Aug. 27, 1957 P. S. OTTEN 2,804,284

HEAT EXCHANGER

Filed April 3, 1953 2 Sheets-Sheet 1

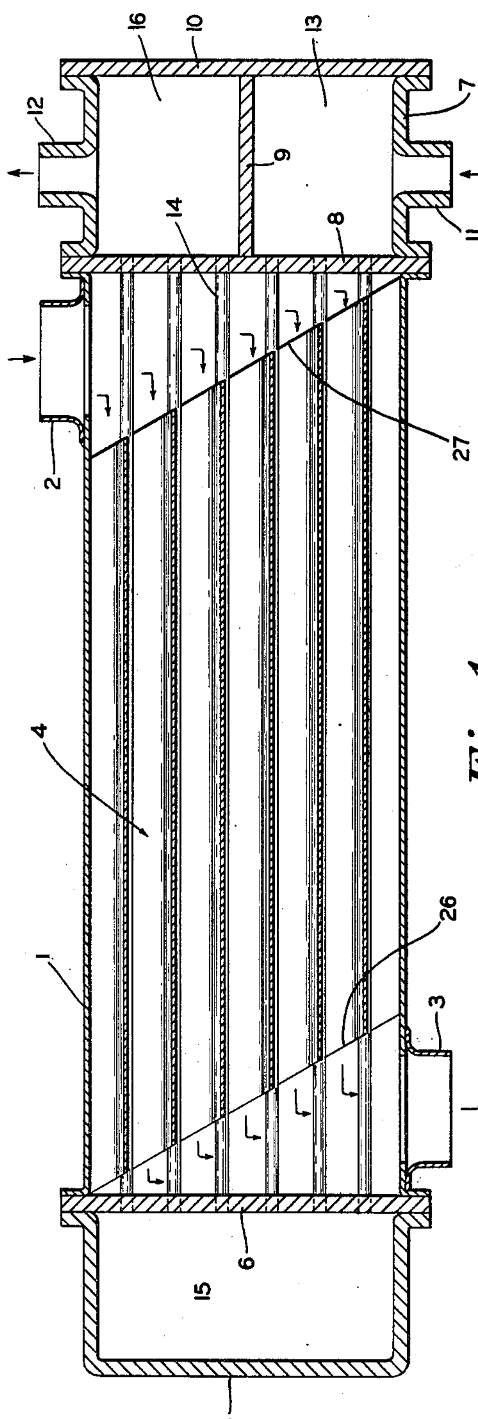

Fig. 1

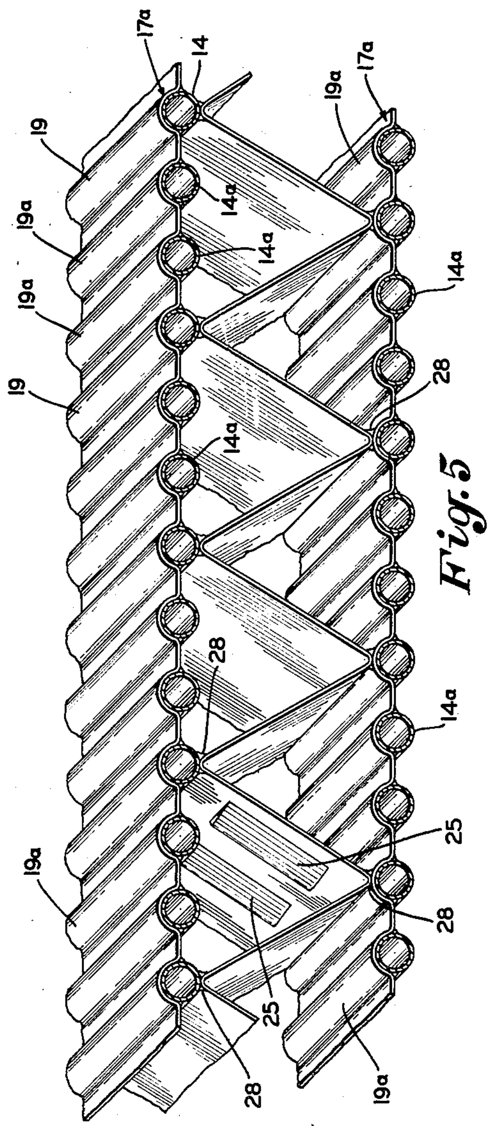

Fig. 5

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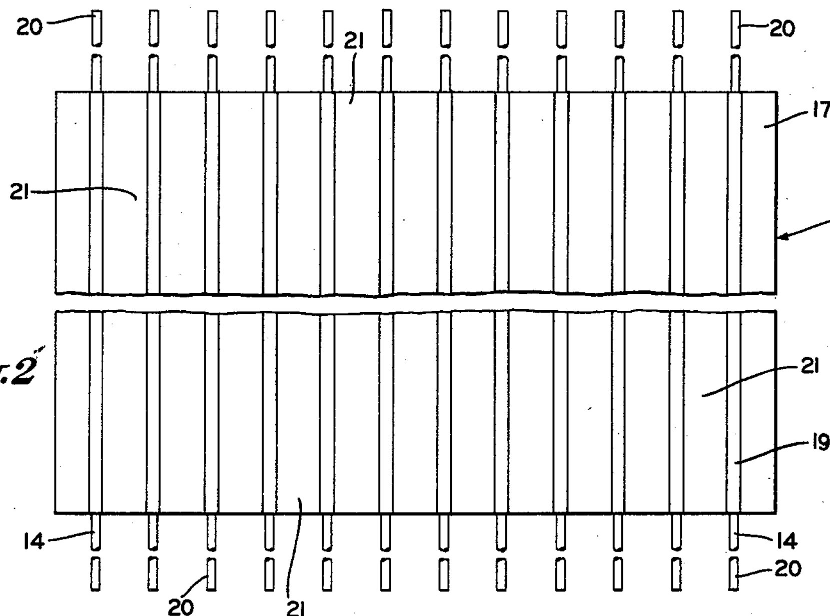

Fig.2

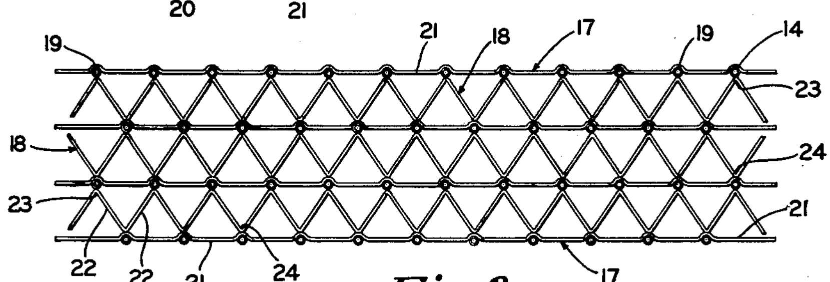

Fig.3

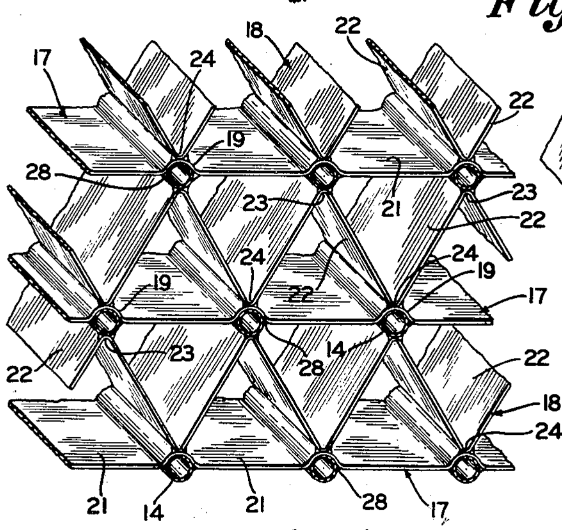

Fig.4

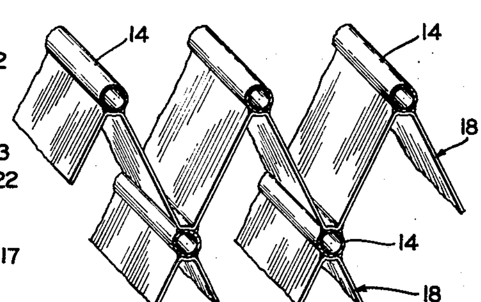

Fig.6

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HEAT EXCHANGER

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2 Claims. (Cl. 257—241)

The invention relates to heat exchangers and more particularly to a strong, light weight, cellular or honeycomb heat exchanger construction of tubes, and fins extending from the tubes, adapted to be used with and to withstand high pressures and temperatures, with the tubes and fins usually made of different metals resistant to the action of or reaction with different heating or heated fluids in contact therewith.

There have been many prior structural heat exchanger arrangements of tubes provided with fins. Complicated problems have arisen in the use thereof with corrosive fluids, and with high operating pressures and temperatures to obtain rapid heat transfer through extensive fin areas.

These problems are further complicated when the tube and fin structure must be light in weight, and also satisfactory for high pressure and temperature operation; and when the tube and fin structure must be adapted to be formed to fit into compartments or cavities of unusual shape without obstruction to the flow of heating and heated fluids passing through the tubes and fin passages.

Thus, it is sometimes necessary in the use of heat exchangers to provide tubes of one material, such as stainless steel, or a selected metal alloy, or copper, with fin heat transfer surfaces formed respectively of another material such as aluminum, copper or a selected metal alloy; and to adapt such tube and fin structure for high pressure and temperature operation as when 2,000 pounds per square inch pressures must be contained within the tubes in which steam, molten salt or molten metal is passed as a heating medium. Such heat exchanger tube and fin structure must for certain uses be very light in weight and capable of being formed to unusual shapes for fitting in available spaces in various crafts or vehicles, such as boats, cars, automobiles, airplanes, locomotives, and the like. In some of such instances, the material from which the tubes and fins are formed must withstand corrosive action of or reaction with the fluids passing in contact therewith at the temperatures and pressures involved.

Furthermore, it is necessary in such instances that the tube and fin structure be designed with a minimum of obstruction to the flow of fluids passing in contact therewith to obtain true counterflow, with the heating medium passing through the tubes in one direction and the material to be heated passing in the other direction through fin passages, and while providing for parallel flow of the fluids in the tubes and fin passages, as compared with fluid flow in a compartment surrounding the tubes at an angle to the tube axes. Also such structures must be designed to provide necessary strength with light weight construction.

I have discovered a new heat exchanger structure which avoids the difficulties, solves the problems and satisfies the requirements outlined, which includes light gauge metal tubes formed of a metal required for efficiently and effectively containing the particular fluid medium passed therethrough, and light gauge, corrugated and triangulated, fin sheet members interconnected with the tubes and formed of a selected metal having high heat transfer characteristics and able to withstand the action of the

particular fluid passed in heat transfer contact therewith; said tube and fin elements being connected as a strong, truss-like structure which contains and sustains high internal tube pressures with exceedingly small tube and fin wall thicknesses.

Accordingly, it is a general object of the present invention to provide a new light-weight tube and fin heat exchanger structure in which the tubes may be designed for use with high operating pressures and temperatures.

Also it is an object of the present invention to provide a new light weight tube and fin heat exchanger structure in which the tubes and fins are structurally interconnected and may be formed of light gauge tube or sheet metal, respectively of different metals, such as for example, stainless steel and aluminum, alloy metal and copper, or copper and alloy metal.

Furthermore, it is an object of the present invention to provide a new light weight tube and fin heat exchanger structure in which a minimum obstruction to flow of fluids in contact with the heat exchanger elements is presented, and in which an exceptionally small percentage of flow of the fluid passing in heat exchange contact with the fins in the fin passages is blocked by the material of which the heat exchanger is formed.

Moreover, it is an object of the present invention to provide a new light-weight tube and fin heat exchanger structure which can be formed to unusual shapes for fitting into confined or odd shaped cavities or compartments in vehicles or craft such as boats, cars, automobiles, airplanes, locomotives or the like.

Moreover, it is an object of the present invention to provide a new light-weight tube and fin heat exchanger structure adapted for true counterflow, with the heating medium fluid passing, for instance, through the tubes in one direction and the fluid or material to be heated passing in the other direction through fin passages; and which also incorporates parallel flow of the heating and heated fluids in the tubes and fins, all with a minimum obstruction to flow.

Furthermore, it is an object of the present invention to provide a new light-weight tube and fin heat exchanger structure in which pressure losses, which may result from skin friction where a gaseous fluid such as air is passed through the fin passages, do not result in inefficient operation but increase the heat transfer rate between the fin surfaces and the gaseous medium passing in contact therewith.

Also, it is an object of the present invention to provide a new light weight tube and fin heat exchanger structure in which little parasitic pressure loss results through turbulence during heat transfer between the fin surfaces and the medium to be heated passing in contact therewith.

Also, it is an object of the present invention to provide a new light-weight tube and fin heat exchanger structure in which the tube and fin members or elements are permanently assembled to form a triangular, cellular or honeycomb construction of truss-like nature having the inherent strength of a truss structure thereby providing an exceedingly high strength to weight ratio as a characteristic of the heat exchanger.

Finally, it is an object of the present invention to provide a new light-weight tube and fin heat exchanger construction which satisfies the existing need in the art, solves the problems indicated, eliminates the difficulties presented for certain uses of prior heat exchanger structures, and obtains the foregoing advantages and desiderata in an efficient, effective and simple manner.

These and other objects and advantages, apparent to those skilled in the art from the following description and claims, may be obtained, the stated results achieved, and the described difficulties overcome by the structures, combinations, arrangements, subcombinations, parts and elements which comprise the invention, the nature of which is set forth in the following general statement, preferred embodiments of which—illustrative of the best modes in which applicant has contemplated applying the principles—are set forth in the following description and shown in the drawings, and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

The nature of the discoveries and improvements of the present invention may be stated in general terms as preferably including in heat exchanger construction, light gauge, preferably seamless metal tubes formed of a selected metal or alloy; light gauge sheet metal fin elements formed of a selected metal or alloy the same as or different from the tube metal or alloy; the tube and fin elements being brazed together to form a unitary truss-like cellular or honeycomb structure; certain of the fin elements being arranged with the tube members in a triangular fashion, with the fin elements extending lengthwise along the tubes, with the tube members forming the corners of each triangle, and with fin elements extending as the triangle sides; certain of said fin elements having rounded portions connected with the tube members at the triangle apices; and certain of the fin elements preferably having rounded grooves in which tube members received therein are brazed thereto.

By way of example, several embodiments of the improved heat exchanger structure of the present invention are shown in the accompanying drawings forming part hereof wherein:

Figure 1 is a somewhat diagrammatic view of a heat exchanger incorporating the improved tube and fin heat exchanger structure;

Fig. 2 is a plan view of a truss-like cellular tube and fin heat exchanger structure incorporating the improvements of the present invention;

Fig. 3 is a fragmentary side elevation of the structure shown in Fig. 2;

Fig. 4 is an enlarged fragmentary perspective view of a portion of the structure shown in Fig. 3;

Fig. 5 is a view similar to Fig. 4 illustrating a slightly modified form of structure; and

Fig. 6 is a view similar to Figs. 4 and 5 illustrating a further modification.

Similar numerals refer to similar parts throughout the various figures of the drawings.

In the apparatus illustrated somewhat diagrammatically in Fig. 1, a heat exchanger shell is indicated at **1** provided with an inlet connection **2** and an outlet connection **3** for the fluid, such as air, to be heated and which is passed through the heat exchanger. The shell **1** encloses a tube and fin structure, bundle or unit generally indicated at **4** arranged in accordance with the present invention.

The shell **1**, as shown, is provided at one end with a removable cap or bonnet **5** bolted or otherwise secured to a tube sheet **6** which in turn is secured in any desired manner to one end of the shell. The other end of the shell **1** is provided with a header **7**, a tube sheet **8**, a partition **9** and a removable head closure **10** assembled together and with the shell **1** in any usual or desired manner. The header **7** is provided with an inlet **11** and an outlet **12** for the fluid heating medium passed through the tubes **14** of the tube structure **4**.

In operation, the heating medium which may be for instance, high pressure steam, enters the lower compartment **13** of header **7** through inlet **11**, then passes through the lower group of tubes **14** of tube and fin structure **4** into the compartment **15** formed by cap **5**, then back through the upper group of tubes **14** to upper compartment **16** in header **7** and out through outlet **12**, as shown by the arrows in Fig. 1. Meanwhile, the fluid to be heated, such as air, passes into the shell **1** through inlet **2**, longitudinally through the fin structure around the tubes of tube bundle **4** and out through outlet **3** as indicated by the arrows.

The heat exchanger illustrated in Fig. 1 is merely illustrative of a use of the improved tube and fin structure of the present invention. The exterior configuration of the heat exchanger may have any required shape to adapt the same for the intended use or installation.

Furthermore, the reverse flow of heating medium through one group of tubes in one direction and another group of tubes in the opposite direction is not a necessary requirement of the present invention since the cap **5** may comprise an inlet header for the heating medium and the header **7** the outlet header therefor with all of the heating medium passing through the tubes **14** in one direction with a true counterflow arrangement with respect to the fluid being heated which passes within the shell in the opposite direction.

Likewise, although the tube and fin structure of the present invention is especially designed for high pressure and high temperature operation, the improved structure can be used as well for cooling rather than heating as where a cooling fluid may be passed under high pressure through the tubes **14**.

The ends of the tubes **14** are secured in the usual manner in the tube sheets **6** and **8** and access may be gained to the interior of the tubes for cleaning, or to the tubes for replacement, by removal of the head closure plate **10** from the header **7**.

In accordance with the present invention, the tube bundle or structure **4** is fabricated as a unit with particular characteristics and in a particular manner to obtain the results described herein. Referring particularly to Figs. 2, 3 and 4, the tubes **14** may be formed, for instance, of light gauge seamless stainless steel tubing having the necessary properties to resist any deleterious action of the fluid passed therethrough, and the tubes **14** are assembled in the tube-fin structure or bundle with fin elements generally indicated at **17** and **18**.

Fin elements **17** and **18** may be formed, for instance, of light gauge aluminum or aluminum alloy sheets. The fin elements **17** are provided with spaced parallel grooves **19** having a configuration in cross section complementary to the arcuate outer cross sectional surface of tubes **14**. When the tubes **14** are assembled with the fin elements **17**, a tube **14** lies longitudinally in each groove **19**, with the ends **20** of each tube **14** projecting beyond opposite edges of the fin element **17**. Thus, each fin element **17** has a flat fin portion **21** extending between tubes **14** lying in adjacent grooves **19** of the fin element **17**.

Fin elements **18** may be formed to generally triangularly corrugated or zig-zag or sawtooth formation with angularly arranged flat fin portions **22** connected between successive upper and lower apices **23** and **24**. The apices **23** and **24** are formed in cross section at the outer surfaces thereof with slightly curved portions complementary to the outer arcuate surfaces of the tubes **14** in cross section. When the fin elements **18** are assembled with the fin elements **17** and tubes **14**, as best shown in Fig. 4, a flat fin portion **22** extends from one upper apex **23** and one tube **14** to the outer surface of a groove **19** surrounding another tube **14** spaced below and offset from the first-mentioned tube **14** at a lower apex **24**. The next angled fin portion **22** of fin element **18** extends from the last-mentioned lower apex **24** upwardly to the next upper apex **23** which contacts with a tube **14** in the next groove **19** formed in a fin element **17**.

Thus, tube members **14** are arranged in cross section in a triangulated formation with a tube **14** at each apex of a substantially equilateral triangle whose sides are formed by fin portions **21** and **22**. This triangulated formation is repeated laterally, viewing Fig. 4, with one series of tubes **14** and one of each of fin elements **17** and **18** at one level; and similar tube and fin assemblies may be repeated for a series of levels in any desired number, such as shown in Fig. 3 where three levels are illustrated. The top or bottom level is finished with one additional fin element **17**.

When assembled in the manner described, a tube-fin structure or bundle 4 has a truss-like formation with either four or six fin portions 21 and 22 radiating from each tube 14 thus providing extensive fin surfaces for each tube, which fin portions 21 and 22 support the tubes 14 in a strong and stable spaced relation.

The triangulated and truss-like assembly of the fin elements and tubes also inherently provide an extremely strong structure for resisting the internal pressure of the pressure fluid contained within the tubes 14 while permitting the fin elements and tubes to be fabricated of extremely light gauge material. For example, the aluminum sheets from which the fin elements 17 and 18 are formed may have a thickness as small as from 0.005" to 0.01", and the stainless steel tubes 14 may have a somewhat equivalent tube wall thickness. Nevertheless the tube-fin structure 4 is capable of containing and sustaining a 2,000 pounds per square inch pressure of the pressure fluid passed through the tubes.

Viewing the tube-fin structure 4 lengthwise of the tubes 14, as in Fig. 3, triangular cells comprising a triangular honey-comb arrangement extends lengthwise of the tubes 14 through which the fluid to be heated passes.

Referring to the modification of the improved tube and fin structure illustrated in Fig. 5, the structure is identical with that illustrated in Figs. 2, 3 and 4 excepting that in each fin element 17*a* additional grooves 19*a* may be provided between the grooves 19 in which those tubes 14 which form the corners of any particular triangle or cell are located. Additional tubes 14*a* may be carried in grooves 19*a* thus increasing the number of tubes in any tube bundle for accommodating a larger volume of heating fluid.

In the modification illustrated in Fig. 6, only tubes 14 and fin elements 18 are used, the fin elements 17 being omitted. This modification of the improved structure is adapted for use where the fin and tube wall thicknesses are heavier or where operating pressures are lower.

In assembling any of the constructions illustrated in the drawings, a series of tubes 14 may be laid in the grooves 19 of a fin element 17, and a triangulated fin element 18 may be positioned thereon with the apices 23 thereof resting on the tubes 14. The various elements so assembled may then be brazed together with either copper or silver solder. Such subassemblies may then be stacked in any desired number of tiers or levels and brazed together forming a tube and fin structure or bundle such as illustrated in Fig. 3.

In brazing the tubes and fin elements together, brazing metal fillets form at the braze connections such as indicated at 28 in Figs. 4 and 5. In referring to stainless steel herein, any of the various chrome or chrome-nickel alloys commonly referred to as stainless steel are intended, 18–8 stainless steel being a type frequently used in the construction of heat exchangers. Likewise, in referring to alloy metal herein, alloys such as the usual chrome or chrome-nickel stainless steel alloys are intended, also Monel metal and brass.

Although the invention is not limited to the exact spacing between tubes 14 or to the size of the tubes, a typical example of tube spacing and size is one in which the tubes 14 are ⅛" outside diameter seamless 18–8 stainless steel tubes arranged on a 1" triangular pitch and brazed to 0.005" to 0.01" thick aluminum sheet fin elements 17 and 18.

The same general assembly procedure may be used with the modified structure illustrated in Fig. 6, by positioning a series of tubes 14 in contact with one series of apices of a fin element 18 and brazing the same, and then such subassemblies may be stacked in any desired number of tiers and brazed together.

If the tube-fin structure 4 is formed as described of stainless steel tubing and aluminum fin elements, the stainless steel tubing is resistant to corrosion of superheated steam, for instance, passed therethrough while the aluminum forms excellent heat transfer characteristics for rapid heat transfer.

Other materials may be used for fabricating the improved structure such as alloy metal tubes and copper fin elements, or copper tubes and alloy metal fin elements, or other desired combinations of selected metals or alloys having the desired tube and fin characteristics.

The improved tube fin structure of the present invention enables true counterflow to be obtained in operation with a heating medium passing through the tubes in one direction and the material to be heated passing in the other direction through the fin passages. In such operation, there is no obstruction to flow of either the heating medium or the heated medium. In other words, since the tubes and fins extend in parallel directions, there is parallel flow of the heating and heated mediums, as distinguished from obstructed flow in usual cellular heat exchanger structures where the material to be heated flows at right angles to and is obstructed by the tubes around which the heated medium is passed.

Another important aspect of the present invention over usual plate fin type heat exchangers is that the separate tubes permit design for high pressures and temperatures and yet the heat exchanger can be made very light in weight with the tubes made of one material and the fins of another material.

Since there is no blocking of or obstruction to the flow of fluid passed through the fin cells, there is no pressure loss except that incident to skin friction which ordinarily speeds up the rate of heat transfer.

Another important aspect of the present invention is that the fin elements and tubes can be formed to unusual shapes for installation into available spaces in boats, cars, airplanes, locomotives, etc. At the same time, because of the relatively small wall thicknesses required for containing and sustaining high pressure operation, the new tube-fin structure is very light in weight while maintaining efficient operating characteristics.

Where it is desirable to introduce some turbulence to the flow of a gaseous fluid to be heated which passes through the fin passages, in order to increase the rate of heat transfer, the same may be accomplished by forming slight indentations or slat-like formations in fin portions 21 or 22, as indicated at 25 in Fig. 5. The introduction of such turbulence reduces film insulation of the fin surface.

As indicated at 26 and 27 in Fig. 1 the opposite ends of the fin elements 17 and 18 may terminate in diagonal planes where a heat exchanger is used of the character diagrammatically illustrated, to maintain uniformity of flow of the heated medium through the shell 1.

Accordingly, the present invention provides an improved tube-fin structure for heat exchangers which is strong, light in weight, and adapted for high pressure and high temperature operation; in which the tubes and fins may be made of different selected metals or alloys; in the use of which there is a minimum obstruction to the flow of fluids therethrough and true counterflow is obtained with parallel flow of the heated and heating mediums; which may be formed to unusual shapes for fitting into confined or odd-shaped cavities; which is permanently assembled to form a triangular, cellular or honeycomb construction of truss-like nature providing in exceedingly high strength to weight ratio; and which accomplishes the new results, overcomes prior art difficulties, and solves long standing problems in the art hereinabove described.

In the foregoing description certain terms have been used for brevity, clearness and understanding; but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such terms are utilized for descriptive purposes herein and not for the purpose of limitation and are intended to be broadly construed.

Moreover, the description of the improvements is by way of example and the scope of the present invention is not limited to the exact details illustrated or to the specific embodiments shown.

Having now described the features, discoveries and principles of the present invention, the construction, operation and use of several embodiments of the improved tube-fin structure, and the advantageous, new and useful results obtained thereby; the new and useful structures, combinations, arrangements, subcombinations, parts and elements which comprise the invention, and mechanical equivalents obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1. A cellular heat exchanger unitary structure for countercurrent movement of heat exchange fluids including a plurality of spaced parallel sheet metal members in stacked relationship, each member having a plurality of grooves coextensive therewith and parallel to the grooves in the other members, a heat exchange tube in each groove and coextensive therewith and forming a tube-groove assembly, a pair of fins connected to and coextensive with a tube and extending radially therefrom, each fin being connected to and coextensive with a different tube in an adjacent sheet metal member, each pair of fins forming a triangularly shaped conduit with a portion of said adjacent sheet metal member, and the conduit being parallel to and coextensive with the adjacent tubes and sheet metal members.

2. A cellular heat exchanger unitary structure for countercurrent movement of heat exchange fluids including a plurality of parallel sheet metal members, the sheet metal members being stacked in spaced relationship with each other, each member having a plurality of laterally spaced grooves coextensive therewith and parallel to similar grooves in the other sheet metal members, a heat exchange tube located in each groove and coextensive therewith forming a tube-groove assembly, a corrugated fin element between adjacent sheet metal members and having adjacent apices oppositely extending, the apices on one side of the element being connected respectively to tube-groove assemblies in one sheet metal member, the apices on the other side of the element being connected respectively with tube-groove assemblies in the adjacent sheet metal member, and the corrugated fin element forming a plurality of triangularly shaped conduits coextensive with and parallel to the tubes.

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