Aug. 20, 1957 C. S. SIMPELAAR 2,803,440

FINNED TUBE CONSTRUCTION

Filed Oct. 2, 1953 4 Sheets-Sheet 1

Fig. 1

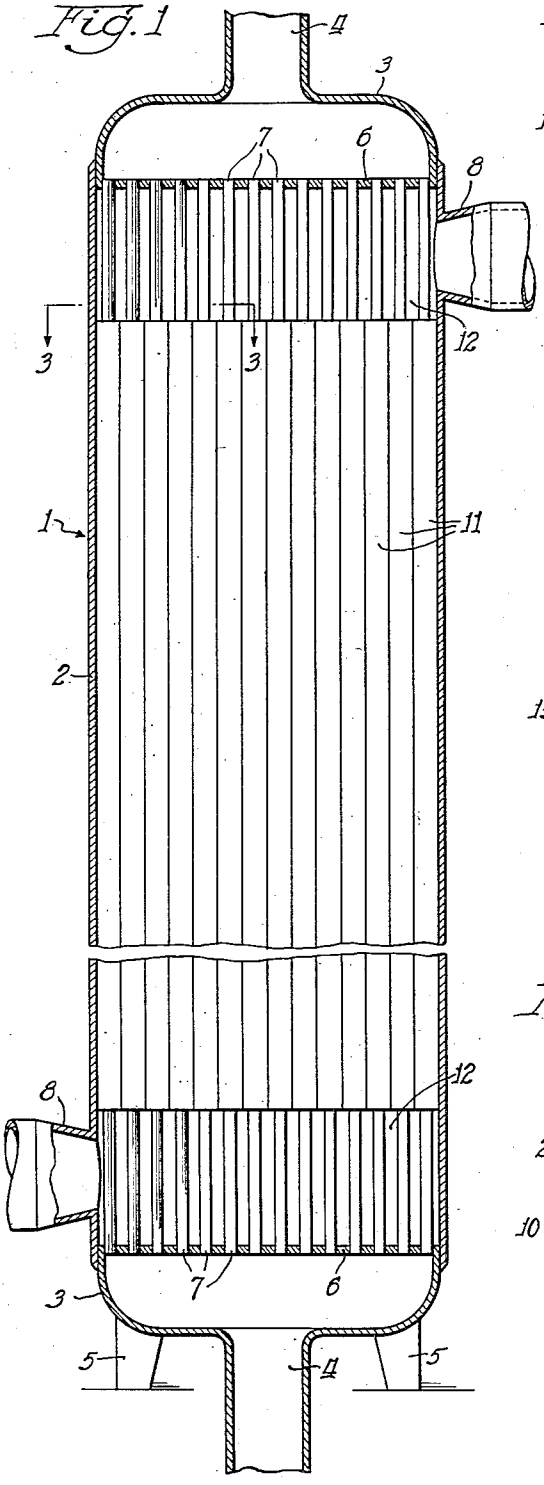
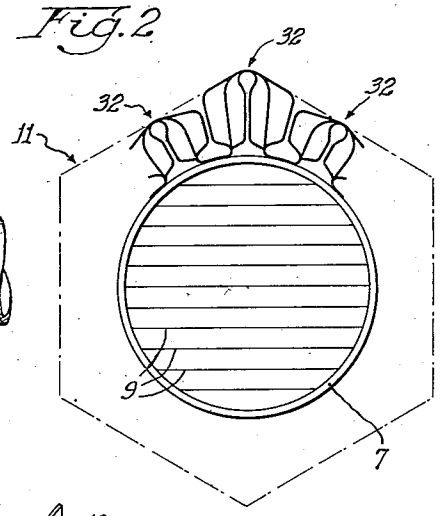


Fig. 2



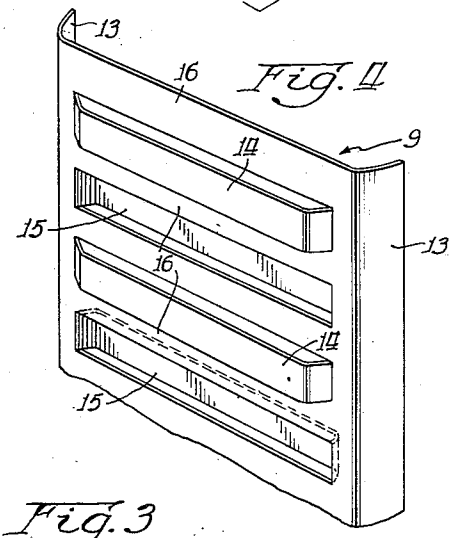
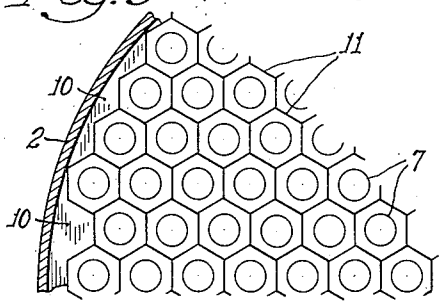


Fig. 4

Fig. 3



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FINNED TUBE CONSTRUCTION

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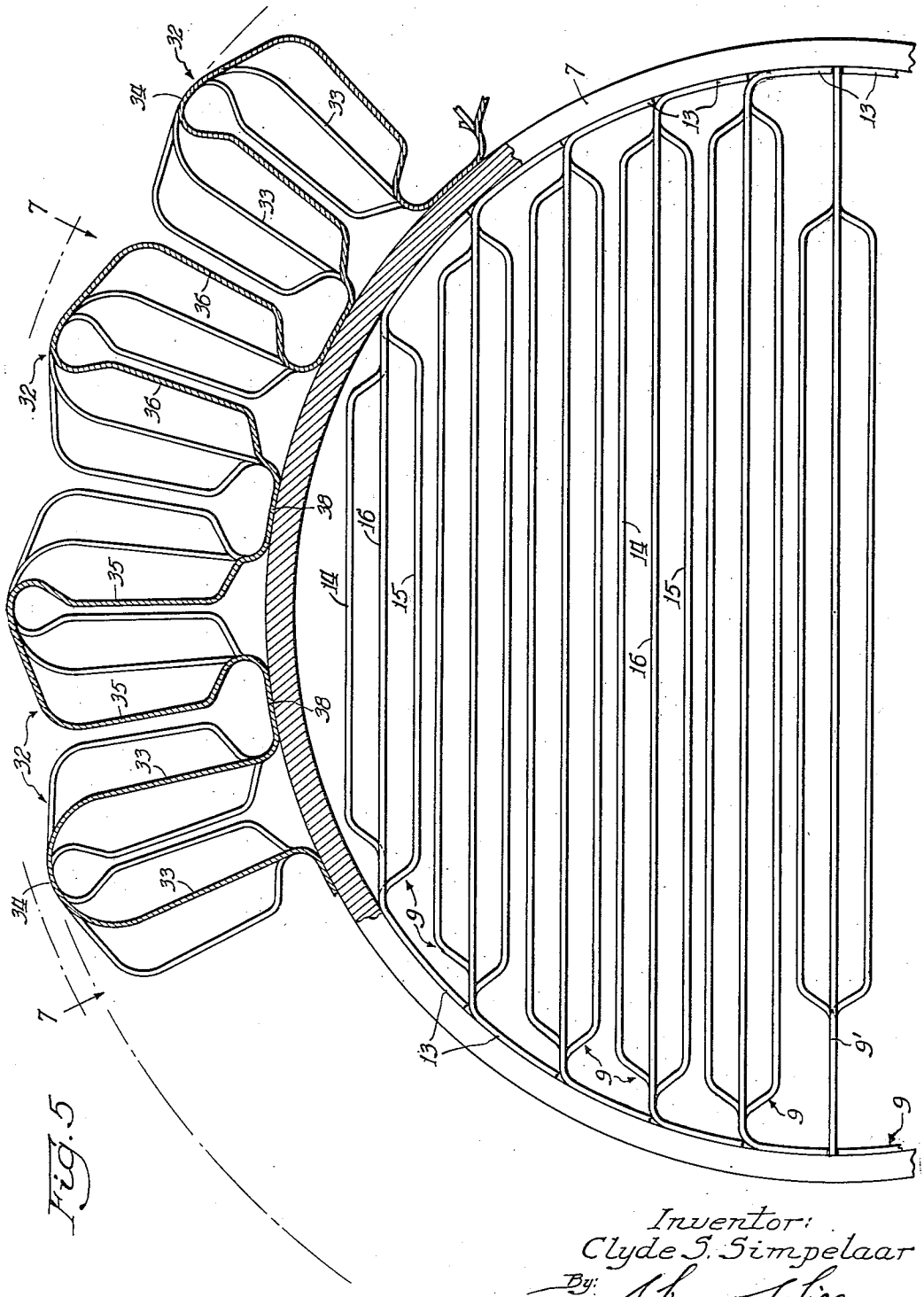


Fig. 5

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FINNED TUBE CONSTRUCTION

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Fig. 6

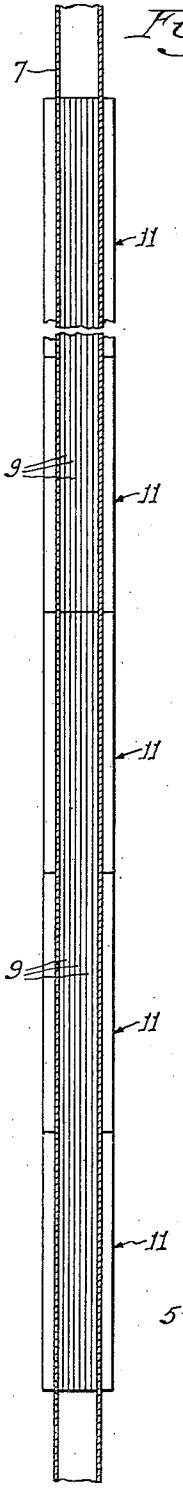


Fig. 7

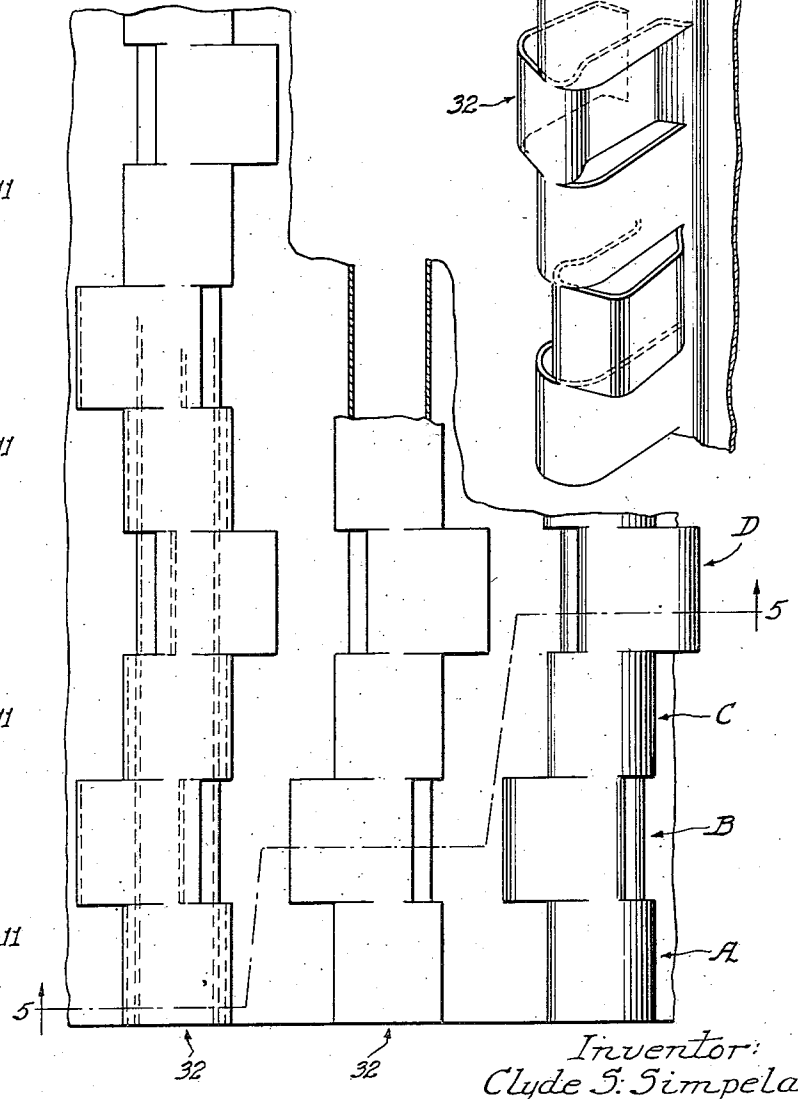


Fig. 8

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FINNED TUBE CONSTRUCTION

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Fig. 11

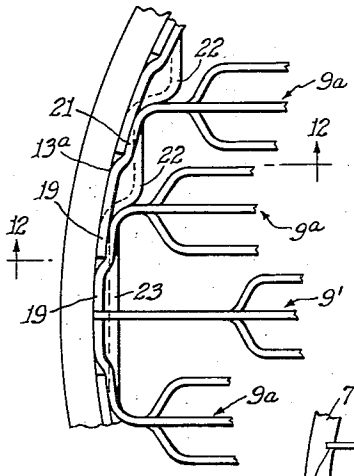


Fig. 10

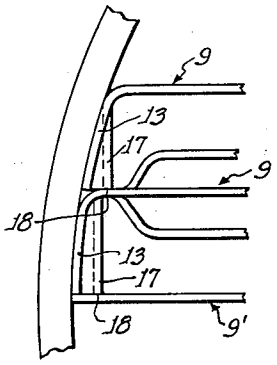


Fig. 14

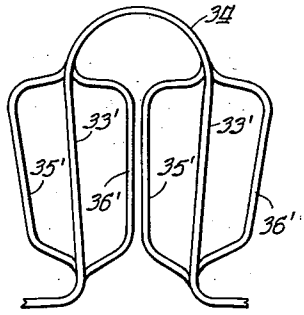


Fig. 13

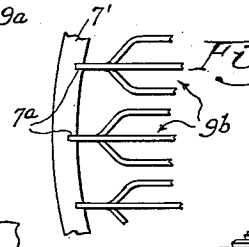


Fig. 12

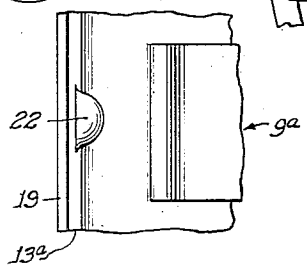


Fig. 9

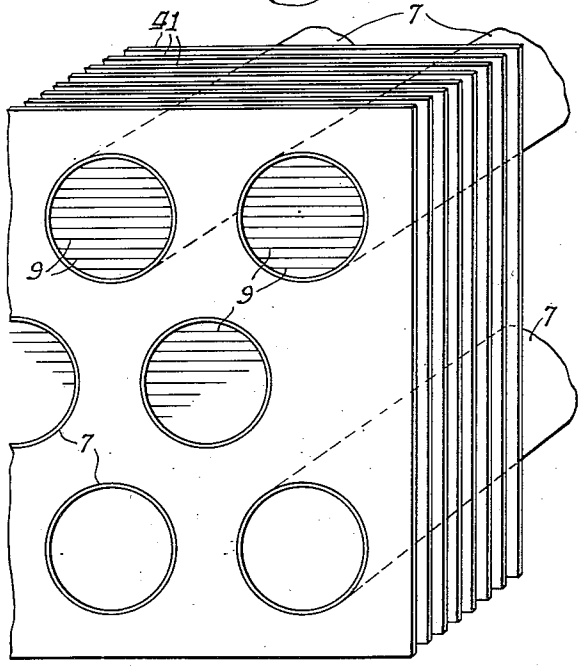
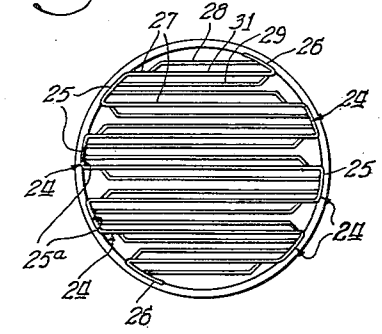


Fig. 15



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2,803,440

FINNED TUBE CONSTRUCTION

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Application October 2, 1953, Serial No. 383,768

11 Claims. (Cl. 257—262.14)

The present invention relates generally to heat exchange structures, and more particularly to a heat exchange structure utilizing tubing containing internal heat transfer fins and, in certain applications, external fins.

The invention is particularly directed to heat transfer tubing which is not only suitable for numerous applications presently employing standard tubing, but is particularly designed for utilization in applications which require high heat transfer efficiency involving wide pressure and temperature differentials, and where extremely large amounts of heat transfer surface must be provided. One example of such an application is in connection with oxygen plants which employ gas to gas heat exchangers. Heat exchangers employed in connection with oxygen plants must provide large amounts of heat transfer surface so that the heat exchangers must be of considerable size to achieve the desired results. Due to design and production limitations of present types of heat exchangers employed in such plants, it is normally necessary to construct each heat exchanger as a plurality or group of individual single units. For example, the largest current individual units being commercially employed have an effective surface volume of about eighteen cubic feet, and to achieve effective results, it is therefore necessary to employ a relatively large number of individual units suitably connected together to provide sufficient heat transfer efficiency. As each individual unit of the present type requires suitable plenum chambers to distribute the fluids throughout the exchange structure, and suitable manifolding between the individual units, considerable losses are introduced in the final exchange structure. In addition to such losses, as the temperatures involved in this type of plant are extremely low, it is necessary to provide insulation means, particularly in connection with the manifold sections which add to losses in performance. These losses are, of course, accented with increase in the heat exchanger size resulting in excessive parasitic pressure losses, limitations in operating, or test pressures, as well as multiplying the number of connections and joints which must be maintained fluid-tight.

A further factor is the necessity of insuring that throughout the complete heat exchange structure, to-wit, individual units, manifolding, etc., the design is such that adequate expansion and contraction is permitted.

From the above, it will be appreciated that if it were possible to build heat exchangers for this purpose as a single, large heat exchanger rather than a number of interconnected individual units, substantially all of the limitations above referred to would be eliminated; only one set of plenum chambers would be required; only one set of connections to the exchanger structure would be necessary; and as the exchanger would be incorporated in a single unit, insulation problems would be minimized. Likewise, the overall size of a large, single unit could be considerably smaller than the overall size of a multiple exchanger construction for the above reasons, and where the single exchanger unit could be made of

cylindrical design, the proportions of effective heat exchange volume to the total or actual volume of the structure would be exceedingly high, and would also require only a minimum amount of low temperature insulation with a minimum amount of losses in operation.

The present invention is directed to a heat exchanger structure utilizing a novel tube construction, the use of which enables the production of single, large heat exchanger units of the type above referred to, and contemplates the use of a tube which is provided with internal fins and, in certain applications, with external fins. I am aware that, in the past, tubes have been provided with internal fin structures as, for example, tubes utilizing radially extending fin members. However, such prior types of finned tubes are incapable as a practical matter of incorporating sufficient heat transfer surface of the high efficiency type needed to render them suitable for applications such as above discussed.

The present invention therefore has among its objects the production of a finned tube construction which is capable of providing the high heat transfer efficiency required in oxygen plant applications, and which is so designed that it may be readily fabricated into relatively very large, single heat exchange structures. For example, a single heat exchange structure utilizing the present invention could be built in lengths of over twenty feet, with a surface density in the range of three hundred to four hundred square feet per cubic foot of volume, and an effective surface volume approaching one thousand cubic feet, as compared with the largest present individual units previously referred to of about eighteen cubic feet or, in other words, about fifty times the effective size of present units.

A further object of the invention is the production of a novel fin tube structure which is so designed that it may be readily fabricated in relatively long lengths of twenty feet or more, and which adapts itself to current production techniques.

A further object of the invention is the production of novel heat exchange fins, both internal and external, for utilization in connection with tubular structures.

Many other objects and advantages of the construction herein shown and described will be obvious to those skilled in the art from the disclosure herein given.

To this end, my invention consists in the novel construction, arrangement, and combination of parts herein shown and described, and more particularly pointed out in the claims.

In the drawings wherein like reference characters indicate like or corresponding parts:

Fig. 1 is a vertical sectional view of a unitary heat exchange structure embodying the present invention;

Fig. 2 is a transverse sectional view through one of the tubes employed in the structure illustrated in Fig. 1;

Fig. 3 is a fragmentary sectional view taken approximately on the line 3—3 of Fig. 1;

Fig. 4 is a perspective view of a portion of one of the internal fin members employed;

Fig. 5 is an enlarged sectional view through a portion of a tube illustrating details of the internal and external fin structures, the section of the external fins being taken approximately on the line 5—5 of Fig. 7 and embodying an external fin structure of generally cylindrical cross section, whereas that illustrated in Fig. 2 of generally hexagonal shape;

Fig. 6 is a longitudinal sectional view through one of the tubes utilized in the exchanger structure illustrated in Fig. 1;

Fig. 7 is a plan development of a portion of the external fin structure as viewed from approximately the line 7—7 of Fig. 5;

Fig. 8 is a perspective view of a single row of external fin elements illustrated in Fig. 7;

Fig. 9 is a perspective view of a portion of a heat exchange structure of the cross flow type utilizing the present invention;

Fig. 10 is an end elevational view of a portion of a tube and internal fin structure illustrating in detail means for accurately spacing the internal fin members;

Fig. 11 is a figure similar to Fig. 9 illustrating a slightly modified form of construction of the tube and the fin members;

Fig. 12 is a sectional view of a portion of a fin member taken approximately on the line 12—12 of Fig. 11;

Fig. 13 is a fragmentary sectional view similar to Figs. 10 and 11 of another modified form of internal tube and fin structure;

Fig. 14 is an end elevational view of a slightly modified form of external fin structure; and

Fig. 15 is an end elevational view of a tube embodying a modified form of internal fin structure.

Referring to the drawings, and particularly Figs. 1 and 2, 1 indicates generally a unitary heat exchange structure which may be cylindrical in cross section, and comprising a housing body 2 of relatively heavy material, and end manifolds 3 having fluid ports or ducts 4, one of which would constitute the fluid inlet, and the other the fluid outlet of one side of the structure. If the device is to be carried by a supporting surface, legs 5, or other suitable supporting means connected to the lower manifold 3, may be utilized. The manifolds 3 may be secured to the housing 2 by any suitable means as, for example, welding, or the like. Positioned adjacent each of the manifolds 3 is a header or tube plate 6, the latter likewise being secured to the housing 2 by suitable means whereby a fluid type joint is produced. Extending between the two header plates 6 is a plurality of tubes 7, the ends of tubes 7 extending through the respective header plates and secured thereto in fluid-tight relationship. Thus, the tubes 7 and manifolds 3 constitute one pass of the exchanger, the other pass comprising the interior of the housing 2. Between the header plates 6 at the exterior of the respective tubes 7, and connected to the housing 2 adjacent opposite ends thereof is a pair of suitable outlet and inlet connections 8 which form the inlet and outlet for the second fluid pass. As illustrated in Fig. 2, which is a diagrammatic representation of the cross section of an individual tube 7, the latter is provided with a plurality of parallel fin members 9, the fin members 9 being substantially equally transversely spaced across the diameter of the tube 7, and extending around the outer surface of the tube 7 is an external fin structure, indicated generally by the numeral 11, having a generally hexagonally shaped periphery. The tubes 7 are so arranged within the housing that the external fin structures 11 on the respective tubes are adjacent one another, with substantially all of the cross sectional area of the housing 2 being filled with the tube and external fin elements. As illustrated in Fig. 3, suitably shaped baffle members 10 may be employed to block off any unfilled portions of the housing which would otherwise permit the by-passage of fluid. As illustrated in Fig. 1, the external fin elements 11 do not extend for the full length of the tubes 7, but terminate in a plane extending substantially parallel to the respective header plates 6 and spaced a sufficient distance therefrom to provide an adequate plenum chamber, indicated generally by the numeral 12 at each end of the housing interior, and providing means for distributing the flow of fluid within the housing throughout the transverse area of the latter.

Internal fin structure

As illustrated in Figs. 4 and 5, which disclose one suitable form of fin structure, the fin members 9 are each constructed as separate elements, a portion of one of which is illustrated in Fig. 4, and may be formed from suitable strip material or the like. In the embodiment

illustrated in Figs. 3 and 4, each of the fin elements 9 is provided with a longitudinally extending flange 13 whereby the fin member is generally channel-shaped in transverse cross section.

Referring to Fig. 5, it will be noted that the horizontal width of each fin member is approximately equal to the length of one of a plurality of equally spaced parallel sectors across the tube and each of the respective flanges 13 is shaped to be complemental to the adjacent inner surface of the tube 7. Likewise the transverse width of the respective flanges 13 increases as the transverse width of the fin member decreases, the flanges being so proportioned that they form means for uniformly spacing the fin members in parallel relationship. As clearly illustrated in Fig. 5, the centermost fin member 9′ is not provided with flanges along its longitudinal edges but extends diametrically across the tube from the inner face of one side wall of the latter to the inner face of the other side wall. The peripheral free edges of the innermost fin member 9 are seated on the adjacent surface of the center member 9′ and in like manner the flanges of succeeding fin members engage the fin member therebelow as viewed in Fig. 5. The fin members 9 below the center member 9′ are identical with those above with the exception that they are reversed in position, the flanges on the fin members in the lower half of the tube extending upwardly, only one pair of such flanges being shown in Fig. 5. Thus, the fin structure illustrated in Fig. 5 utilizes a centrally positioned fin member and a group of similar shaped fin members on each side of the central member, the corresponding fin members of each group being identical, with the fin members on one side of the central member being reversely positioned with respect to the fin members on the opposite side.

As illustrated in Fig. 5, the offset strip fins 14 and 15 are positioned in respective planes which extend parallel to the plane of the strip fins 16, with the spacing between the planes of adjacent offset strip fins of adjacent fin members being spaced approximately equal to or slightly less than the distance between the planes of the offset fins of a single member and the strip fins 16 of such member. The arrangement is such as to provide maximum heat transfer from the fluid passing through the tube to the fin members and the adjacent side wall of the tube itself.

It might be mentioned that Fig. 2 is drawn to a scale of two to one, the tubes in the embodiment of the invention illustrated being approximately one inch in diameter and constructed from suitable metal, as for example, aluminum or copper. In commercial application, the diameter of the tubes would generally range from three-fourths of an inch to one and one-half inches, depending upon the particular application, in which case the wall thickness of the tube would normally run from substantially 0.025″ to 0.100″. Likewise, the gauge of the material from the fins would generally run from substantially .004″ to .02″, depending upon the material, size of the particular tube employed, and the operating conditions. The fin spacing preferably would be such to provide surface area in the range of 200 to 400 square feet beyond a certain minimum, wall thickness has selectively little function in heat transfer, the tube wall thickness being primarily a function of operating conditions; i. e., the pressure to be withstood by the walls in separating the fluids between which heat transfer takes place. Wall thickness is essentially therefore a function of fabrication methods and operating pressures. For example, in the embodiment of the invention illustrated, utilizing a one inch tube, assuming copper was utilized as the material, the tube wall may normally be substantially .025″ in thickness, and the fins may be constructed from copper substantially .006″ in thickness, in which case the fins may be soldered to the tube wall. Where aluminum is employed as the material, the tube wall thickness of a one inch tube may be substantially .036″, and the thickness of the material forming the internal

fins may then be substantially .01". In such construction in which both the tube and the fins would be of aluminum, brazing could be employed connecting the fins with the inner surface of the tube wall. In the embodiment of the invention illustrated in Fig. 4, the strip fins **14**, **15**, and **16** are of equal width with approximately eight strip fins per inch, with the offsets of the fins **14** and **15** with respect to the fins **16** being substantially .024". The length of the flanges **13** are such as to space the strip fin on one fin element **9** substantially .019" from the adjacent strip fins of the adjoining fin element.

Although illustrative examples using copper and aluminum tubing have been given, in a tube wall, conductivity of the material as between copper and aluminum, has for practical purposes an infinitesimal effect on heat transfer due to the extremely short heat flow path. This, of course, is not true of extended surfaces where the length of flow path may be substantially within the range of from ten to fifty times that of the tube wall thickness. As a general observation, in most heat transfer structures, the resistance to heat flow through the tube is probably about substantially one percent or within the range of the total resistance. In most structures, normal test error would exceed the differences accountable to a range of tube materials from steel to copper.

It will be appreciated that due to the thinness of the material employed in the fin elements **9**, and also from the fact that the flanges **13** thereof follow the curvature of the internal surface of the tube, there may be some tendency, particularly where the lighter gauges of material are employed in the fin structure, for the fin elements to nest, thus destroying accurate alignment of the strip fins on adjoining fin elements. To eliminate this difficulty in those cases where it may exist, means may be provided for insuring accurate spacing of the fin elements. Such a structure is illustrated in Fig. 10 wherein the flanges **13** of the respective fin elements **9** are provided with small, inwardly offset beads or ribs **17** to form an inwardly extending shoulder **18** which will bear on the adjacent face of the succeeding fin element, thereby preventing any possibility of a nesting action therebetween. It will be appreciated that due to the curvature of the tube, succeeding beads **17**, in a direction outwardly from the center fin member **9'**, will be staggered inwardly so that there will be no tendency for the beads **17** to nest, and eliminating any necessity of longitudinally staggering the beads **17** on adjoining fin members.

In some cases it may be desirable to employ a nesting type of fin member, such construction being illustrated in Figs. 11 and 12, wherein the fin members **9*a*** are provided with flanges **13*a*** having offset edge portions **19**, the material adjacent the edge portions **19** being offset approximately the thickness of the material employed so that the portions **21** may be nested between the offset portions **19** of the succeeding fin members. As such offset is only the thickness of the material employed, additional means for providing accurate spacing of the fin members may be provided, such means, in the construction illustrated, comprising a series of longitudinally spaced dimples or recesses **22** formed in the flanges **13*a***, thereby forming inwardly extending projections along the inner surface of the flanges **13*a*** which are seated on the preceding fin member. The innermost fin members **9*a*** may be provided with an inwardly extending bead **23** constructed in a manner similar to the beads **17** illustrated in Fig. 10, which are adapted to seat on the center fin member **9'**. As illustrated in Fig. 13, in some cases, it may be desirable to provide the tube **7'** with longitudinal internal grooves **7*a*** of a size to receive and support the longitudinal edges of the fin members **9*b***. This form being particularly suitable where the tube **7'** is formed as an extrusion.

While the internal fin structure is illustrated in Figs. 4, 5, 10, 11, 12 and 13 as embodying a plurality of individual fin members assembled within the tube, in some cases it may be desirable to fabricate the fin structure as a unitary structure, such a construction being illustrated in Fig. 15. In this construction the fin structure is formed from a single sheet of material which is suitably formed to provide a series of corrugations **24**, the width of the corrugations successively tensioning outwardly from the center one with the connecting portions **25** and end flanges **26** being shaped to be complementary to the internal surface of the tube, or as illustrated, to longitudinally extending grooves **25*a*** in the tube. In this construction, the transversely extending portions **27** of the corrugated member are transversely slit to form a series of strip fins which are offset out of the plane of the corrugations to provide strip fins **28** and **29** corresponding to strip fins **14** and **15** of the construction illustrated in Figs. 4 and 5, and the intermediate strip fins **31** corresponding to the strip fins **16**. In the construction illustrated in Fig. 15, one of the strip fins **28** and **29** terminates at the connecting walls **25** or flanges **26** extending between fin **27** and the offset strip fin is likewise slit so that the fin members **28** and **29** are formed from material initially forming a part of the fin member **27** and a portion of the connecting wall **25** or flange **26**. The opposite ends of the strip fins **28** and **29** are shaped in a manner similar to the strip fins **14** and **15** in the construction illustrated in Figs. 4 and 5. Thus, the construction illustrated in Fig. 15 is such that it may be formed by suitably designed dies in a stamping operation. Other forms will suggest themselves to those skilled in the art, and the grids formed as described above may be fabricated from strip-like material folded to form the fins and to complementally fit in heat transfer relation with the inner tube wall. The grids may for example be arranged so that each successive grid is displaced 60° from the preceding grid or other angular displacement which may give suitable turbulence throughout the tube length.

External fin structure

The external fin structures illustrated in Figs. 2, 5, 7 and 8 are constructed of sheet material which is suitably formed and applied to the exterior surface of the tube in a form of a plurality of longitudinally extending sections, each section encircling the peripheral surface of the tube and secured thereto by suitable bonding, brazing, or other means, to effect an efficient heat transfer connection. In the embodiment of the invention illustrated in Fig. 2, the overall outer configuration is of hexagonal cross section, while in the form illustrated in Figs. 5, 6, and 7 it is circular. In both cases the sheet material comprising the external fin elements is shaped to form a plurality of longitudinally or axially extending corrugations, indicated generally by the reference character **32**, each of the corrugations **32** initially being generally U-shaped in cross section, having leg portions **33** connected adjacent their outer longitudinal edges by cross or connecting portions **34**. As clearly illustrated in Figs. 7 and 8, the leg or wall portions **33** each have a series of parallel slits **35** which extend transversely with respect to the axis of the tube, as well as the axis of each individual U-shaped corrugation. As clearly illustrated in Fig. 7, corresponding slits **35** in adjoining corrugations are aligned in respective planes extending perpendicular to the axis of the tube. The metal intermediate adjacent pairs of certain of the slits **35** is deformed out of the plane of the leg portion or wall associated therewith, the metal between the corresponding slits of the opposite leg portion being deformed in the same direction as that of the first portion to form a pair of strip fins which are offset out of the planes of the respective leg portions. As illustrated in Fig. 8, alternate sections of the corrugation are undeformed, with the

intermediate offset fin elements being alternately offset to the right and left of the respective leg portions. Corresponding fin elements on the respective corrugations may be offset in the same direction. Thus the corrugations may be longitudinally divided into a plurality of groups of strip fins, with the fins of each group being radially arranged around the tube in spaced relation. In the embodiments of the invention illustrated, the fins forming the first group A are positioned in the initial planes of the leg portions 33 of the corrugations; the strip fins 35 of group B are deformed or offset to the left as viewed in Fig. 5; the strip fins comprising group C are positioned in the same relation as the fins comprising group A, and are composed of undeformed portions of the corrugations 32; while the strip fins 36, comprising group D, are offset to the right with respect to the fins 33. The sequence may then be repeated, the next group of fins being undeformed, and the following group offset to the left corresponding to the fins of group B, and so on. Corresponding strip fins offset in the same direction of each corrugation thus may be positioned in common planes so that each corrugation 32 is divided into six longitudinally extending, radially spaced rows of strip fins, with the alternate strip fins comprising undeformed material of the particular corrugation, and the intermediate fins being alternately off-set to the left and right, respectively. As clearly illustrated in Figs. 7 and 8, the corresponding slits 35 in opposite leg portions of the respective corrugations terminate in spaced relation at the connecting portion 34, whereby the fins of each successive group are integrally connected to the adjacent fins of the next successive group by the portions 37 intermediate the outer ends of the slits 35.

Each corrugation 32 is connected adjacent the external surface of the tube 7 by the portions 38, which are suitably connected in heat transfer relation to the tube surface by soldering, brazing, or other suitable means, to provide a good heat transfer connection between the external fin structure and the surface of the tube. The main difference between the external fin structures illustrated in Fig. 2, and those illuctrated in Figs. 7 and 8, other than the number of corrugations employed is that in the construction of Fig. 2, the radial height of the corrugations is alternately increased to form the hexagonal overall configuration.

The construction illustrated in Fig. 14 is generally similar to that illustrated in Figs. 2, 5, 7, and 8 with the exception that the longitudinally extending series of suitable fins are composed substantially entirely from metal forming the leg portions of the corrugation. Thus the connecting portion 34' of the corrugation is a continuous integral member extending throughout the longitudinal length of the respective corrugations, with the slits 35' extending only in the leg portion 33' and up into the connecting portion 34'. It will be apparent that in this construction the metal comprising the offset strip fins 36' and 35' must be stretched to provide the additional fin length required in the offset fins over that of the undeformed fins 33', such stretching being considerably greater than that of the fins 35 and 36 in the construction illustrated in Fig. 5.

Heat exchanger assemblies employing finned tubes

The structure illustrated in Figs. 2, 5, and 6 has particular application in heat exchanger assemblies wherein counterflow principles are utilized, such a construction being illustrated in Fig. 1 wherein a bundle of internally and externally finned tubes 7 are utilized in a counterflow of exchanger.

Where a cross flow heat exchange structure is desired, a series of internally finned tubes constructed in accordance with the present invention may be employed in combination with a series of transverse plate-like fins which are in heat transfer relation with respect to the external surface of the tubes. Such a construction is illustrated in Fig. 9, wherein the tubes 7 are provided with parallelly extending, internal fin structure 9 constructed in accordance with the present invention, with tubes 7 extending through a series of plate-like, external fin member 41, the latter extending transversely to the axis of the parallel tubes 7, and suitably bonded to the latter in heat exchange relationship. Thus one fluid may flow through the tubes 7, and the other fluid may flow between the parallel plates 41 in a transverse direction to the axis of the tubes 7 to provide a cross flow construction.

While the internally finned tube structure herein disclosed may be employed in multiple tube types of heat exchange structures in place of other types of finned or unfinned tubes, wherever high heat transfer efficiency is required, the invention is of particular application in the cross flow and counterflow exchangers such as those herein disclosed.

Where the externally and internally finned tubes, such as those illustrated in Figs. 1, 2, 5 and 6, are employed, the internal fins may be assembled in units of several feet in length, while the external fins, for convenience in fabrication and assembly, may be made in shorter units. For example, in the structure illustrated in Fig. 6, wherein the length of the tube 7 may be twenty feet or more, the internal fin unit is illustrated as being approximately two feet in length, whereas the external fin units are approximately eight inches in length.

In assembling the internal fins with the tubes 7, the respective units of assembled fins may be inserted through the tube and axially moved to the desired position, following which successive units are inserted until the desired internal length of tube is filled with fins, suitable jigs and equipment being employed to achieve the desired results. The elements of the assembled structure are then suitably bonded together by soldering, brazing, or the like. The completed tube may then be fabricated into the heat exchange structures similar in construction to the various prior tube-type exchanger structures.

In the cross flow type of construction illustrated in Fig. 9, the internal fins may be assembled in the tube in substantially the same manner as that described for the construction illustrated in Fig. 5, following which the tubes may be assembled with the fin members 41, using fabrication techniques and equipment similar to that employed in connection with cross flow types of exchanger structures utilizing standard tubes.

While there have been forms of internally finned tubes heretofore employed in various applications, some of which at first glance may appear similar to the internally finned tube herein shown and described, the present structure provides heat exchange characteristics which cannot be achieved by prior structures and, at the same time, enables the fabrication of internally finned tubes in relatively long lengths, and also enables the production of very large heat exchangers constructed as single units as distinguished from a plurality of manifold units, which result was not feasible with prior heat exchange structures. Taking the oxygen reduction field as an example, it will be apparent that the present invention enables the production of heat exchange structures of exceptional size and capacity with an elimination of interconnections inherent in the utilization of a number of small units, and a consequent saving in manufacturing, installation, and maintenance expenses, as well as highly improved efficiency characteristics.

It will also be apparent from the above disclosure that the present invention may be employed with tubes having cross sectional shapes other than circular, the fin structure being accordingly modified, and as seamless tubing may be employed, heat exchange structures for high pressure applications may be readily designed. Consequently, the present invention can be adapted to practically any pressures and designs to which shell and tube designs can be constructed. Thus it is possible, in many cases, to utilize a single heat exchanger constructed in accordance with the present invention to serve an entire plant, which

heretofore has not been feasible except in relatively small installations.

Having thus described my invention, it is obvious that various immaterial modifications may be made in the same without departing from the spirit of my invention; hence, I do not wish to be understood as limiting myself to the exact form, construction, arrangement, and combination of parts herein shown and described, or uses mentioned.

What I claim as new and desire to secure by Letters Patent is:

1. In a high efficiency heat exchange structure, the combination of a cylindrical hollow tube, a plurality of elongated fin members lying in respective planes which are parallel to a diametrically extending plane, each fin member extending transversely across the tube and being provided with longitudinally extending flange members, a diametrically extending fin member having its longitudinal edges substantially continuously secured to the internal surface of the tube in heat transfer relation therewith, the flanged fin members being stacked one upon the other at opposite sides of and with the flanges of all fin members extending toward said diametrical fin member, with the flanges of the adjacent members at opposite sides of said diametric fin member being seated on the latter, said flanges being secured to the tube side walls in heat transfer relation therewith, the fin members at opposite sides of said diametrically extending fin member successively diminishing in width outwardly therefrom, a plurality of strip fins formed from each of said fin members, said strip fins extending transversely to the longitudinal axis of the respective fin members from which they are formed, and a plurality of generally U-shaped fin structures each of which extends longitudinally along the outer face of the tube with the leg portions of the fin structures operatively engaged with the tube in heat transfer relation, said fin structures being substantially uniformly arranged about the circumference of the tube and having a series of substantially parallel slits formed in the leg portions thereof, each adjacent pair of slits defining a strip fin, certain of said strip fins being offset out of the plane of the other strip fins of the associated fin structure.

2. In a high efficiency heat exchange structure, the combination of a fluid conducting tube, a plurality of fin element portions in said tube and operatively engaged with the side walls thereof in heat transfer relationship, said fin element portions extending longitudinally within said tube and lying in parallel planes extending parallel to the axis thereof, each fin element portion extending transversely across the tube with the respective longitudinal edge portions of said fin element portions being substantially continuously secured to respective opposite disposed portions of the internal surface of the tube in heat transfer relation therewith, the fin element portions at opposite sides of said diametrically extending plane being symmetrically positioned with respect thereto, and successively diminishing in width outwardly therefrom, a plurality of strip fins formed from each of said fin element portions, said strip fins extending transversely to the longitudinal axis of the respective fin element portions from which they are formed, a plurality of fin structures each of which extends longitudinally along the outer face of the tube with longitudinally extending portions of the fin structures operatively engaged with the tube in heat transfer relation, said fin structure being generally U-shaped in transverse cross-section with the free longitudinal edges of the leg portions thereof being operatively secured to the tube in heat transfer relation therewith, said leg portions having a series of substantially parallel slits therein extending generally radially with respect to the longitudinal axis of the tube axis of the tube, the slits of one leg portion being longitudinally aligned with the slits of the other leg portion of that element, each pair of adjacent slits defining a strip fin.

3. In a high efficiency heat exchange structure as defined in claim 2, wherein certain pairs of circumferentially aligned strip fins being laterally offset to the right of an adjacent pair of strip fins and others being offset to the left of such adjacent pair of strip fins to divide each fin element into a plurality of longitudinally extending rows of strip fins, corresponding pairs of strip fins of adjacent fin elements being correspondingly offset with said strip fins extending in generally radial directions.

4. In a high efficiency heat exchange structure as defined in claim 2, where one of said fin element portions extends diametrically across the tube and the remaining fin element portions are provided with longitudinally extending flanges, the fin element portions being stacked one upon the other at opposite sides of and with the flanges of all fin element portions extending toward said diametrical fin member, corresponding flanges cooperating to form an arcuate wall and engaged throughout their length with the tube side walls in heat transfer relation therewith.

5. In a high efficiency heat exchange structure as defined in claim 2, wherein one of said fin element portions extends diametrically across the tube and the remaining fin element portions are provided with longitudinally extending flanges, the fin element portions being stacked one upon the other at opposite sides of and with the flanges of all fin element portions extending toward said diametrical fin element portion, said flanges being secured to the tube side walls in heat transfer relation therewith, and means formed in said flanges engageable with an adjacent fin member operative to define the spacing between such fin element portions.

6. In a high efficiency heat exchange structure as defined in claim 2, wherein one of said fin element portions extends diametrically across the tube and the remaining fin element portions are provided with longitudinally extending flanges, said flanges being outwardly offset intermediate their side edges whereby said fin element portions may be stacked one upon the other in nesting relation at opposite sides of and with the flanges of all fin element portions extending toward said diametrical fin element portion, said flanges being secured to the tube side walls in heat transfer relation therewith.

7. In a high efficiency heat exchange structure as defined in claim 2, wherein said plurality of fin element portions in said tube are constructed from a single sheet of material having transversely formed corrugations, the leg portions of which form the fin element portions, and the longitudinally extending portions are generally complemental to the internal surface of the tube and are secured thereto in heat transfer relation, and said strip fins are formed on said leg portions.

8. In a high efficiency heat exchange structure as defined in claim 2, wherein said plurality of fin element portions in said tube have longitudinal edge portions which are interlocked with integral portions of the tube in heat transfer relation thereto.

9. In a high efficiency heat exchange structure as defined in claim 2, wherein said plurality of fin element portions in said tube are constructed from a single sheet of material having transversely formed corrugations, the leg portions of which form the fin element portions, and the longitudinally extending portions are generally complemental to the internal surface of the tube and are secured thereto in heat transfer relation, said tube having longitudinally extending grooves therein complementally shaped to and adapted to receive said connecting portion, operative to interlock the fin element portions to the tube.

10. In a high efficiency heat exchange structure, the combination of a fluid conducting tube, a plurality of longitudinally extending fin members positioned in respective parallel planes which are parallel to the axis of the tube, the longitudinal edge portions of said fin members being substantially continuously secured to the internal surface of the tube in heat transfer relation therewith, a plurality of outwardly directed fin elements ex-

tending longitudinally along the external surface of the tube and substantially uniformly arranged about the circumference of the tube, said fin elements being generally U-shaped in transverse cross section with the free longitudinal edges of the leg portions thereof being operatively secured to the tube in heat transfer relation therewith, said leg portions having a series of substantially parallel slits therein extending generally radially with respect to the longitudinal axis of the tube, the slits in one leg portion being longitudinally aligned with the slits on the other leg portion of that element, each pair of adjacent slits defining a strip fin, each pair of circumferentially aligned strip fins being connected at their outer ends by the intermediate portion of the associated U-shaped fin element, such intermediate portion extending continuously from one end of the fin element to the other and operatively connecting longitudinally adjacent pairs of strip fins, certain pairs of circumferentially aligned strip fins being laterally offset to the right of an adjacent pair of strip fins and others being offset to the left of such adjacent pair of strip fins to divide each fin element into a plurality of longitudinally extending rows of strip fins, corresponding pairs of strip fins of adjacent fin elements being correspondingly offset with said strip fins extending in generally radial directions.

11. In a high efficiency heat exchange structure, the combination of a fluid conducting tube, a plurality of outwardly directed fin elements extending longitudinally along the external surface of the tube and substantially uniformly arranged about the circumference of the tube, said fin elements being generally U-shaped in transverse

cross section with the free longitudinal edges of the leg portions thereof being operatively secured to the tube in heat transfer relation therewith, said leg portions having a series of substantially parallel slits therein extending generally radially with respect to the longitudinal axis of the tube, the slits in one leg portion being longitudinally aligned with the slits on the other leg portion of that element, each pair of adjacent slits defining a strip fin, each pair of circumferentially aligned strip fins being connected at their outer ends by the intermediate portion of the associated U-shaped fin element, such intermediate portion extending continuously from one end of the fin element to the other and operatively connecting longitudinally adjacent pairs of strip fins, certain pairs of circumferentially aligned strip fins being laterally offset to the right of an adjacent pair of strip fins and others being offset to the left of such adjacent pair of strip fins to divide each fin element into a plurality of longitudinally extending rows of strip fins, corresponding pairs of strip fins of adjacent fin elements being correspondingly offset with said strip fins extending in generally radial directions.

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