March 11, 1952 H. C. DUGAN 2,588,500

PROCESS FOR MAKING HEAT EXCHANGERS

Filed Aug. 18, 1945 2 SHEETS—SHEET 1

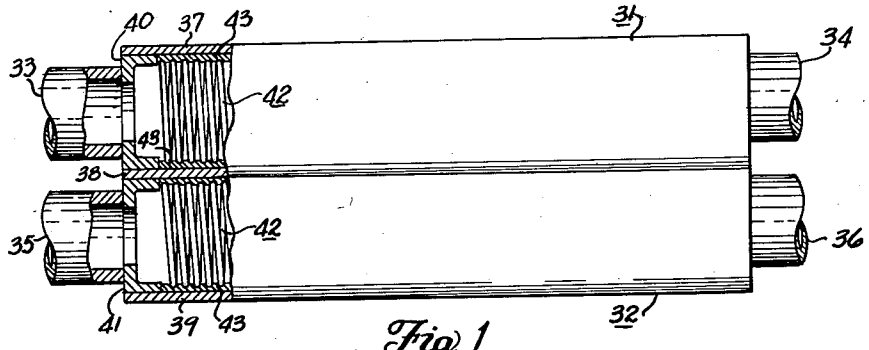



Fig. 1

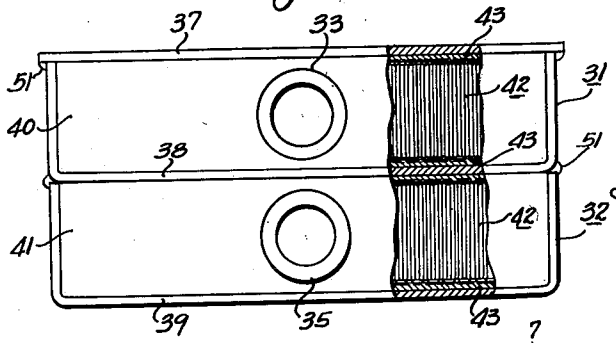



Fig. 2

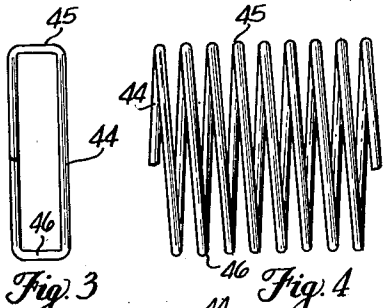



Fig. 3

Fig. 4

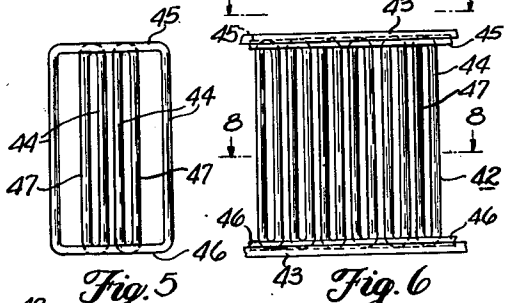



Fig. 5

Fig. 6

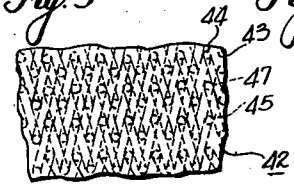



Fig. 7

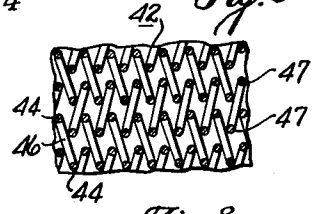



Fig. 8

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March 11, 1952 H. C. DUGAN 2,588,500

PROCESS FOR MAKING HEAT EXCHANGERS

Filed Aug. 18, 1945 2 SHEETS—SHEET 2

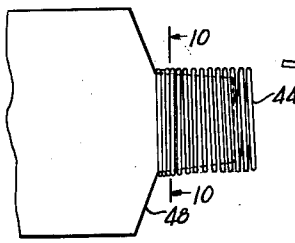



Fig. 9

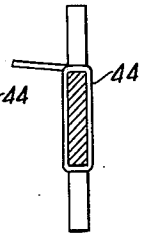



Fig. 10

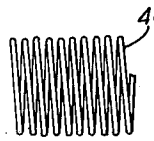



Fig. 11

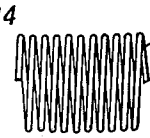



Fig. 12

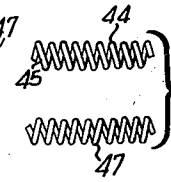



Fig. 13

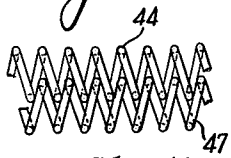



Fig. 14

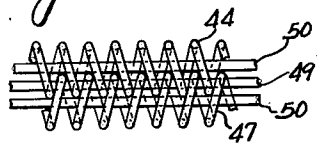



Fig. 15

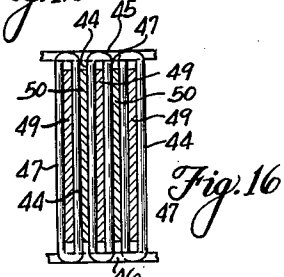



Fig. 16

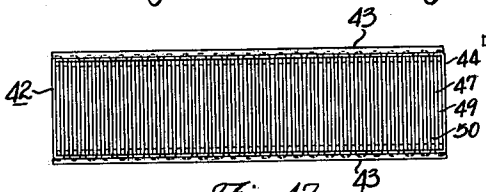



Fig. 17

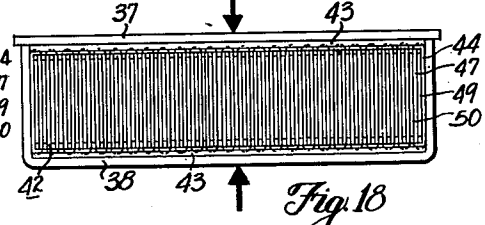



Fig. 18

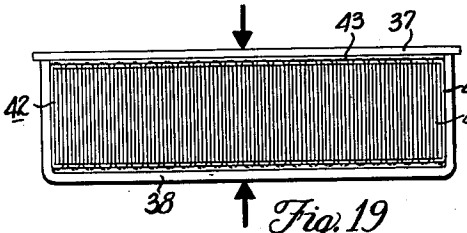



Fig. 19

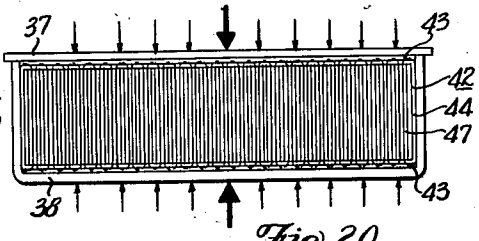



Fig. 20

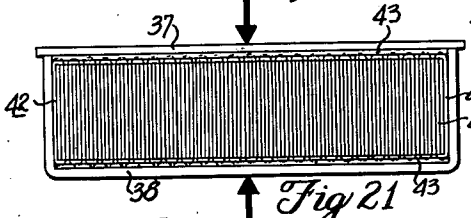



Fig. 21

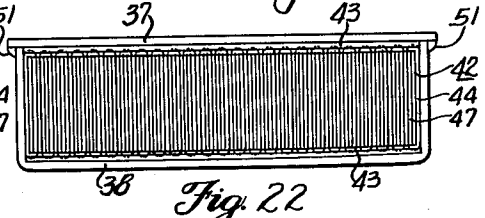



Fig. 22

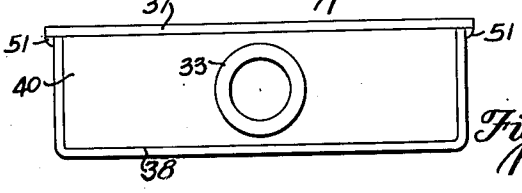



Fig. 23

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Patented Mar. 11, 1952 2,588,500

# UNITED STATES PATENT OFFICE

2,588,500

## PROCESS FOR MAKING HEAT EXCHANGERS

Hugh C. Dugan, Elyria, Ohio

Application August 18, 1945, Serial No. 612,979

7 Claims. (Cl. 29—157.3)

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My invention relates to the method of making heat exchanging devices and of the secondary or fin portion of the device within a fluid chamber thereof.

An object of my invention is to provide an improved method of making a heat exchanger.

Another object is to provide an improved method of constructing the secondary or fin portion of a heat exchanger.

Another object is to provide for a novel and improved process of constructing parts of my new heat exchanger and of assembling the parts to form the complete exchanger.

Another object is the provision of an improvement in the art of making heat exchange devices and of parts thereof.

Other objects and a fuller understanding of my invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a longitudinal side view of a two-chamber heat exchange device embodying my invention, a portion being cut away to show the interior arrangement;

Figure 2 is an end view of the device shown in Figure 1, with a portion cut away to show the interior arrangement of the parts;

Figure 3 is an enlarged end view of one of the rectangular coils used in the practice of my invention, and is an end view of the coils shown in Figure 4;

Figure 4 is a side view in enlarged form of one of the rectangular coils used in the practice of my invention and illustrates a coil with a right-hand turn. The loops of Figure 4 are somewhat pulled apart for better purposes of illustration. The single loop of Figure 3 is then on the left end of the coil in Figure 4;

Figure 5 is another enlarged view of coils used in my invention and shows two coils with right-hand turns enmeshed or nested with an adjacent and intermediate coil having left-hand turns;

Figure 6 is an enlarged view of a portion of the mat composed of a plurality of enmeshed coils bonded together in spaced relationship;

Figure 7 is a view of my improved mat of coils looking in the direction of the arrows 7—7 of Figure 6;

Figure 8 is a cross-sectional view of my improved mat of enmeshed coils taken through the line 8—8 of Figure 6;

Figure 9 is a view showing the winding of a coil on a mandrel;

Figure 10 is an end view of the coil being wound on a mandrel and is taken along the line 10—10 of Figure 9;

Figure 11 is a side view of a coil having a right-hand turn, that is, a right-hand coil;

Figure 12 is a side view of a coil having a left-hand turn, that is, a left-hand coil;

Figure 13 shows a right-hand coil positioned

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above a left-hand coil, with both coils disposed with their horizontal broad flat sides disposed parallel to, and adjacent, each other;

Figure 14 is an enlarged view of the coils shown in Figure 13 and illustrates them as moved together in enmeshed position, the loops of one being partially inserted between the loops of another, respectively;

Figure 15 is a view similar to that of Figure 14 with the addition of showing a locking bar and spacing bars inserted through the loops of the coils;

Figure 16, also an enlarged view, is a transverse section through the enmeshed coils of Figure 15, and shows the enmeshed coils in upright position on their short or narrow flat side, and also shows portions of next adjacent coils to indicate the spacing of the coils;

Figure 17 shows my improved mat or enmeshed coils, looking at the open ends of the coils with the locking bars and spacing bars in place and a bonding material added to the top and bottom of the assembled coils;

Figure 18 shows the improved mat positioned in the fluid chamber of a heat exchange device and illustrates the application of external pressure to the opposite walls of the fluid chamber to press the mat therebetween, and locking and spacing bars being then in the mat;

Figure 19 is similar to that of Figure 18 but with the locking and spacing bars removed;

Figure 20 is a view similar to that of Figure 19 and in addition shows the treatment of the bonding material by heat or otherwise to bond the assembled coils together and to the opposite walls of the chamber, the heat or other treatment being illustrated diagrammatically by the small arrows, the large arrows representing the pressure against the chamber walls;

Figure 21 is a view similar to that of Figure 20 and shows the parts after the termination of the heating or other treatment, the coils and other parts of the device then being cooled;

Figure 22 is a view similar to that of Figure 21 and shows the connection made between the upper and lower walls of the chamber after the cooling and application of pressure has ceased, and the device is ready for final assembly by joining all walls together to enclose the chamber; and

Figure 23 is similar to that of Figure 22 and shows the end wall and pipes thereto assembled to the chamber to enclose the same. The enclosed chamber shown in Figure 23 is similar to one of the enclosed chambers of the heat exchange device shown in Figures 1 and 2.

My invention applies to one-chamber and multiple-chambers heat exchange devices. In Figures 1 and 2 a two-chamber heating device is shown as an embodiment of my invention. The invention is directed particularly to the exchange of heat between the fluid in a chamber and a

metal wall of the chamber. The fluid, of course, may be either liquid or gas. The wall of the chamber through which heat is to be transferred is considered to be the primary heat exchange portion of the device, and the surface of the wall is often referred to as the primary surface. The projections from the wall out into the chamber, variously called fins, pins, rods, and the like, are referred to as the secondary heat exchange portions of the device, and the surfaces thereof are referred to as the secondary surfaces.

In my invention there is a novel and improved construction of the projections or secondary portions in the fluid chamber of the heat exchange device and in the combination of the secondary portion and primary portion of the device. My invention is novel and constitutes an improvement in the construction of heat exchanging devices and the method of making the same.

Referring to Figures 1 and 2, there is shown a heat exchange device having an upper chamber **31** and a lower chamber **32**. The upper chamber **31** has conduits or pipes **33** and **34** opening into the ends thereof and in communication with the interior of the chamber. Similarly, chamber **32** has the conduits **35** and **36** in communication therewith. As shown in the figures, each chamber is enclosed by opposite metal walls, the upper chamber **31** having opposite metal walls **37** and **38** and lower chamber **32** having opposite metal walls **38** and **39**, the wall **38** forming a common heat exchange wall between the two chambers. In the construction shown, the bottom walls are bent upward to also form the side walls of the chambers. The chamber **31** has end walls **40** on opposite ends thereof and the chamber **32** has end walls **41** on opposite ends thereof, the end walls **40** and **41** having flanged portions to provide strength to the assembly. The long flat walls **37**, **38**, and **39** are relatively thin but extend over a considerable area, and being metal tend to bulge or warp under internal pressure unless fortified by internal support. The fluid passing through the chambers may be under considerable pressure and the broad thin walls **37**, **38**, and **39** will buckle or sag without a proper internal construction, as provided by my invention.

There is mounted within the fluid chambers a mat denoted generally by the reference character **42**. The mat **42** is provided for each fluid chamber of the complete device. The mat **42** is bonded to the opposite metal walls of the chambers by the bonding material **43**. The bonding material **43** may be a soft solder of lead and tin, a silver solder, a brazing material for aluminum or for steel, or any other material adapted to provide a good thermal connection and bond between the mat **42** and the walls of the chamber. The bonding material **43** may be a foil added to the parts and heated or otherwise treated in place, or it may be a portion of the wall itself which may be fused to bind the mat **42** in proper thermal and mechanical connection to the wall proper. For purposes of clarity in illustration, the bonding material is shown as a flat layer **43**. However, it is to be understood that the bonding material **43** as solder or similar substance flows around the end portions of the mat **42** which thereby become embedded in the bonding material and the bonding material between the mat **42** and the wall may be very thin so that the mat and wall are substantially adjacent to each other and thermally and mechanically connected.

My improved mat **42** is composed of a plurality



of coils disposed adjacent and parallel to each other. I preferably enmesh adjacent coils together to nest or partially insert the loops of one inside another. I also preferably form the loops in rectangular shape, that is, as coils of rectangular cross-section shape. I preferably form the rectangular coils with long, broad sides opposite each other and short narrow sides opposite each other in the form of a long thin rectangle. To better illustrate the structure and arrangement of parts, the views of Figures 3, 4, 5, 6, 7, and 8 are enlarged. Figure 3 is an end view and Figure 4 is a side view of a part of one of my coils. This coil is formed with a right-hand turn. The loops of the coil in Figure 4 are somewhat pulled apart to better show the individual loops. A single loop, as shown in Figure 3, may be considered as comprising two long pins along the long or broad side of the rectangle and as having short bent-over portions **45** and **46** at the ends of the rectangle, the bent over portions **45** and **46** being integral with the long pins forming the long or broad side of the rectangle.

Besides providing a plurality of coils with a right-hand turn I also provide an equal number of coils with a left-hand turn, the coils of left-hand turn being denoted by the reference character **47**. Coils of right-hand turn and coils of left-hand turn are disposed alternately and with their broad sides adjacent to each other. The several coils are then moved inwardly of each other to enmesh oppositely wound coils together. By this enmeshment the loops of one coil are inserted between the loops, respectively, of an adjacent coil. In this way, each coil is partially disposed within adjacent coils. The individual loops or long broad side portions thereof are spaced apart by the thickness of the wire forming the adjacent coils. In this manner the loops are uniformly spaced from each other longitudinally of the coils, the spacing being determined by the diameter of the wire used in making the coils.

In Figure 5 three coils only are shown for simplicity of illustration. A right-hand turned coil **44** is enmeshed with a left-hand turned coil **47**. On the other side of the coil **47** another right-hand coil **44** is also enmeshed with the coil **47**. It is therefore seen that two coils **44** are partially extended within the coil **47**. It is to be noted that the long broad sides of the enmeshed coils are equally spaced from each other. The long broad sides of the two coils **44** enmeshed within the coil **47** are spaced from each other. The long broad sides of the coils **44** within the coil **47** are equally spaced from the long broad sides of the intermediate coil **47**. As a plurality of alternately wound coils **44** and **47** are progressively enmeshed and spaced equally from each other there is thus formed an assembly of enmeshed coils having these broad sides or pins equally spaced from each other laterally across the assembled mat.

In Figure 6 there is shown a portion of a mat composed of a plurality of coils **44** and **47** having a bonding material **43** applied to the outer surfaces thereof, that is, upon the short narrow sides **45** and **46** of the coils. This bonding material **43** may be of foil, solder or other suitable bonding substance adapted to form a thermal and mechanical bond. Upon heating or other suitable treatment, the bonding material **43** flows around the end portions **45** and **46** and bonds together the coils in assembled and spaced relationship. If desired, the bonding material **43** may be heated or otherwise treated to bond the

coils together to make the complete mat prior to assembly in the walls of the heat exchanger fluid chamber. However, I prefer to heat or otherwise treat the bonding material **43** after the mat **42** is in the fluid chamber so as to bond the coils together and to the walls of the fluid chamber in one operation.

Figure 7, being a plan view looking down in the direction of the arrows **7—7** of Figure 6 illustrates the spaced relationship of the coils. Figure 8 being a view in Figure 6 in the direction of the arrows **8—8**, likewise illustrates the spaced relationship of the parts. It is seen from these several views that the coils may be considered as forming a plurality of pins and rods extending at right angles to the wall of the fluid chamber. These longitudinal pins or rods may be considered as having bent over portions, such as portions **45** and **46** in Figure 3, which are disposed parallel to, and adjacent to, the wall of the fluid chamber. This bent over portion provides for improved thermal connection and heat exchange between the pins or rods and the chamber wall. Moreover, the pins or rods are interconnected by the short bent over portions so that there is a quick and ready exchange of heat therebetween and added uniformity of heat exchange throughout the chamber. The bonding material **43** embeds the short end portions of the loop and thermally and mechanically joins them together to keep the long broad sides of the loops or pins uniformly spaced apart, in thermal and mechanical connection with each other and in thermal and mechanical connection with the wall of the chamber through which heat is to be exchanged.

By reason of the relative fineness of the wire forming the coils and the small sub-divided space formed between them by the described spacing, there is provided a rapid and efficient heat exchange between the fluid in the chamber and the broad or long side portions of the coils extending in the fluid path. The numerous number of broad side portions or pins in a given area provides a large amount of secondary heat exchange surface for exchange of heat between the coils and the fluid. As will be readily recognized by one knowing the needs and requirements of an efficient heat exchanger, the present invention provides means for quick, ready and uniform exchange of heat between a fluid chamber wall and the fluid within the chamber.

The construction of my mat having the rectangular coils enmeshed together provides other advantages all of which will be apparent from inspection of the construction thereof. For example, the straight disposition of the long broad sides of the coils between opposite walls of the fluid chamber provides for adding strength and rigidity to the fluid chamber. The straight-sided coils have considerable strength and rigidity upon compression and can stand considerable stress upon application of external pressure to the opposite walls of the fluid chamber. Also, the coils being mechanically as well as thermally bonded to the opposite walls of the chamber tie or connect the opposite walls together at a plurality of uniformly spaced points all over the expanse of the opposite wall. Upon introduction of fluid under pressure within the chamber tending to expand and buckle the opposite wall thereof, the rectangular coils hold the opposite walls together and prevent the chamber walls from buckling. My improved mat therefore not only adds to the heat exchange properties of my heat exchanger but also adds to its mechanical



strength, durability and serviceability. Many other improved results are readily apparent from the showing and description of a device embodying my invention.

In Figures 9 to 23, inclusive, there are shown the steps taken in making my improved heat exchange device, particularly the making of my improved mat for a heat exchange device. In Figure 9 a coil **44** is formed by coiling wire around a revolving mandrel **48**. This wire may be made of copper, stainless steel, brass, iron, aluminum, "Monel" metal, or other material having good heat conducting qualities, the desired physical strength and the desired workability for forming coils in the desired shape. As shown in Figure 10, the mandrel about which the wire is wound to form a coil is of the general shape of the coil to be formed, in this case of long rectangular shape. As seen in Figure 9, the mandrel is formed with sloping surfaces to facilitate the ready removal of the coil from the mandrel as the winding of the coil progresses.

After coils are formed with a right-hand turn as shown in Figure 11, then a similar number of coils are formed with a left-hand turn as shown in Figure 12. The right-hand coils **44** and left-hand coils **47** are of equal size and similar shape. The coils are alternately stacked to have oppositely wound coils adjacent to each other. It is found preferable to nest the coils together by laying one coil, such as coil **47** in Figure 13, flat on its broad side. Another coil of opposite turn, such as coil **44** in Figure 13, is placed over it with the broad sides of the coils adjacent to each other.

Adjacent coils **44** and **47** are then pressed together as shown in Figure 14 to insert loops of one between the loops of the other, respectively. The loops of each are thereby spaced apart by the loops of the other. As seen in Figure 14, the loops are enmeshed with each other so that one coil is partially inserted within the other coil. Although Figure 14 shows only two coils enmeshed, it is to be understood that successive alternately wound coils are progressively added to the assembly and progressively enmeshed with the coils forming the mat.

In order to hold the assembled and enmeshed coils together for handling and mounting in the heat exchange device, a locking bar **49** is slid longitudinally of the coils to lock the enmeshed coils in position, as shown in Figure 15. This locking bar **49** is preferably a long thin steel member of such thickness as is desired to hold the adjacent enmeshed coils in required spaced relationship. To space the progressively added coils from the coils already enmeshed in a particular coil, spacing bars **50** are also slid longitudinally through the center of each coil. The spacing bars **50** are of equal thickness and are also similar in thickness to the locking bar **49**.

Figure 16, being a transverse view of the enmeshed coils positioned vertically, better illustrates and demonstrates the purpose and utility of the locking and spacing bars **49** and **50**, respectively. As seen, bars **49** hold the enmeshed coils **44** and **47** in locked position and yet spaced from each other by the thickness of the locking bar **49**. Also, the spacing bars **50**, of equal thickness, prevent the next adjacent coil extended into a coil from moving too far inwardly. As the bars **49** and **50** are of equal thickness the long broad sides of the enmeshed coil are positioned equidistantly from each other. This equal spacing provides for a uniform and regular ar-

rangement of the interstices in my improved mat through which the fluid may freely flow and come in contact with all surfaces of the coils in my mat.

As shown in Figure 17, there is next applied to the assembled mat of enmeshed coils a bonding material **43**. This bonding material may be added or applied to the sides of the mat prior to or after assembly of the mat with the fluid chamber. In the illustration of Figure 17, the bonding material **43** is placed on the mat **42** as a foil or sheet of soldering substance.

The mat **42** is then placed between walls **38** and **37** of a fluid chamber as shown in Figure 18. The wall **37** is movable with respect to the remainder of the chamber so that the mat **42** may be placed down in the tray formed by the bottom wall **37**. In speaking of the assembly of the device, the walls **38** and **37** are referred to as being movable toward and away from each other in assembling or dis-assembling the device. If the soldering material **43** has not previously been applied to the mat **42** it is now applied on the top and bottom portion between the coils and the two opposite metal walls. Also, the bonding material **43** may be integral with the walls **38** and **37** and not separately applied. In such case the bonding material **43** may nevertheless be considered as a layer of material at the junction of the mat **42** with the walls **38** and **37**. When the walls **38** and **37** are of suitable material then the walls may be brazed or otherwise bonded directly to the mat **42**. The material on the inner surface of the walls **38** and **37**, although integral with the walls, may appropriately be considered as bonding material for thermally and mechanically bonding the opposite walls **38** and **37** to the coils and bonding the coils together at the walls.

At this point external pressure is applied to the walls **38** and **37** to press the walls toward each other and against the mat **42** to provide firm engagement between the mat **42** and the wall. This external pressure may be provided by a ram, press, or other suitable means applied uniformly over the outside area of the walls **38** and **37**, respectively. This uniform pressure is indicated diagrammatically by the large arrows opposing the walls **38** and **37** in Figures 18, 19, 20, and 21. The external pressure is sufficient to hold the walls **38** and **37** in parallel relationship and to press them in firm engagement with the mat **42** therebetween.

While the external pressure is being maintained as in Figure 19 all of the locking bars **49** and spacing bars **50** are withdrawn by sliding them longitudinally out of the coils through the open end of the chamber. The walls of the chamber held in firm engagement with the mat **42** maintain the coils in their straight relationship. Also, while the opposite walls of the chamber are under external pressure so as to hold the coils in position and the opposite walls in fixed relationship, the bonding material **43** is heated or otherwise treated to fuse it and to cause the bonding material to bond the coils together at the walls **38** and **37** and to bond the coils to the walls **38** and **37**. The several small arrows in Figure 20, as distinguished from the large pressure indicating arrows, are for the illustration of the application of heat or other treatment to the assembled parts.

The external pressure on the walls **38** and **37** is preferably maintained until after the bonding material has cooled and a proper bond, thermal and mechanical, is established between the mat **42** and the said opposite walls. After solidification and cooling, or completion of other bonding, the external pressure on the walls **38** and **37** is removed. As the walls **38** and **37** are now firmly held together by the long flat sides of the coils extending between the walls, the walls will not buckle or warp under any internal pressure that may be applied. The top and bottom walls may next be connected and hermetically sealed by brazing or welding as at the fillets **51** shown in Figure 22. This joining of the opposite walls at **51** may be done while the assembly is under the external pressure shown in Figure 21 or it may be done after the external pressure is removed.

The enclosure in the fluid chamber is next completed by adding the opposite end walls **40** as shown at one end, for example, in Figure 23. The enclosed and assembled fluid chamber is then substantially similar to the upper chamber **31** in the device as shown in Figures 1 and 2. The process is substantially the same for making multiple unit devices in which one chamber is progressively added on top of other chambers as in Figures 1 and 2. When more than one chamber is being constructed the mat **42** may be placed in the plurality of trays formed by the bottom wall of the chambers, the chambers stacked together, the pressure applied to all of them simultaneously, and the heating or other treatment applied to all of them at once.

This method of forming my improved heat exchanger device and particularly the mat for the fluid chamber thereof is simple and economical in manufacture and provides a simple and effective way of making devices embodying my improved construction.

Although I have described my invention in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of the method and the combination and arrangement of process steps may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. The process of making a heat exchanger comprising the steps of: providing two fluid chamber walls, at least one of which is a heat transfer wall; forming a plurality of metal coils each having a flattened side; assembling said coils in side by side and inter-engaged relationship; positioning in a plane the flattened side of the respective loops of each coil between and in contact with the flattened side of respective loops of adjacent interengaged coils to provide a contiguous series of said flattened loop sides in said plane; placing the said assembly of coils between said walls with said series of flattened sides adjacent said heat exchange wall; pressing said walls together against said coils to make thermal connection between said coils and said heat exchange wall; and connecting said walls to enclose said chamber.

2. The process of making a heat exchanger comprising the steps of: providing a fluid chamber wall through which heat is to be exchanged; forming a plurality of rectangular shaped coils of heat conducting material; assembling said coils in side by side and inter-engaged relationship; positioning in a plane a straight side of the respective loops of each coil between and in contact with the straight side of respective loops of adjacent interengaged coils to provide a contiguous series of said straight sides in said plane; placing said as-

sembly of coils adjacent said wall with said series of straight sides adjacent said wall; pressing said wall and coils together to provide good thermal connection between said wall and said coils; and connecting said wall to other chamber walls to enclose said chamber.

3. The process of making a heat exchanger comprising the steps of: providing a fluid chamber wall through which heat is to be exchanged; forming a plurality of coils having a flattened side and having a right-hand turn and a plurality of coils having a flattened side and having a left-hand turn; assembling said coils together with coils of opposite turn disposed adjacent to each other and with said flattened sides disposed in a flat plane; enmeshing the loops of adjacent coils to position adjacent coils partially within each other and to position the flattened sides of adjacent coils in sequential engagement in said plane; placing the flattened sides of said enmeshed coils adjacent said wall; pressing said enmeshed coils and said wall together; bonding the flattened sides of said enmeshed coils to said wall while the coils and wall are pressed toward each other; and connecting said wall to other walls of the chamber to enclose the coils in said chamber.

4. The process of making a mat for the fluid chamber of a heat exchanger, comprising the steps of: winding heat conducting wire to form a plurality of coils having right-hand turns and a plurality of coils having left-hand turns, said oppositely turned coils being formed with relatively long straight sides disposed parallel to each other and joined at the ends by relatively short sides, placing oppositely turned coils adjacent to each other; enmeshing adjacent coils to extend the loops of each coil between loops of adjacent coils and partially within said adjacent coils; aligning the long straight sides of adjacent coils in parallel relationship; spacing the long straight sides of enmeshed loops of adjacent coils from each other and from the long straight sides of the enmeshed loops of other adjacent coils extended within said adjacent coils substantially equi-distant; and metallically bonding said enmeshed coils together on a side of the assembled coils in the plane of said short sides.

5. The process of making a mat for the fluid chamber of a heat exchanger, comprising the steps of: forming a plurality of wire coils having loops of rectangular shape having right-hand turns and a plurality of coils having loops of similar rectangular shape and having left-hand turns; placing oppositely turned coils adjacent to each other; positioning a first pair of opposite loop sides of adjacent rectangular coils parallel to each other; positioning a second pair of opposite loop sides of adjacent rectangular coils in flat planes between which the respective first pairs of loop sides extend; inserting the loops of each coil between the loops of adjacent coils, respectively, to space the said first pair of opposite loop sides of said adjacent coils apart by said inserted loops; spacing the inserted loop sides of each said coil from the inserted loop sides of said adjacent coils substantially equidistant from the inserted loop sides of other coils in said adjacent coils; interengaging the second pair of opposite loop sides in said flat planes to form a contiguous series of said interengaged loop sides in said flat planes; applying metallic bonding material to a side of the assembled coils in one of said flat planes; and treating said bonding material to bond said coils together in said spaced relationship.

6. The process of making a mat for the fluid chamber of a heat exchanger, comprising the steps of: forming a plurality of coils of heat conducting material, half of said coils being formed with a right-hand turn and half of said coils being formed with a left-hand turn, said coils being formed in rectangular cross-sectional shape with two short sides and two long sides; placing oppositely turned coils together with their long sides, respectively, adjacent to each other; moving said coils together to insert loops of each coil between loops, respectively, of an adjacent coil and to position each coil partially within an adjacent coil; positioning the long sides of each coil parallel to the long sides of each adjacent coil and parallel to the long sides of another coil partially within said adjacent coil; spacing the long side of said each coil from a long side of said adjacent coil and from the long side of said another coil partially within said adjacent coil a substantially equal distance; aligning the short sides of adjacent coils in flat parallel planes on opposite sides of the assembly of coils to interengage said adjacent coils in heat-exchange contact at said flat planes; and bonding said coils together along a short side of said coils at a said flat plane with a bonding metal to secure the coils in said spaced relationship and to thermally bond the adjacent coils together along said short side at said flat plane.

7. The process of making a heat exchanger having oppositely disposed fluid chamber walls disposed in parallel flat planes comprising the steps of: forming a plurality of wire coils having right-hand turns and wire coils having left-hand turns, said coils being being formed with opposite straight sides disposed parallel to each other; enmeshing oppositely turned coils together; positioning said opposite straight sides of enmeshed coils in parallel relationship; locking said enmeshed coils together; spacing said enmeshed coils from each other and within each other; positioning the portions of said coils joining said straight sides in planes parallel to, and next adjacent, the flat planes of said walls; and metallically bonding said enmeshed coils to the surface of said walls.

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## REFERENCES CITED

The following references are of record in the file of this patent:

### UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 83,019 | Baggott | Oct. 16, 1868 |
| 145,907 | Schpakowsky | Dec. 23, 1873 |
| 299,972 | Fontneau | June 10, 1884 |
| 493,721 | Holder | Mar. 21, 1893 |
| 641,992 | Nussbaum | Jan. 23, 1900 |
| 790,979 | Peirce | May 30, 1905 |
| 1,559,180 | Prat | Oct. 27, 1925 |
| 2,154,217 | Savage | Apr. 11, 1939 |
| 2,196,186 | Berg | Apr. 9, 1940 |
| 2,222,721 | Ramaur | Nov. 26, 1940 |
| 2,247,179 | Kritzer | June 24, 1941 |

### FOREIGN PATENTS

| Number | Country | Date |
|---|---|---|
| 330,590 | Great Britain | June 12, 1930 |
| 417,668 | Great Britain | Oct. 10, 1934 |
| 425,376 | Great Britain | Mar. 13, 1935 |
| 430,015 | Great Britain | June 6, 1935 |