or desirable and the several described parts are united in a soldering or like process into an integral structure. Tubes 37 are in a projecting relation to side margins of the fin strips and are adapted to be received in similarly formed slots 42 in a header plate 43 and in similarly formed slots 44 in a header plate 45. By means constituting a seal and a bond, the header plates 43 and 45 are made fast to the tubes 37, the relationship between the header plates and tubes and between the header plates and side margins of the fin strips 38 being substantially the same as that of corresponding parts in the first considered embodiment. Manifold means may be bolted to the header plates and suitably constructed for flow of a fluid to and through the tubes 37. As presently illustrated, the manifold means would locate an inlet at one manifold member and an outlet at the opposite manifold member for a single pass of the connected fluid through the heat exchanger core. If desired, however, the interiors of the tubes 37 could be suitably partitioned and the manifold members constructed for multi-pass flow substantially in the manner shown in FIG. 3.

In both forms of the invention, the heat exchanger unit provides compact, high performance heat transfer surface in a manner to accomplish intercooling and like functions in an effective manner using a relatively small space or volume. Customary requirements of an intercooler are maintained, however, including cleanability. The manifold members at opposite ends of the heat exchanger unit are readily removed, and, when so removed, expose the tubes 10 or the tubes 37 for thorough cleaning from end to end thereof.

The invention has been disclosed with reference to particular embodiments. Structural modifications have been discussed and these and others obvious to a person skilled in the art to which the invention relates are considered to be within the intent and scope of the invention.

What is claimed:

1. A heat exchanger unit, including open ended tube means providing on each of opposite sides thereof a substantially continuous broad and flat external heat transfer surface, a strip of corrugated fin material mounted to each of said opposite sides and oriented to define a flow passage of selected direction externally of the tube means for a first fluid to flow over a respective side of said tube means, said tube means forming a flow passage internally thereof for a second fluid to flow from end to end thereof, a header plate at each end of said tube means forming at least one continuous slot accommodating a respective end of said tube means, and means uniting said tube means, said fin strips and said header plates into an integrated structure in which said fin strips are joined directly to said tube means, the ends of said tube means being accommodated in said header plate slots with limited freedom of relative self adjustment, said uniting means including deposited metal in said slots fixing the tube means relatively to said header plates and forming a seal and a bond between said tube means and the margins of said slots.

2. A heat exchanger unit according to claim 1, wherein said tube means is comprised of a plurality of individual tubes square-like in cross section stacked one upon another, side walls of said tubes cooperating defining said external heat transfer surfaces on opposite sides of the stacked tube assembly, walls of said tubes connecting said side walls defining internal partitions in said tube means extending lengthwise thereof.

3. A heat exchanger unit according to claim 2, characterized by manifold means mounted in endwise relation to said tube means and utilizing said internal partitions for a multi-pass flow of said second fluid through said tube means, said manifold means providing an inlet and an outlet for said second fluid at ends of the internally formed flow passage through said tube means.

4. A heat exchanger unit according to claim 3, wherein connecting walls of certain of said tubes are notched at their ends, said manifold means including at least one manifold member formed with a series of
pockets opening through one face thereof and separated by ribs in relatively projecting relation to said face, said manifold member being mounted with said face in abutting relation to a header plate, said ribs being received in said notches and said pockets defining flow turnaround areas closed against intercommunication across said face by interengagement of said ribs in the notched portions of said tubes.

5. A heat exchanger unit according to claim 4, wherein said manifold means includes a pair of manifold members constructed as set forth and disposing in abutting relation to respective header plates, the separating ribs in the pair of manifold members being relatively offset.

6. A heat exchanger unit according to claim 1, wherein said tube means is comprised of at least a single tube flattened to provide an internal flow area elongated in a diametral sense and to provide relatively broad flat sides defining said external heat transfer surfaces, the fin strips being mounted to and uniting with said side surfaces, the header plate slots being formed in a complementary relation to the flattened tube configuration and providing limited freedom of relative self adjustment of respective tube means.

7. A heat exchanger unit comprising longitudinally spaced apart header plates each having one or more elongate slots therein, tube means disposed between said header plates with its ends received in corresponding slots therein, said tube means being elongated in the sense of said slots and providing on at least one side thereof a relatively broad and flat heat transfer surface, strip fin material in a superposing contacting relation to said heat transfer surface externally thereof, and means for holding said strip fin material to said tube means to define a flow path for a fluid to flow over said tube means intimately of said header plates, the slotted header plates and said tubes means defining a flow path for another fluid to flow through said tube means.

8. A heat exchanger unit according to claim 7, characterized by a plurality of tube means, said header plates each having a plurality of slots arranged to locate said plurality of tube means in substantially parallel spaced relation with at least intermediate tube means presenting heat transfer surface on each of opposite sides thereof, strip fin material being installed between adjacent tube means in common contact with opposing side heat transfer surfaces and joined thereto, said slots being formed for limited self adjustment of said tube means therein without stressing the joints between said tube means and said strip fin material, and means for fixing said tube means in said slots in a position of substantial compression relative to interposed strip fin material and at the same time acting as a seal and a bond between said tube means and margins of said slots.

9. A heat exchanger unit according to claim 7, wherein said tube means projects at its opposite ends through and beyond said header plates, said tube means at its ends being transversely slotted at spaced locations, manifold members mounted to said header plates and at their margins seating to said plates, the opposing faces of said manifold members presenting recessed flow pockets spaced apart by transverse ribs, said ribs being accommodated in transversely slotted portions of said tube means substantially to seat upon a respective header plate, corresponding ribs on opposing manifold members being offset, means partitioning the interior of said tube means to define with said pockets and said ribs a multi-pass serpentine flow path through said tube means, and manifold inlet and outlet connections for said other fluid to enter upon and to leave said serpentine flow path.

10. A heat exchanger unit according to claim 9, wherein said tube means is comprised of multi sided tubes in a stacked relation, corresponding sides of said tubes cooperating to define said broad and flat heat transfer surfaces and other corresponding sides being in mating contact to define said partitioning means.

11. A heat exchanger unit according to claim 9, wherein said tube means is a one-piece flattened tube internally elongated in one diametral dimension, fin material being installed in said tube to be substantially coextensive in length therewith with corrugations of the fin material running lengthwise of the tube, said fin material defining said partitioning means and being slotted at locations to coincide with slotted portions of the tube.

12. A heat exchanger unit according to claim 7, characterized in that said tube means comprises at least one row of multi-sided tubes stacked one upon another to form a tube means transversely partitioned, corresponding sides of said tubes cooperating to define said broad and flat heat transfer surfaces and other corresponding sides being in mating contact transversely to divide said tube means.

13. A heat exchanger unit according to claim 12, characterized by manifold members mounted to said header plates and chambered to communicate with said tube means at opposite ends thereof, at least one of said manifold members having at least one rib in transverse intersecting relation to said elongate slots and to the tube means received therein providing in conjunction with the multi-sided tubes comprising said tube means for multi-pass flow of said other fluid through said tube means.

14. A heat exchanger unit according to claim 13, wherein said rib substantially seats to a header plate at the junction of other corresponding sides of adjacent tubes in said tube means.

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