May 18, 1954

J. R. GIER, JR

SINUOUS WIRE STRUCTURAL AND HEAT EXCHANGE ELEMENT AND ASSEMBLY

2,678,808

Filed Nov. 23, 1949

2 Sheets-Sheet 1

Fig. 1

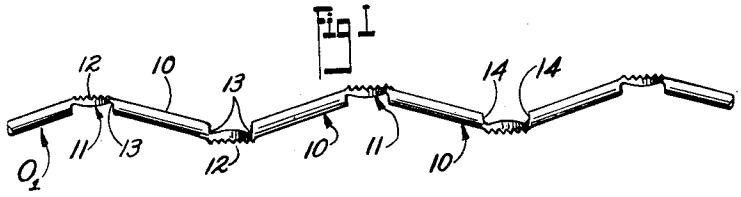


Fig. 2

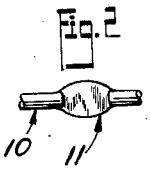
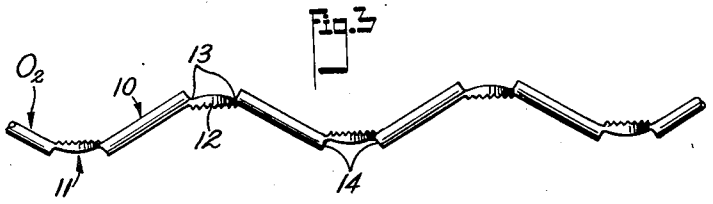


Fig. 3



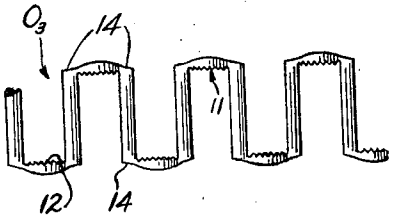


Fig. 4

Fig. 5

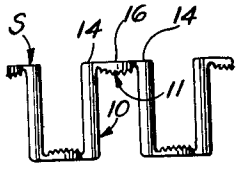


Fig. 6

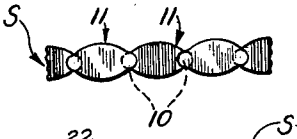


Fig. 7

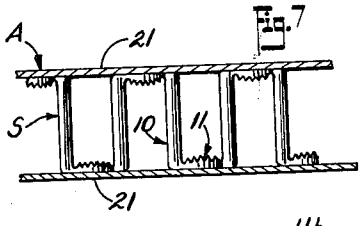


Fig. 8

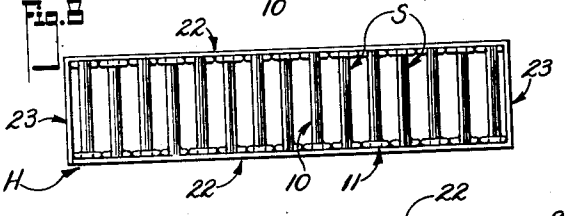


Fig. 10

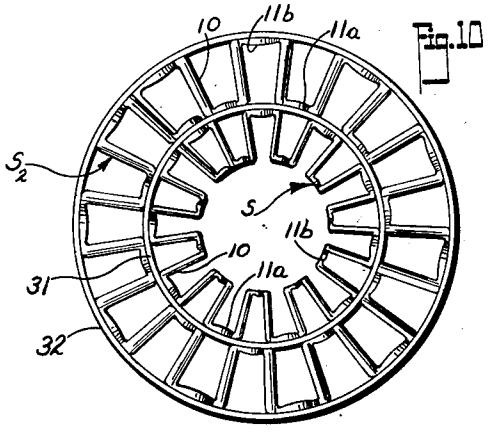
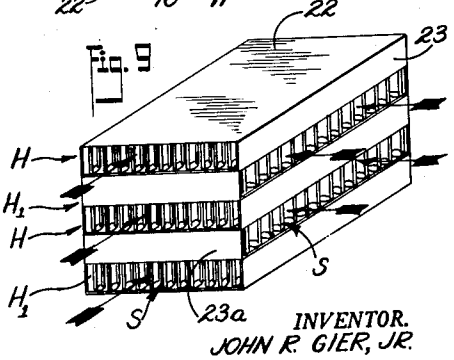


Fig. 9



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Fig. 13

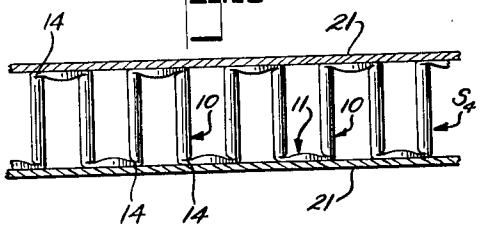
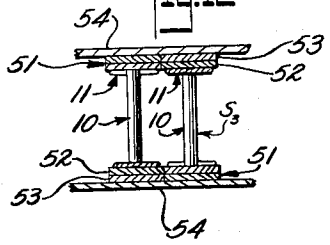


Fig. 12



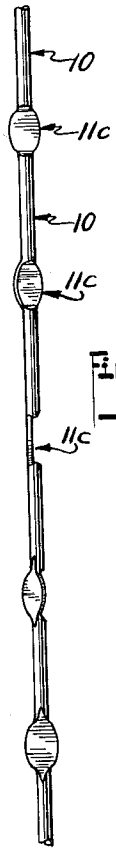


Fig. 15

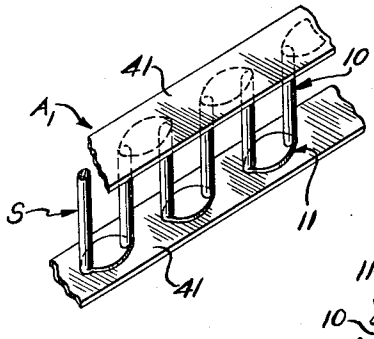


Fig. 11

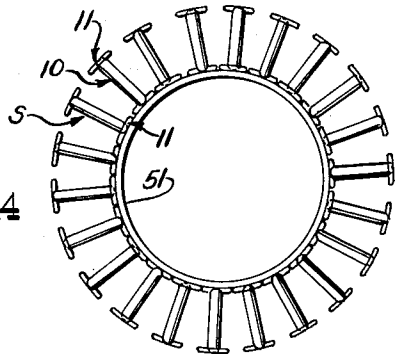


Fig. 14

Fig. 16

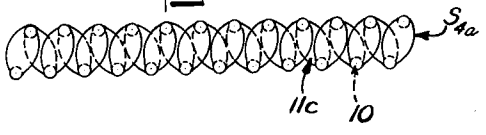
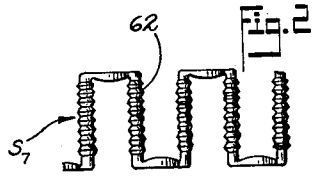


Fig. 21



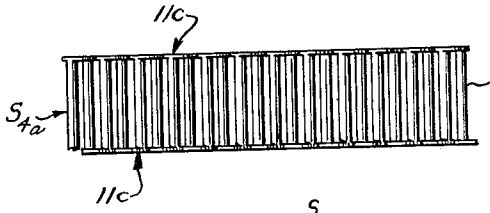


Fig. 17

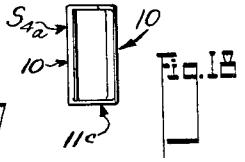


Fig. 18

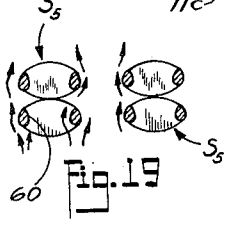


Fig. 19

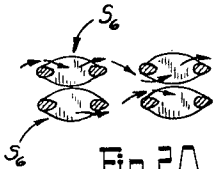


Fig. 20

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UNITED STATES PATENT OFFICE

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SINUOUS WIRE STRUCTURAL AND HEAT EXCHANGE ELEMENT AND ASSEMBLY

John R. Gier, Jr., Hudson, Ohio

Application November 23, 1949, Serial No. 129,159

17 Claims. (Cl. 257—245)

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This invention relates broadly to structural elements of general application as well as to new and useful heat exchangers and heat exchanger elements wherein the novel structural elements facilitate the commercial manufacture and assembly of unusually efficient and effective heat exchange units.

It has been determined by calculations and demonstrated by laboratory experiments that of all the means known for extending the surface of plates or tubes, the most effective and efficient are a plurality of wire-like pins or filaments extending generally perpendicular to the plates or tubes at their points of attachment thereto and disposed transversely to the fluid flow.

For example, when employed in connection with heat exchangers of the plate type, the pin method of extending the surface would ideally involve the endwise attachment of a plurality of wire-like pins perpendicular to and between adjacent plates. The size of the wire and the spacing of the pins are chosen to produce an optimum heat transfer coefficient for a given rate of fluid flow between the plates. Similarly the pins may be formed between concentric tubes or may extend from both surfaces of a single tube, each pin being radially disposed. Although calculations and experiments have shown heat exchangers of this type to be the most efficient known, to my knowledge the pin type of extended surface has found very little use outside of laboratories, because of the difficulties heretofore encountered in their manufacture and fabrication. It will be recognized that to produce a commercial-type heat exchange unit may involve the bonding of literally millions of wires or pins to the fluid separating surfaces because the heat transfer coefficient increases as the pins become more numerous per unit area and smaller in perimeter.

It is an object of the present invention to facilitate the fabrication of structural elements including heat exchangers embodying pins, wires or the like for extending the surface of the fluid constraining plates or tubes; and more particularly, it is an object to facilitate the building up of heat exchanger units of the aforesaid type wherein the pins or the like are bonded to the plates or tubes by the employment of furnace brazing techniques.

It is well known in the furnace brazing art that in order to obtain an intimate and effective joint there should be a substantial area of close contact between the parts. (This is inconsistent with the basic pin-type heat exchanger construction wherein relatively small diameter pins extend between or from plates or tubes.) I have found that a readily brazed heat transfer element may be produced by forming from wire stock a sinuous element having columnar legs (which may have the same cross-section as the wire stock), the legs being integrally connected at their ends by flattened ligaments. Each of the legs are preferably perpendicular to the planes of the associated flattened ligaments. The edges of the sinuous element, which comprise the flattened ligaments, may be formed to lie in spaced planes and such ligaments provide feet of substantial area that may be readily brazed to a planar, curved, or tubular metal wall. When the sinuous elements are assembled with their base elements and heated the brazing material readily flows between the flattened ligaments and the plates or tubes, establishing a perfect brazed connection. Since the ligaments only serve to preliminarily connect the pins, they may be quite thin, hence the ligaments do not interfere appreciably with fluid flow, and in fact may serve the desirable function of turbulence promotion. The completed heat exchange assembly closely approximates the laboratory ideal assembly wherein discrete pins are connected to or between plates or tubes, and may in fact surpass it because of the turbulence effect of the ligaments.

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A plate or tube type of heat exchange assembly formed in this fashion has the advantage that the pins act as stays and prevent separation of the sheet metal walls or tubes under the action of fluid under pressure.

It is a feature of the invention that the sinuous wire elements may be brazed or electrically welded between thin metal strips and these strips in turn brazed to or between plates. This form makes possible the commercial production of a heat exchanger assembly the exposed surface of which is formed of corrosion resistant material such as stainless steel, even though the latter material cannot be readily furnace brazed. For example, I contemplate that for such applications the sinuous wire-like elements may be formed of stainless steel wire resistance-welded to strips of stainless steel, the strips being clad on their outer surfaces with a readily brazed material such as copper or low carbon steel. These composite strips may in turn be furnace brazed to or between plates or tubes likewise formed of a readily brazed material, and as a result of the furnace brazing operation, all the surfaces exposed to fluid flow are formed of a corrosion-resistant metal. Yet, this assembly is readily completed by the high-production, economical, furnace brazing process

with ordinary commercial equipment without the use of fluxes.

Another object of the invention resides in insuring that when sinuous wire elements are wrapped around tubes, the pins thereof are substantially radial. This is accomplished by forming the connecting flattened ligaments along one edge so that they are longer than those along the other edge. As a result of this construction and by properly proportioning the parts, if the shorter ligaments are disposed so as to be at the smaller radius of the coil, the pins will necessarily be radially disposed.

Other objects reside in facilitating fluid flow past the pins which may be accomplished by forming the pins so as to have an airfoil section, and in increasing the heat transfer coefficient which may be accomplished by forming the pins to have a corrugated, threaded, or otherwise extended surface.

It is a feature of a modified form of my invention that two rows of pins may be produced from a single wire. This facilitates handling and renders the element more flexible and is accomplished by forming the column elements in staggered rows with angularly disposed connecting ligaments.

The manner in which these and other objects and advantages may be realized will be apparent in the following detailed description of the preferred embodiment of the invention.

In the drawings:

Figs. 1 to 6 show various steps in a preferred sequence of forming operations:

Fig. 1 is a side view of the wire after flattening;

Fig. 2 is a view of a flattened ligament;

Fig. 3 shows the wire after the first bending step;

Fig. 4 shows the wire after the second bending step;

Fig. 5 is a side view of the completed element;

Fig. 6 is an edge view thereof;

Fig. 7 is a side view showing an element bonded between plates;

Fig. 8 is an end view of a plate-type heat exchange assembly;

Fig. 9 is a simplified drawing of a cross flow heat exchanger core embodying the invention;

Fig. 10 shows the elements wound about tubes;

Fig. 11 shows the sinuous elements are attached between strips;

Fig. 12 shows a modified form of sinuous element;

Fig. 13 shows a form wherein the surfaces presented to fluid flow may be made of corrosion-resistant material;

Fig. 14 shows the elements laid axially along a tube;

Fig. 15 shows the wire after the flattening step for a modified form of sinuous element;

Fig. 16 is an edge view of the modified form resulting from the wire shown in Fig. 15;

Fig. 17 is a side view thereof;

Fig. 18 is an end view thereof;

Fig. 19 shows a modified form wherein the pins are of airfoil section;

Fig. 20 shows another form of airfoil pin unit, and,

Fig. 21 shows how the pin surface may be extended.

Figs. 1 to 6 illustrate a preferred form of structural element formed in accordance with the invention. A suitable method and apparatus for forming such elements will be outlined briefly here and forms the subject matter of my copending application, Serial No. 342,823, filed March 17, 1953, and entitled Method and Apparatus for Forming Sinuous Wire Structural and Heat Exchange Elements.

The first operation O_1 of the element is performed by flattening wire stock at spaced intervals which (as seen in Fig. 1) results in an elongated wire-like member having legs 10 having a cross-section like that of the wire stock and flattened ligaments 11. Although it is not necessary in the broader aspects of my invention, I prefer that each ligament 11 have a flattened portion 12 with notched corners at the opposite surface, the ligaments being automatically offset relative to the legs 10. The flattening operation may be carried out in any suitable manner, as described in my aforesaid pending application, and the zig-zag shape imparted to the wire as seen in Fig. 1 facilitates the preferred method of formation. The ligaments 11 are considerably wider and considerably thinner than the legs 10 and I prefer that their thickness be, at most, one-half, or better still, one-fourth, of the diameter of the legs 10, and their width be substantially greater than the diameter of legs 10.

Operation O_2 is formed by reversely bending the wire at notches 13, resulting in the form shown in Fig. 3. It will be noted that the partial ends 14 of the legs 10 are approaching the plane of the ligaments opposite the flat surfaces 12 thereof.

Operation O_3 illustrated in Fig. 4, shows a further bending or gathering operation wherein the legs 10 are brought into parallel relationship and the ends 14 are closely aligned with the outer edges of ligaments 11. It will be noted that when bent in this manner the ends of the legs 10 at a given edge of a sinuous element are remote from one another.

The completed sinuous element S is shown in Figs. 5 and 6. The outer surface of ligaments 11 are flattened and coplanar with the flat ends 14 of legs 10, thereby providing flat surface 16, which may be readily brazed or otherwise bonded to a supporting member, the method of attachment depending upon the composition of the metals involved.

Although the sinuous elements shown in Figs. 5 and 6 may be of rather general utility as structural units, I contemplate that the units will be particularly useful when one or both edges, that is one or both rows of ligaments 11, are bonded to supporting sheets, plates or tubes to form an assembly which is at once a structural element and an efficient heat exchange device. For example, as seen in Fig. 7, the sinuous element S is bonded between plates or strips 21 of sheet metal to form a structural assembly A. The ligaments 11 greatly facilitate the bonding operation because they, as well as the ends 14 of legs 10, present ample surface for engagement with the sheets 21 with which the elements S may be bonded to the sheets by the economical mass production furnace brazing process.

The assembly A is an efficient and effective device from both the structural and heat exchange standpoint. Structurally elements 10 act as columns which are recognized as being the most efficient utilization of metal for resisting compression as well as tension loads. Thus, an assembly such as that shown in Fig. 7 can be made in the form of a composite sheet and used as a structural element wherever a sturdy, lightweight plate construction is required, as in bridge

decks, aircraft panels, and the like. Assembly A also closely approaches the ideal in a heat exchange unit, which, as mentioned previously, is one wherein a plurality of pins are extended from or between plates or tubes.

It can be seen that the ligaments 11 offer very little resistance to fluid flow between the plates. Furthermore, legs 10 act as stays to prevent separation of the plates if the fluid therebetween is under a high pressure.

Fig. 8 shows an end view of a heat exchange assembly H which may be used to build up a plate-type heat exchanger (as shown in Fig. 9). The sinuous elements S are furnace brazed between top and bottom sheets 22, and in order to restrain the fluid through the unit side walls 23 are included.

As seen in Fig. 9, units H may be alternated with similar units H_1 to produce (as indicated by the arrows) a cross-flow, plate-type heat exchanger. Units H_1 will have their side portions 23a disposed perpendicular to the portions 23 to properly direct the flow of fluid. A heat exchanger produced as shown in Fig. 9 is not only the most efficient known, but by employing the elements made in accordance with the invention may be produced rapidly and economically and assembled in a mass production, continuous brazing furnace.

The sinuous elements S are likewise suitable for disposition about or within tubular fluid conductors. For example, in Fig. 10 an inner tube 31 has bonded to its iner surface a spiral length of sinuous element S_1. Preferably member S_1 has one row of ligaments 11a longer than the inner row 11b so that the legs 10 will be generally radial. An outer row of sinuous elements S_2 may be bonded to the outside of tube 31 and likewise its inner ligaments 11a shorter than its outer ones 11b. If it is desired to confine the external heat exchange fluid an outer tube 32 may be bonded to the ligaments 11b of the elements S_2. Of course, one or the other of the tubes or of the rows of sinuous elements may be omitted or other rows may be added including additional tubes, according to the service to which the unit is to be put.

In certain applications I may wish (as seen in Fig. 11) to initially bond the elements S between elongated parallel strips, such as 41, and these strips in turn may be laid side by side and bonded between the sheets if so desired. This construction is useful wherein the elements S are made of metal that is difficult to furnace braze, such as stainless steel. Under these circumstances strips 41 may be made of a material that is readily brazed, such as ordinary steel, and resistance welded to the ligaments 11 of the strips S. The assembly A_1 thus produced may be in turn furnace brazed between sheets of a material amenable to such processes because the strips 41 are also of a readily brazed material. Under some circumstances brazing material may also be made to flow between any one connected area of the welded joint between ligaments 11 and strips 41.

For use at elevated temperatures or where corrosive fluids pass over the heat exchange elements, it may be desirable to insure that all surfaces subjected to the corrosion-inducive fluids are of a corrosion-resistant material such as stainless steel. As mentioned before, stainless steel is not amenable to ordinary furnace brazing processes, but in the form shown in Fig. 12 I am enabled to produce a corrosion-resistant unit wherein only the areas subjected to the corrosive agents are of stainless steel, the remainder of the unit being of ordinary steel. This is accomplished by forming the sinuous elements S_3 of a corrosion-resistant metal such as stainless steel. In addition, composite strips 51 are formed, each of which consists of a layer of corrosion-resistant metal 52 and a layer of metal 53 that is readily brazed. Layers 52 and 53 may be joined by a known cladding process or by any other joining process. The sheets or fluid separating members 54 may be formed of a readily brazed metal. The elements S_3 are first welded, preferably by the resistance process, between the strips 51, the strips being turned so that the corrosion-resistant layers 52 are welded to the ligaments 11.

The assembled strip-like units may then be laid side by side between the units 54 and permanently bonded thereto by ordinary furnace brazing processes. The brazing material firmly joins the parts, including the joints between the edges of strips 51. Thus, it can be seen that all surfaces subject to the corrosive action of fluids passing about the heat exchange element are of corrosion-resistant material, but nevertheless final assembly and bonding is accomplished by a high-speed furnace brazing process.

A modified form of sinuous element S_4 is shown in Fig. 13. This is produced by bending the legs 10 relative to the ligaments 11 oppositely from that disclosed in Figs. 1 to 6. This brings the partial ends 14 of the legs 10 against the end portions of the ligaments. The parts are united by the brazing metal which will flow between the ends 14 of the legs and the associated ligament portions so that the end portions of the ligament portions overlying the ends 14 of the intermediate portions joined thereby become the flattened ends of the resultant legs 10, respectively.

Thus, in the form illustrated in Figures 1 through 5, each sheared end surface of each intermediate portion becomes an end surface of a resultant leg whereas, in the form illustrated in Figure 13, the thin ligament metal overlying and bonded to the sheared end surface of an intermediate portion becomes the end surface of the resultant leg. In either event, the heat can pass to and from each leg through its end.

In the claims, the words "end" or "end surface," when used in referring to the legs are meant to include, and to be generic to, the type of leg shown in Figures 1 through 5 wherein the sheared end surface of the intermediate portion is the end of the resultant leg and to the type shown in Figure 13 wherein the thin overlying portion of the ligament bonded to the sheared end surface of the intermediate portion is the end of the resultant leg, except insofar as the words may be further specifically limited by other modifying wording in the claims.

In either form of the invention, each ligament is connected to the sides of its associated resultant legs, respectively, and the ends of its associated legs are substantially flat and flush with its wide smooth outer face portion which extends between its associated legs, so that there is formed a smooth continuous surface, extending from the radially outermost limits of its associated legs across the ends thereof and the space therebetween.

The end portions of each resultant leg, beginning at the flat ends and extending a substantial distance therefrom toward the axial mid-portion of the leg, are preferably straight so that

each such end portion is at an abrupt angle to the plane of the surface to which its end face is connected. Such an arrangement provides a pin fin structure in which the heat can flow to or from the wall through the end of the leg.

In Fig. 14 is illustrated a tubular heat exchange device wherein rows of the sinuous elements S extend lengthwise along the tube 51, the ligaments 11 along one edge being brazed to the surface of the tube. Of course, the element may be brazed to either the inner or the outer surfaces and other tubes may be added as shown in Fig. 10.

Figs 15 to 18 show a form which has several advantages, an important one being that a two-row element is produced which reduces the number of pieces that must be handled to build up a structural or heat exchange unit. As seen in Fig. 15, the wire stock is formed with legs 10 and flattened ligaments 11c, but instead of being coplanar and alternately offset as in prior constructions successive ligaments 11a are angularly disposed relative to one another. For example, in the form shown, each ligament is turned 45° from the one preceding it so that the first and fifth ligaments are parallel but offset oppositely, and the first and eighth are parallel and offset into the same plane.

When the wire shown in Fig. 15 is wrapped around the proper mandrel and sized, a square sinuous element S_{4a} is produced wherein parallel rows of columns or legs 10 are joined by angularly-disposed ligaments 11c. If the angular offset between adjacent ligaments in Fig. 15 is 45°, the ligaments on one edge of the sinuous element will all be parallel and angularly offset from those at the other edge by 45°.

The aforesaid angles are not critical, but are determined solely by the angle of twist between ligaments 11c after the first flattening operation. The element S_{4a} is somewhat more flexible than those shown previously and can readily adapt itself to wrapping about a tube or within a tube. Likewise it has a broader base and is more stable when arrayed in rows between plates or strips. Furthermore, the positioning of every element, in effect, results in the positioning of two rows of structural or heat exchange pins instead of one.

Fig. 19 is an enlarged cross-section of the legs or columns 60 in a modified form of strip S_5 wherein the wire stock is preformed into an airfoil section. It will be recognized that the columns or legs will necessarily produce turbulence in the fluid stream and in some applications it may be desirable to facilitate fluid flow past the pins with some reduction in turbulence. This may be accomplished by arranging the sinuous strips formed from airfoil section stock wherein fluid flows across the ligaments, as shown in Fig. 19.

It is also possible to form the legs into an airfoil section during the forming operations that produce the sinuous strips, in which case the assemblies S_6 may be arranged for flow parallel to the ligaments as seen in Fig. 20.

As seen in Fig. 21, where maximum heat transfer is desired the legs 62 of units S_7 may be formed to provide an extended surface as by grooving, threading, or similar operations, performed either on the wire stock or during the operations that form the sinuous elements.

Of course the relative size and proportioning of the elements depends upon the nature and function of the heat exchanger or structural element. For heat exchanger application, for example, typical proportions and sizes may range from pins or legs of .025" diameter, ⅛" long and spaced .060" apart to pins ⅛" in diameter, ¾" long and spaced $\frac{5}{16}$" apart. Obviously, still larger elements may be produced.

Although I have, throughout this specification, made special emphasis on the heat exchange applications of my invention, as mentioned previously I contemplate that my sinuous elements may also be used to produce structural panels, decks, foil sections, and the like of an exceedingly light and strong construction.

I contemplate that the term "metal that is difficult to braze" refers to metals having stable oxides, that is, oxides that have a low dissociation pressure. Chromium and its alloys, for example, fall within this group. Conversely, the expression "readily brazed metal" refers to a metal or alloy having oxides of a high disassociation pressure. Copper, iron, steel, etc. are examples of metals that fall within this group.

Having completed a detailed description of my invention so that others skilled in the art may practice the same, it will be apparent that other forms thereof may be provided without departing from the essence of the invention as defined in the appended claims.

What is claimed is:

1. A pin assembly for the general purposes described and comprising a length of wire of small diameter having ligament portions alternating with intermediate portions along its length, each of said intermediate portions being integrally connected at its ends with the ligament portions, respectively, between which it is disposed, each of said ligament portions being wide and thin relative to the intermediate portions which it connects and defining a pair of generally flattened oppositely disposed faces, each intermediate portion, at its juncture with each ligament portion to which it is connected, having the major portion of its cross section exposed at approximately 90° to, and intersecting, one face of said pair of faces, said one face of said pair of faces being offset inwardly of the wire from one surface thereof, the junctures of said ligament portions with the intermediate portions being readily bendable whereby the assembly may be bent into sinusoidal shape by swinging each intermediate portion clockwise about its juncture with one of its ligament portions and counterclockwise about its juncture with the other of its ligament portions.

2. A pin assembly according to claim 1 characterized in that the said offset face of each ligament is offset from said one surface of the wire inwardly beyond the axis of the wire.

3. A pin assembly according to claim 2 characterized in that, progressively from one end of the assembly to the other end, each ligament portion is offset, circumferentially of the axis of the wire, through a predetermined angle from the one next adjacent to it.

4. An assembly according to claim 3 characterized in that said angle is 180°.

5. An assembly according to claim 3 characterized in that said angle is 45°.

6. An assembly according to claim 1 characterized in that alternate ones of said ligament portions are of the same length as each other and the said ligament portions therebetween are of the same length as each other but are of a different length than said alternate ligament portions.

7. A member for the purposes described and comprising a length of small diameter wire hav-

ing ligament portions alternating with intermediate portions along its length, each of said intermediate portions being integrally connected at its ends with the ligament portions, respectively, between which it is disposed, said ligament portions being wide and thin relative to the intermediate portions of the wire therebetween and defining inner and outer faces, said wire being in corrugated form with the ligament portions defining the crests of the corrugations and the intermediate portions defining the sides of the corrugations, said intermediate portions having sheared end surfaces, respectively, and providing with the ligament portions resultant connected legs each of which legs is straight at its end portions, extends at an abrupt angle to the outer faces of its connecting ligament portions, and has substantially flat ends each of which is substantially flush with the outer face of its associated connected ligament portions.

8. A member according to claim 7 characterized in that each one of each pair of intermediate portions connected by an associated ligament portion is connected to its associated ligament portion at the part of its end boundary which is nearest to the other intermediate portion of the pair.

9. A member according to claim 7 characterized in that each one of each pair of intermediate portions connected by an associated ligament portion is connected to its associated ligament portion at the part of its end boundary which is farthest from the other intermediate portion of the pair, and each ligament portion has end portions juxtaposed in face to face relation against, and brazed to, the ends of its associated intermediate portions and providing the ends of the resultant legs.

10. A member according to claim 7 characterized in that the outer faces of the ligament portions and ends of the resultant legs connected by the ligament portions at one edge of the member are brazed to a metal wall element in face to face relation thereo.

11. A member according to claim 10 characterized in that each one of each pair of intermediate portions connected by an associated ligament portion is connected to its associated ligament portion at the part of its end boundary which is nearest to the other intermediate portion of the pair.

12. An article according to claim 10 characterized in that the flat end of each resultant leg is at substantially 90° to the axis of the resultant leg.

13. An article according to claim 10 characterized in that each one of each pair of intermediate portions connected by an associated ligament portion is connected to its associated ligament portion at the part of its end boundary which is farthest from the other intermediate portion of the pair, and each ligament portion has end portions juxtaposed against, and brazed to, the ends of its associated intermediate portions and providing the ends of the resultant legs.

14. A member according to claim 7, characterized in that the crests are at the edges of the member, and the ligament portions at one edge of the member are arranged in a row which extends endwise of the member and are parallel to each other and each extends so that a line from the axis of one of its legs to the axis of the other of its legs is on a bias transversely of the row at a predetermined angle, and the ligament portions at the other edge of the member are arranged in a row which extends endwise of the member and are parallel to each other and each extends so that a line from the axis of one of its legs to the axis of the other of its legs extends on a bias transversely of the row at a predetermined angle different from said first mentioned angle, and such that the projections of the said lines of said ligament portions on a common surface parallel to the edges of the member are in zig-zag relation with respect to each other.

15. A member according to claim 10 further characterized in that, at the other edge of the member, the outer faces of the ligament portions and the ends of the resultant legs connected by the last mentioned ligament portions are brazed to a metal wall element in face to face relation thereto.

16. A member for the purposes described and comprising a length of small diameter wire having ligament portions alternating with intermediate portions along its length, each of said intermediate portions being integrally connected at its ends with the ligament portions, respectively, between which it is disposd, said ligament portions being wide and thin relative to the intermediate portions of the wire therebetween and defining inner and outer faces, said wire being in corrugated form with the ligament portions defining the crests of the corrugations and the intermediate portions defining the sides of the corrugations, said intermediate portions having sheared end surfaces, respectively, and providing with the ligament portions resultant connected legs each of which legs is straight at its end portions, extends at an abrupt angle to the outer faces of its connecting ligament portions, said sheared end surfaces being flat and substantially flush with, and exposed in their entirety at, the outer face of its associated connected ligament portions and each forming a continuation of the outer face of its associated connected ligament portion.

17. A member according to claim 16 characterized in that the outer faces of the ligament portions and said sheared end surfaces of the resultant legs connected by the ligament portions at one edge of the member are brazed to a metal wall element in face to face relationship thereto.

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