May 15, 1962 L. H. GRENELL ET AL 3,034,204

HEAT EXCHANGER

Original Filed July 21, 1950 4 Sheets-Sheet 1

*Fig. 1*

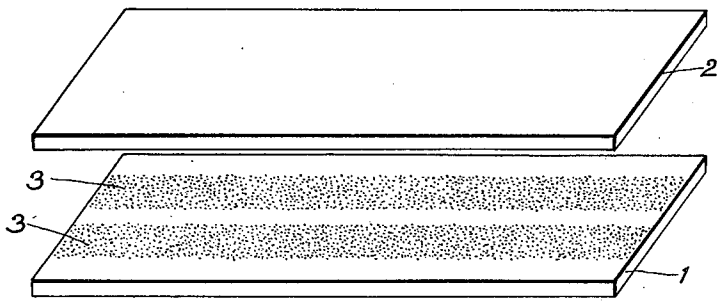



*Fig. 2*

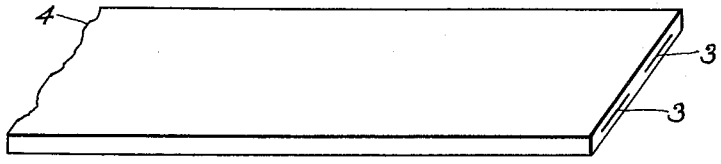



*Fig. 3*

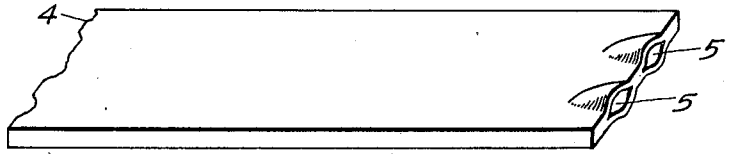
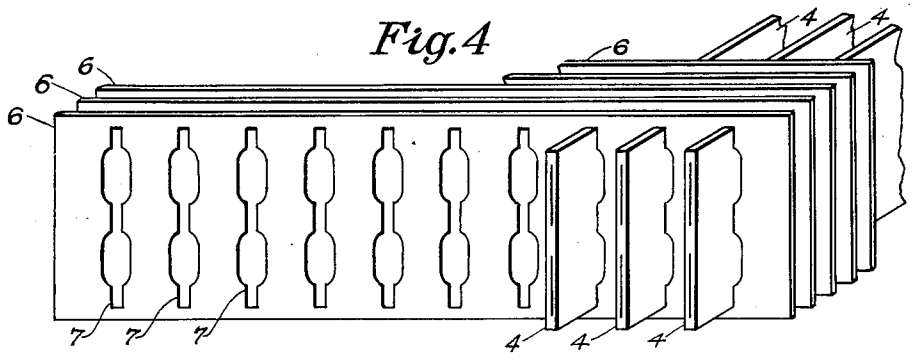



*Fig. 4*




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Fig. 5

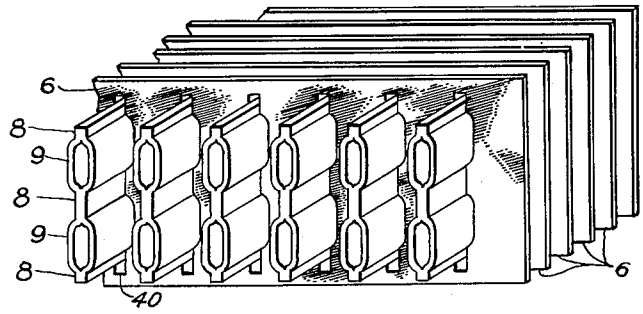



Fig. 6

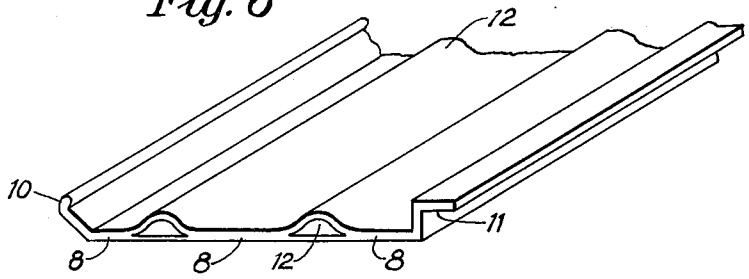
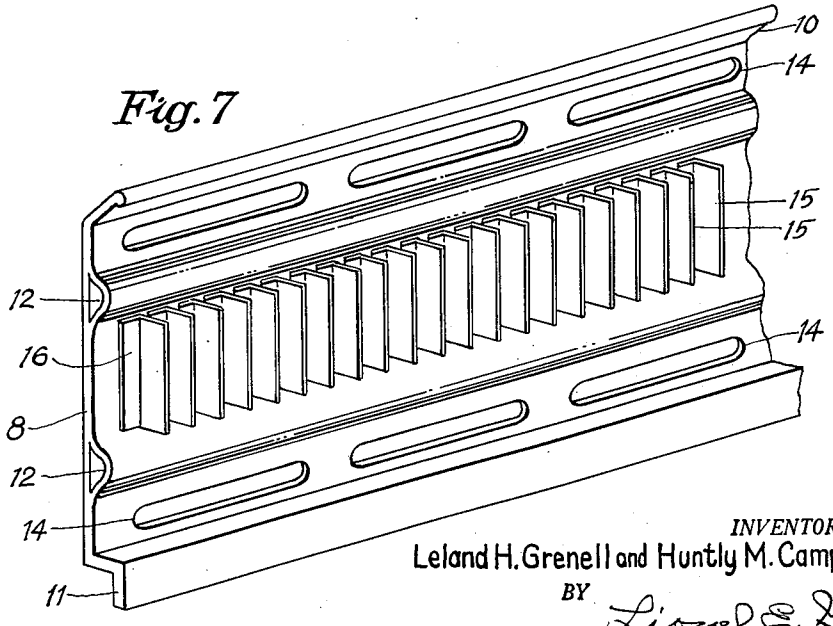



Fig. 7




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*Fig. 8*

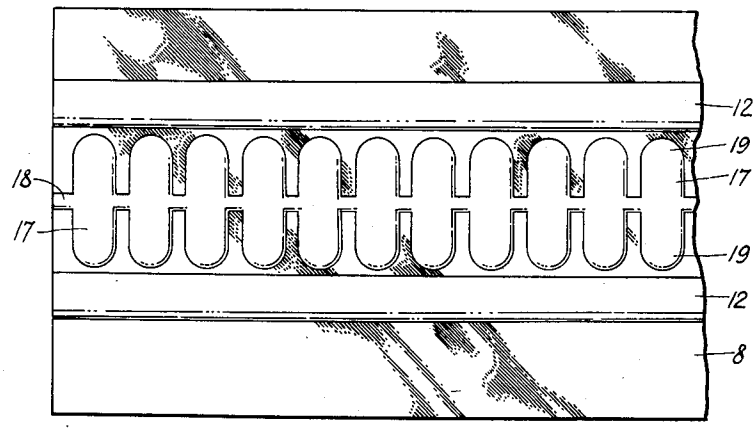
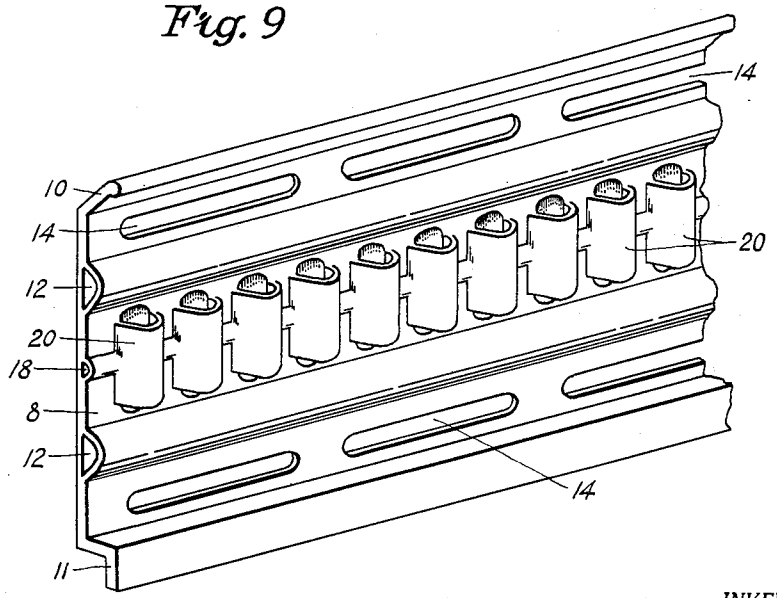



*Fig. 9*




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*Fig. 10*

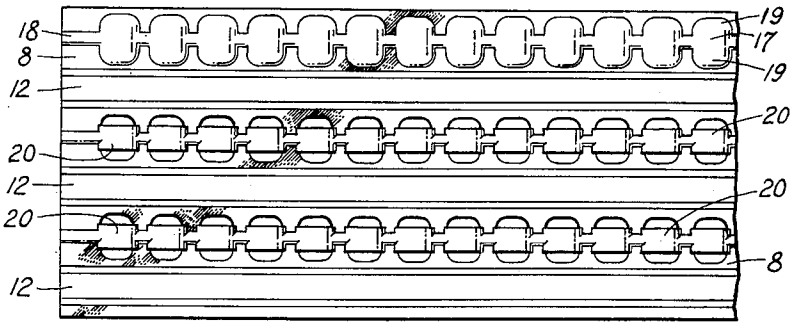



*Fig. 11*

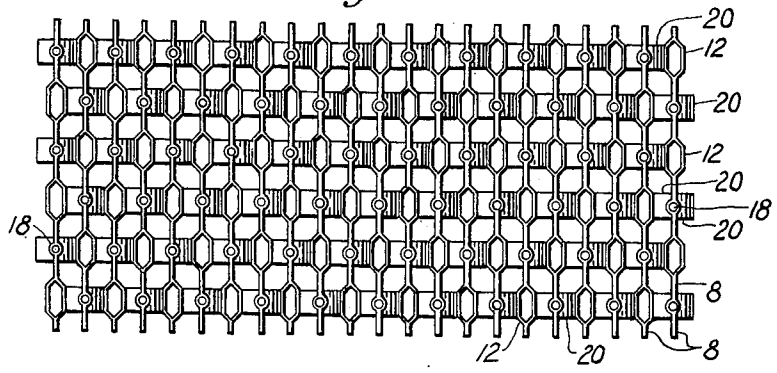
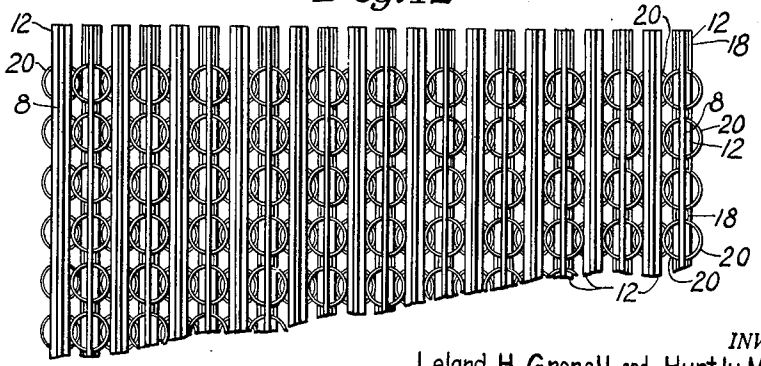



*Fig. 12*




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United States Patent Office 3,034,204 Patented May 15, 1962



3,034,204

# HEAT EXCHANGER

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Application Dec. 2, 1955, Ser. No. 552,982, which is a division of application Ser. No. 175,226, July 21, 1950, now Patent No. 2,759,247, dated Aug. 21, 1956. Divided and this application Mar. 20, 1956, Ser. No. 575,921

12 Claims. (Cl. 29—157.3)

This invention relates to heat exchangers and in particular to a method for manufacturing heat exchange cores and the like of sheet metal. This is a division of co-pending application Serial No. 552,982 filed December 2, 1955, now abandoned, which in turn is a division of co-pending application Serial No. 175,226 filed July 21, 1950, now Patent No. 2,759,247.

Tubular type radiator cores for use with internal combustion engines such as those used in motor vehicles and airplanes and radiant heaters for home use have heretofore been manufactured by various methods of assembling the tubes with fins, and soldering the assembly. For example, one method for manufacturing automotive radiators involves forming openings in the fins, holding the fins in proper spaced relation, and pushing the individual tubes through the openings in the fins. Such a method requires that the fin and tube stock be relatively thick in order to have the necessary strength for the assembling operation. Some such cores contain as many as between one hundred and two hundred tubes and more, each of which must be inserted individually by hand. The tubes are coated with solder and the assembly core is heated to solder the tubes and fins together to improve the strength and heat transfer. Sometimes the solder connection is faulty and the efficiency of such cores is low due to the poor metal to metal contact. Methods have been suggested for improving the metal to metal contact between the tubes and the fins, such as filling the tubes with water and freezing in order to expand the tube within the opening in the fin, or filling the tubes with a liquid and heating to effect such expansion. These methods of construction and assembly are fraught with various disadvantages among which are, for instance, high cost of manufacture due to the number and kind of processing steps required and wastage of tubes, fins, and partly assembled cores, even with skilled operators.

It is therefore an object of this invention to provide an improved method for the economical manufacture of heat exchange cores. Another object is to provide a method of manufacturing and assembling heat exchange cores in which a substantial saving in time of assembly is effected over prior practice. Another object is to provide a method of manufacture facilitating assembly of tubes and fins in heat exhanger cores. Still another object is to provide a method of manufacturing heat exchange cores adapted to be carried out mechanically instead of manually. A still further object of the invention is to provide a simple economical method for manufacturing heat exchange cores, which cores are of improved design having fins both perpendicular and parallel to the tubes therein. A further object is the provision of heat exchangers suitable for both radiant and convection heating.

The foregoing objects and advantages, as well as others which may become apparent from the detailed description hereinafter, are accomplished in accordance with this invention by providing fins on the surface of a metal sheet having internal tubular passageways. The finned sheet is made by providing fins on a tube sheet formed by sandwiching a pattern of non-bonding or separation material between two sheets of metal, forming a single



layer of metal between the areas covered by the separation material by pressure welding, and applying a fluid pressure on the inner surfaces held apart by the separation material to form cavities within the sheet in accordance with the pattern. Any desired processing may be employed intermediate the aforenamed steps provided such processing does not interfere with the functioning of said steps. The diameter, length and positioning of the tubes or cavities formed within the sheet by the fluid pressure and the resulting bulges or ribs on the surface depend mainly upon the pattern dimensions and designs in which the separation material is originally applied. No undesirable voids exist between adjacent tubular passageways since the metal of the sheets intermediate the passageways are forged or pressure welded into one layer of metal forming a web between the passageways of substantially uniform composition, or if the sheet has only one passageway the web extends on either side of the passageway. The web being substantially thicker than the tube walls provides a sturdy support for the fins thereon and likewise is a good conductor for transfering heat from the tubes to the fins. In prior methods only the thin tube walls were available for supporting the fins, thus requiring thicker walled tubes or leading to frail structures.

In accordance with the present invention, the fins are supported by the web but, if desired, they may also be supported by the tube walls. For example, if the fins are to encompass the tube walls on one or both sides of the sheet, it is preferred to first assemble the fins and tube sheets, then to expand the tubes by fluid pressure so as to provide good metal to metal contact between the tube wall and fin, and finally to weld the assembly. If the fins encompass the tube walls on both sides of the sheet, it is preferred to provide the fins with openings suitably contoured for the edges thereof to contact the web with an enlargement of the openings in the tube areas, then to place them in the desired spaced relation, to coat the sheets containing the separation material with tin or other solder or suitable welding material, then to insert the sheets through the openings in the fins and then to expand the sheets until the resulting tube walls firmly contact the edges of the openings in the fins. Welding or soldering of the assembly is then relatively simple since the edges of the openings in the fins are in firm contact with the sheet surface and the operation can be accomplished merely by heating the entire assembly to the soldering or welding temperature. Each sheet may be so designed as to provide a plurality of tubes, so that the handling of individual tubes is not necessary. The process of forming the expanded sheet is set forth and claimed in copending application of Leland H. Grenell, Serial No. 128,116, filed November 18, 1949, now Patent No. 2,690,002 issued September 28, 1954. If the fins do not encompass the tube walls but are merely supported by the web between the tubes in said sheet, then the fins may be provided on the web either before or after the tubes have been expanded. For instance, the fins may be attached to the web by welding, or the like, or may be formed of the web itself. In the latter instance a pattern of separation material other than that utilized in forming the tubes may be applied and the web expanded by fluid pressure to form bulges thereon which upon being suitably opened may serve as fins between the tubes.

Having described in the foregoing in a general way the nature and substance of this invention, there follows a more detailed description of preferred embodiments thereof with reference to the accompanying drawing in which:

FIGURE 1 is a perspective view illustrating two sheets of metal, one of which is coated with a pattern of separation material,

FIGURE 2 is a perspective view illustrating the tube

sheet formed when the sheets of metal of FIGURE 1 have been brought together and hot rolled,

FIGURE 3 is a perspective view illustrating the tube sheet of FIGURE 2 after the edge has been opened up in the separation material areas,

FIGURE 4 is a perspective fragmentary view illustrating a partial assembly of fins and tube sheets,

FIGURE 5 is a perspective fragmentary view of a heat exchange core illustrating the assembly after the tube sheets have been expanded,

FIGURE 6 is a perspective fragmentary view of an expanded tube sheet illustrating another embodiment of this invention,

FIGURE 7 is a perspective fragmentary view of a heat exchange core illustrating the tube sheet of FIGURE 6 provided with fins,

FIGURE 8 is a plan view of a part of an expanded tube sheet illustrating another embodiment of the invention,

FIGURE 9 is a perspective fragmentary view of a heat exchange core illustrating the tube sheet of FIGURE 8 provided with fins,

FIGURE 10 is a plan view of a part of an expanded tube sheet illustrating another embodiment of the invention,

FIGURE 11 is a plan view of a heat exchange core illustrating another embodiment of the invention, and

FIGURE 12 is a vertical fragmentary view of the heat exchange core of FIGURE 11.

Referring to FIGURE 1, for the manufacture of heat exchange devices, sheets **1** and **2** of metal, 0.070 inch thick and composed of 92% to 94% copper, 2.05% to 2.60% iron, phosphorus in amount up to 0.025%, lead in amount up to 0.05%, and the balance zinc, are first degreased by emersion in an organic solvent bath, such as naphtha or white glycerine, at room temperature and then wiped free of solvent. The sheets are then cleaned in an acid bath containing, for example, approximately one part by volume of 68% nitric acid, one part by volume of 95% sulphuric acid, and one part by volume of water at room temperature. Such treatment is designed to remove any oxide film on the metal, the clean surface on the sheet being desirable in order to secure good bonding in the subsequent hot rolling operation. The sheets are then rinsed thoroughly in cold water and subsequently in hot water and air dried at room temperature.

A separation or weld-preventing material **3**, consisting of a mixture of graphite in water glass, is then applied in a thin layer in spaced strips throughout the length of sheet **1**, the number of strips applied corresponding to the number of tubes desired in the finish sheet. Such separation material may be sprayed through a masking die, painted through a stencil, squeezed through a silk screen, or applied in any suitable manner. For instance, if the separation material **3** is to be applied through a silk screen to the selected area, graphite in the ratio of about three to four kilograms to three liters of water glass solution is satisfactory. A thinner more fluid mixture is, of course, used if the separation material is to be applied by painting or spraying on the selected areas.

The elongation of the metal during subsequent rolling must be allowed for in the shape and dimension of the pattern of separation material originally applied to the sheet. For instance, the strip and pattern is lengthened in the direction of rolling in substantially inverse proportion to the change in thickness of assembly. Pattern lines that run perpendicular to the direction of rolling for instance to form headers are, therefore, increased in width in substantially inverse proportion to the change in thickness of the assembly. Tube pattern lines such as **3** that run in the direction of rolling are not changed appreciably in width. Thus, if one wishes a conduit or header running perpendicular to the direction of rolling one inch in diameter and the assembly thickness during the rolling operation is reduced to one-half the original thickness, then the pattern lines running perpendicular to the direction of rolling must be made only about one-half inch wide. The thickness of the layer of separation material decreases in direct proportion with the decrease in thickness of the assembly during rolling due to the spreading or elongation of the material during the rolling operation. The thickness of the layer of separation material after rolling should be sufficient to prevent bonding of the metal except where such bonding is desired.



After the tube pattern of separation material **3** has been applied to sheet **1**, the sheet **2** is placed on sheet **1** with the separation material **3** between them. If sheet **2** is permitted to move freely in frictional contact with the separation material on sheet **1** prior to the subsequent hot rolling operation, the pattern is likely to be damaged or distorted so that the desired conduit system will not be obtained. The sheets are therefore fastened together to avoid obliteration of the pattern, by any suitable means, such as heli-arc welding the edges, tacking the edges together by spot-welding, or by crimping the edges, or the like.

The assembly is then placed in a furnace and heated to about 900° C. To prevent oxidation of the inner faces of the sheets **1** and **2**, the edges of the assembly may be completely sealed as by welding or the like, or an inert or reducing atmosphere may be employed in the furnace if desired. The temperature of 900° C. is about 160° C. below the melting point of the alloy and is sufficiently high to effect pressure welding of the two sheets of metal in the hot rolling step to be described hereinafter. The exact temperature to be used for pressure welding is, of course, dependent upon the melting point of the particular metal or alloy utilized and should be relatively close thereto.

Inasmuch as each sheet of metal, **1** and **2**, is 0.070 inch thick and the layer of separation material **3** is only about 0.002 to 0.005 inch thick, the assembly is about 0.14 inch thick. As soon as the assembly has reached a temperature of about 900° C. it is hot rolled in one pass to a thickness of about 0.070 inch and is then cleaned with acid, washed and dried as described in the foregoing treatment of sheets **1** and **2**. It is desirable to hot roll to a reduction of at least 35% in order to insure welding of the sheets, and a reduction of approximately 50% in one pass is preferable as is described in the foregoing. The welded sheet is then cold rolled to a finish gauge of about 0.048 inch thickness, is then annealed at a temperature of 750° C. one half hour to remove the hardening effect of the cold rolling, and is then cleaned by acid, washing, and drying treatments as described hereinbefore. The cold rolling step is carried out in order to accurately control the thinness of the sheet. If sufficient accuracy in gauge for the particular use can be obtained by hot rolling, the entire reduction can be carried out by hot rolling, and the cold rolling and annealing treatments referred to in the foregoing may be omitted. The strength of the sheet formed by the hot rolling step is appreciably greater than that of the cast structure obtained with spot-welding techniques. The cast structure formed by spot-welding contains appreciably larger grains than the sheet prior to such welding, whereas the sheet formed by the hot rolling step has a grain size substantially uniform throughout the sheet. The welded sheet **4**, illustrated in FIGURE 2, is then coated with tin by dipping in a molten bath thereof, and the unbonded edge of the sheet in the areas adjacent the separation material **3** is then pried open mechanically as illustrated at 5, FIGURE 3, to permit a nozzle for applying fluid pressure to be inserted therein.

Referring to FIGURE 4, fins **6** are then formed from sheet metal about 0.003 inch thick of the alloy composition set forth in the foregoing and having suitably shaped openings as illustrated at **7** to permit the insertion of the tube sheets **4**, FIGURE 4, the openings **7** being so shaped as to encompass and contact the subsequently formed tube walls as well as the web of the sheet.

The fins are then placed in suitable spaced relation

as in a comb or other suitable die for holding the edges thereof and the tube sheets **4** are then inserted in the openings **7**, as illustrated in FIGURE 4. The tube sheets **4** may be inserted individually into the openings **7** by hand, or they may likewise be held in suitable spaced relation in a comb or other suitable die, and all inserted simultaneously into the openings **7**. The latter method is preferable from the standpoint of mass production. Nozzles for applying fluid pressure are then inserted in the openings **5** in the tube sheets and pressure is applied until the metal in the unwelded inner portions of the sheet containing the separation material is expanded to provide the tubes, with the walls fitting snugly within the opening **7** in the fin **6** as illustrated in FIGURE 5. With the expanded tube walls **9** tightly engaging the edges of the openings **7** in the fin **6**, the assembly is heated to a temperature sufficient to cause the tin on the expanded tube sheet surface to weld or solder the fins to the tube sheet. The finished heat exchange core, FIGURE 5, then has tubes **9** with fins **6** perpendicular thereto and also fins parallel thereto as represented by the web **8** of the tube sheet. As will be understood in the art the amount of fluid pressure necessary will vary with the gauge, temper and composition of the metal used.

The tube sheet expands when pressure is applied with litle or no thinning of the cavity wall, the expansion being accomplished by a separation or opening up of the metal with a resultant decrease of sheet width, depending on the design and dimension of the cavities. Therefore, in order for the tube walls to engage the fin properly it is desirable to take into account such creeping of the sheet **4** during expansion by designing pear-shaped or ovoid openings **7** in the fin **6**. Such creeping phenomena can be avoided if desired, of course, by suitably holding the edges of the sheet **4** stationary and effecting the expansion by a thinning of the tube wall. The shrinkage in width of sheet **4** during expansion is illustrated in FIGURE 5, as leaving an opening **40** between the edge of expanded tube sheet **4** and fin **6**. Further, if desired, the tube sheets may be expanded prior to assembly with the fins and the opening **7** may then be so designed as to eliminate the openings **40**.

In order to further clarify the invention there follows another embodiment thereof describing the manufacture of a radiant heater for home use in which the heater is designed to be positioned adjacent the base board about the walls of the room. Such a heater may be manufactured, for instance, by sandwiching a pattern **3** between sheets **1** and **2** and pressure welding to form a tube sheet **4** by hot rolling the assembly all substantially as set forth in the foregoing embodiment. The edges of the tube sheet **4** are likewise pried open mechanically as illustrated at **5**, FIGURE 3, to facilitate the application of fluid pressure.

The tube sheet **4** is then placed in a die having one unrecessed face, and one face recessed in accordance with the pattern of the separation material within the sheet, and fluid pressure is then applied through the openings **5**. The resulting tube sheet then has the tubes formed by expansion only on one side of the sheet as illustrated in FIGURE 6 at **12**. A similar result may be obtained by making, for example, sheet **1** many times thicker than sheet **2** so that expansion upon the application of fluid pressure occurs only on one side of the sheet and a die in this instance is not necessary. Likewise, if other than ovoid or substantially round tube walls are desired, any desired contour thereof can be formed by providing the recesses in the die face plate with the desired contour. The web **8** of the expanded tube sheet is then bent at substantially right angles as at **11** on one side thereof, and is bent as at **10** on the other side thereof. Fins **15** are then secured to the tube sheet by spot welding or brazing the right angle portions **16** of the fins **15** to the web **8** intermediate the tubes **12**, as illustrated in FIGURE 7. In order that the fins can be suitably spot-welded to the web, it is desirable that the sheets **1** and **2** and fins **15** be formed of an alloy of relatively high electrical resistance and an alloy of 68.50% to 71.50% copper, 1.00% to1.50% manganese, an amount up to 0.05% of iron, an amount up to 0.07% of lead, with impurities not greater than about 0.10%, and with the balance zinc is preferred for the purpose. This alloy has the advantage that it not only has the necessary electrical resistivity for spot welding techniques but is well suited for the pressure welding or roll bonding operation utilized in forming the tube sheet. Slots or openings as illustrated at **14** in FIGURE 7 are then made in the web **8** between the tubes **12** and sides **10** and **11**. The side **10** of the tube sheet is the top of the radiant heater and the side **11** of the tube sheet is the bottom of the radiant heater when in position with the fins toward the wall of the room. The slots **14** facilitate the passage of air over the tubes and through the fins. The resulting heater although having thin walled tubing is of sturdy efficient design.

In another embodiment, illustrated in FIGURES 8 and 9, a radiant heater having tubes **12**, web **8**, slots **14**, and sides **10** and **11** formed similar to the embodiment of FIGURE 7 is provided with fins utilizing the metal of the web. In order that this may be accomplished, a tube pattern of separation material **3** is sandwiched between sheets **1** and **2** to form the tubes as in the foregoing embodiment but there is also applied in the same manner a fin pattern of separation material between the strips **3** and spaced therefrom of a design such that after pressure welding and upon expansion the bulges **17** are formed on the web **8** between the tubes **12**. The duct **18** is opened after the pressure welding step at the edge of the sheet as at **5**, FIGURE 3, and serves as the means for applying fluid pressure to form the bulges **17**. The die utilized during the expansion to confine the expansion to only one surface of the sheet, as in the foregoing embodiment, must have its face recessed to accommodate the bulges **17** and duct **18** as well as the tubes **12**. After the bulges **17** have been formed, the ends **19** thereof are cut off to open the bulges and provide the fins **20**. As will be noted, each fin **20** is of a tube-like structure open at each end so that the air may pass therethrough. The fin pattern may, of course, be of any suitable design and may be applied to the sheet of metal in the same manner and at the same time the tube pattern is applied. Inasmuch as the fin and tube patterns do not touch one another, there is no passageway between the tube cavity and the bulges utilized for fins. By forming the fins in this way a much lighter more economical structure is obtained with improved heat transfer due to the fact that the tubes, web, and fins are all one piece of metal. Further this method of manufacture readily lends itself to continuous operation and mass production. In manufacture, the tubes and fin bulges may be simultaneously expanded by proper application of the fluid pressure and the ends **19** of the fin bulges subsequently cut off, or if desired, the fin bulges may be first expanded, the ends **19** thereof then cut off, for example with any suitable milling machine, and the tubes finally expanded. Further, the bulges **17** may be opened by splitting lengthwise, or by other deformation, to form fin-like projections on the web.

In another embodiment for forming heat exchange cores for automobiles and the like, as illustrated in FIGURES 10, 11, and 12, alternate fin and tube patterns are sandwiched between two sheets of metal, the assembly is pressure welded by hot rolling to a reduction in thickness thereof of at least 35% as set forth in the foregoing embodiments, the fin and tube patterns are opened at the edge of the sheet as illustrated for strips **3** as at **5** in FIGURE 3, fluid pressure is applied to expand within a die having suitably recessed face plates those areas of the sheet containing the separation material, and the ends **19** of the fin bulges are cut off, all substantially as described in the foregoing embodiments. In FIGURE 10 the top row of fin bulges are illustrated prior to the operation of cutting off the ends **19**, while in the lower two rows of bulges the ends **19** have been removed to provide

the fins 20. Upon removal of the ends 19 from the top row of fin bulges 17 the resulting expanded tube sheet then has alternate rows of tubes 12 and fins 20. In this embodiment both sides of the sheet are permitted to expand so that the tubes 12 and fins 20 appear as bulges on both sides of the sheet, as illustrated in FIGURE 11 which shows an end view of a plurality of such sheets assembled face to face as a heat exchange core. Such a core may be utilized in the cooling system of an internal combustion engine, or the like. Prior to such assembly, the tube sheets are coated with tin either before or after expansion. The sheets are then assembled in such fashion that each tube in each sheet contacts a row of fins on the adjacent sheets as illustrated in FIGURE 11, which is a top or plan view of the heat exchange core, and FIGURE 12, which is a front or vertical view of the core of FIGURE 11.

The faces of the die in which the tube sheets are expanded are provided with recesses so contoured as to provide tubes of hexagonal outline, FIGURE 11, and fins of circular outline, FIGURE 12. The tubes 12 thus present flat sides against which the fins 20 of the adjacent sheet abut. The assembly is then heated to weld or solder the adjacent sheets together to form the finished heat exchange core. Both the fins and tubes may have a different contour or design it only being necessary that the adjacent sheets can be suitably welded together. The walls of the tubes and the fins are only about half the thickness of the web 8 thus contributing to the economy of the structure and facilitating heat transfer. With such a construction a substantial portion of the total weight of the metal is utilized as radiating surface.

While in the foregoing specific rolling, annealing, and cleaning sequences are described for forming the tube sheets, it will be understood that various rolling, annealing and cleaning techniques, trimming, tacking the sheets together, shaping and other such operations may be employed in accordance with this invention between the step of applying the separation material and the step of applying the fluid pressure, depending upon the prevailing practice and the physical characteristics desired in the finished product. For instance, the hot and cold rolling may be carried out in a number of steps depending upon the economics of the situation and available rolling equipment, or the cold rolling or annealing, or both, may be omitted entirely. Whereas, the pressure weld is accomplished by hot rolling the assembly in accordance with the preferred practice set forth herein, it is to be understood that some metal sheeting may be suitably pressure welded merely by applying sufficient pressure at room temperature and that such pressure welding technique may be utilized in accordance with this invention. Regardless, however, of the intermediate processing used, it is necessary that the metal of the sheets be suitably joined to form one substantially uniform layer at all superposed points not held apart by the separation material prior to application of the fluid pressure.

The process is well suited for continuous operation. For example, the patterns of the separation material may be applied successively to the surface of a strip of metal being unwound from a coil, a second strip of metal being unwound from another coil may be superposed on the pattern-coated strip, and the strips then tacked together by spot-welding, edge crimping, or the like and fed continuously through a heating furnace and hot rolling mill. After the rolling and other such processing has been completed, the pressure welded strip containing the separation material is then expanded by applying fluid pressure as described above to the internal metal surfaces coated with separation material and the fins welded thereto or formed by opening the appropriate bulges as described.

Any suitable separation material may be employed, its chief function being to prevent bonding of the coated surfaces during the welding operation. For instance, in addition to the graphite-water glass mixture set forth in the foregoing, other inorganic ingredients and mixtures may be employed such as zinc oxide, kieselguhr or other diatomaceous earths, flint, talc, powdered quartz, clays, and the like and mixtures thereof with each other and with graphite and water glass or the like. The separation material used must, of course, be so compounded as to flow or elongate with the metal and retain uniformly sufficient thickness to prevent bonding where not desired. Likewise, although the embodiment is described in the foregoing with particular reference to certain alloys, the process of this invention is applicable to brass and other copper base alloys and to other metal sheeting, for example, aluminum, magnesium, steel, and the like adapted to be pressure welded. As will be apparent from the foregoing, the process of this invention permits the fabrication of a sheet of metal provided with internal ducts or internal passageways of substantially any desired design or pattern, which cavitied sheet of metal with appropriate conduit pattern is adapted for use as a lower cost, more efficient heat exchange device than is obtainable with prior processes. Relatively thick low cost sheet stock may be employed since the desired cavity wall thinness may be obtained by thinning of the metal in the immediate area upon which the fluid pressure is applied. In prior methods, in which the cavity wall was stamped or drawn, the sheet stock used had to be substantially of the thinness desired in the cavity wall.

The assembly of the tubes and fins can be accomplished mechanically by employing suitable combs or dies as are available in the art and the resulting heat exchanger has the advantage of having fins both parallel and perpendicular to the tubes therein.

The copper-manganese-iron-lead-zinc alloy set forth hereinbefore is particularly well suited for such heat exchangers inasmuch as it is well suited for the pressure welding operation in forming the tube sheet and has sufficient electrical resistance to permit spot welding of the assembly. It is not necessary to handle individual tubes in accordance with the present invention and the heat exchanger provided is strong and sturdy even though very thin sheet stock is utilized. The fins may be formed of the web material or secured thereto by spot welding, or utilizing welding agents such as tin, solder, brazing compounds, or the like, it only being necessary that the fins and sheets be firmly attached. It is to be understood that the embodiment of the present invention as shown and described is only illustrative and that many changes may be made therein without departing from the spirit and scope of the invention as set forth in the following claims.

Having thus described the invention what is claimed and desired to secure by Letters Patent is:

1. In the process of making heat exchangers, the steps which comprise sandwiching a pattern of separation material between two sheets of metal, pressure welding the metal of the sheets into a single layer of metal in those areas not covered by said material by hot rolling the resulting assembly to a reduction in thickness of at least 35%, applying fluid pressure to the internal surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said pattern form bulges on at least one surface of said sheet, forming slots through the single layer of metal between said bulges and the edges of said sheet, bending said edges out of the plane of the sheet to form a support for and define a housing for the portion of the sheet containing said bulges, and welding fins on said single layer of metal between said bulges.

2. In the process of making heat exchangers, the steps which comprise sandwiching a tube pattern of separation material and a separate fin pattern of separation material between two sheets of metal, pressure welding the resulting assembly into a single layer of metal in those

areas not covered by said material, and thereafter applying fluid pressure to the internal surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said tube pattern have been formed therein and bulges substantially in accordance with said fin pattern have been formed thereon and providing fins on said sheet by opening said fin bulges to form fin-like projections.

3. In the process of making heat exchangers, the steps which comprise sandwiching separation material between two sheets of metal in a predetermined configuration defining a tube pattern, a fin pattern and a common conduit pattern interconnecting said tube pattern and said fin pattern for subsequent simultaneous inflation of all said patterns, pressure welding the resulting assembly into a single layer of metal in those areas not covered by said material, applying fluid pressure to the internal surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said tube pattern have been formed therein and bulges substantially in accordance with said fin pattern have been formed thereon, removing the inflated common conduit pattern from the inflated sheet, and providing fins on said sheet by opening said fin bulges to form fin-like projections.

4. In the process of making heat exchangers, the steps which comprise providing a plurality of tube sheets formed by sandwiching a tube pattern of separation material and a separate fin pattern of separation material between two sheets of metal, pressure welding the two sheets into a single layer of metal in those areas not covered by said material, coating the resulting sheet with a solder and applying fluid pressure to the internal surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said tube pattern have been formed therein and bulges substantially in accordance with said fin pattern have been formed thereon, and providing fins on said sheet by opening said fin bulges to form fin-like projections; and thereafter assembling said resulting tube sheets face to face and heating until the assembled tube sheets are soldered together.

5. In the process of making heat exchangers, the steps which comprise providing a plurality of tube sheets formed by sandwiching separation material between two sheets of metal in a predetermined configuration defining a tube pattern, a fin pattern and a common conduit pattern interconnecting said tube pattern and said fin pattern for subsequent simultaneous inflation of all said patterns, pressure welding the two sheets into a single layer of metal in those areas not covered by said material, coating the resulting sheet with a solder and applying fluid pressure to the internal surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said tube pattern have been formed therein and bulges substantially in accordance with said fin pattern have been formed thereon, removing the inflated common conduit pattern from the inflated sheet, and providing fins on said sheet by opening said fin bulges to form fin-like projections: and thereafter assembling said resulting tube sheets face to face and heating until the assembled tube sheets are soldered together.

6. In the process of making heat exchangers of the type suitable as a radiant heater positioned adjacent the baseboard about the walls of a room, the steps which comprise sandwiching a pattern of separation material between two sheets of metal, pressure welding the metal of the sheets into a single layer of metal in those areas not covered by said material by hot rolling the resulting assembly to a reduction in thickness of at least 35%, said pattern being of the configuration desired for flow of heat exchange fluid in said heater but foreshortened in the direction of said rolling, applying fluid pressure to the internal surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said pattern are formed on only one surface of said sheet, bending opposite edges of said sheet at an angle away from the flat surface thereof to form a support for said sheet and define with the wall surface a housing for said passageways, forming slots to permit the passage of air therethrough between said passageways and said edges of the sheet, and welding fins on said single layer of metal between said passageways.

7. In the process of making heat exchangers, the steps which comprise sandwiching a tube pattern of separation material and a separate fin pattern of separation material between two sheets of metal, pressure welding the resulting assembly into a single layer of metal in those areas not covered by said material, and thereafter applying fluid pressure to the internal surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said tube pattern have been formed therein and bulges substantially in accordance with said fin pattern have been formed thereon and providing fins on said sheet by cutting off the ends of said bulges.

8. In the process of making heat exchangers, the steps which comprise sandwiching a tube pattern of separation material and a separate fin pattern of separation material between two sheets of metal, pressure welding the resulting assembly into a single layer of metal in those areas not covered by said material, and thereafter applying fluid pressure to the internal surfaces of said resulting sheets held apart by said material until passageways substantially in accordance with said tube pattern have been formed therein and bulges substantially in accordance with said fin pattern have been formed thereon, providing fins on said sheet by opening said fin bulges to form fin-like projections and assembling a plurality of such resulting sheets in face-to-face relationship to provide a heat exchanger core.

9. In the process of making heat exchangers, the steps which comprise sandwiching a pattern of separation material between two sheets of metal, joining the metal of the sheets into a single layer of metal in those areas not covered by said material, applying fluid pressure to the interior surface of said resulting sheet held apart by said material until passageways substantially in accordance with said pattern form bulges on at least one surface of said sheet, forming slots through the single layer of metal between the edges of said sheet and the bulges adjacent said edges, bending said edges out of the plane of the sheet to form a support for and define a housing for the portion of the sheet containing said bulges, and providing fins on said single layer of metal between said bulges.

10. In the process of making heat exchangers, the steps which comprise sandwiching a pattern of separation material between two sheets of metal, joining the metal of the sheets into a single layer of metal in those areas not covered by said material, said pattern being of the configuration desired for flow of heat exchange fluid in said exchangers, applying fluid pressure to the interior surfaces of said resulting sheet held apart by said material until passageways substantially in accordance with said pattern are formed on only one surface of said sheet, bending opposite edges of said sheet at an angle away from the flat surface thereof to form a support for and defining a housing for the portion of the sheet containing said passageways, forming slots to permit the passage of air therethrough between said edges of the sheet and said passageways adjacent said edges, and providing fins on said single layer of metal between said passageways.

11. The process of claim 7 including the step of interposing between said sheets of metal, together with said tube and fin patterns, additional separation material defining a common conduit pattern interconnecting said tube pattern and said fin pattern, and removing said com-

mon conduit pattern following said application of fluid pressure.

12. The process of claim 8 including the step interposing between said sheets of metal, together with said tube and fin patterns, additional separation material defining a common conduit pattern interconnecting said tube pattern and said fin pattern, and removing said common conduit pattern following said application of fluid pressure.


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