

July 19, 1960

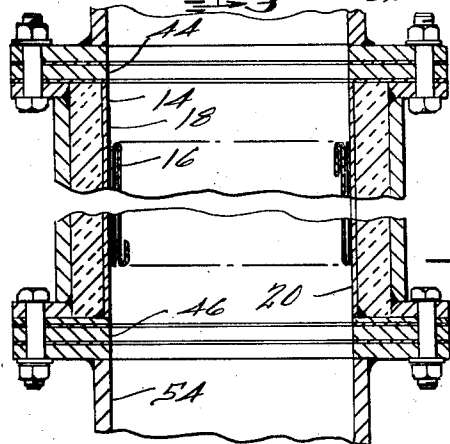
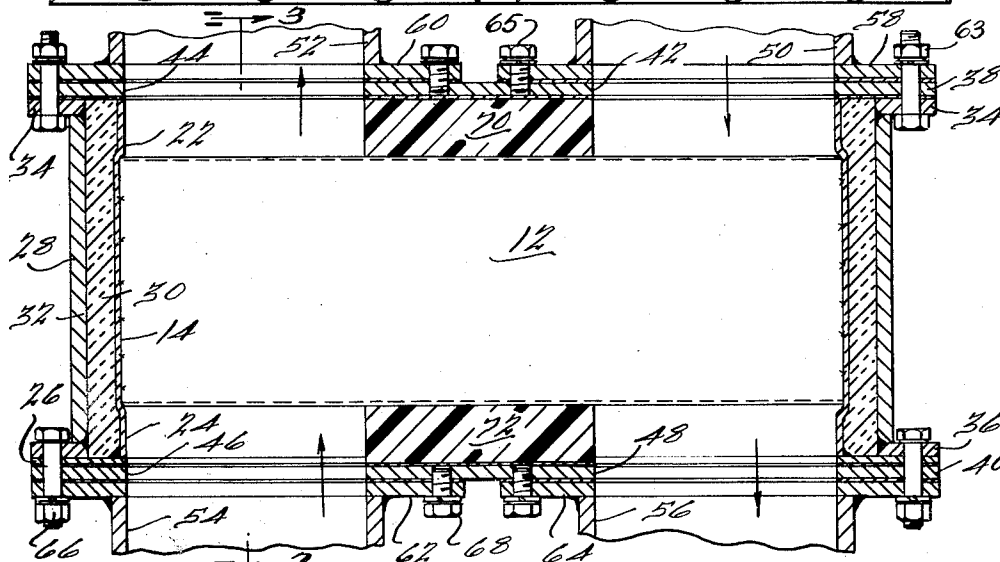
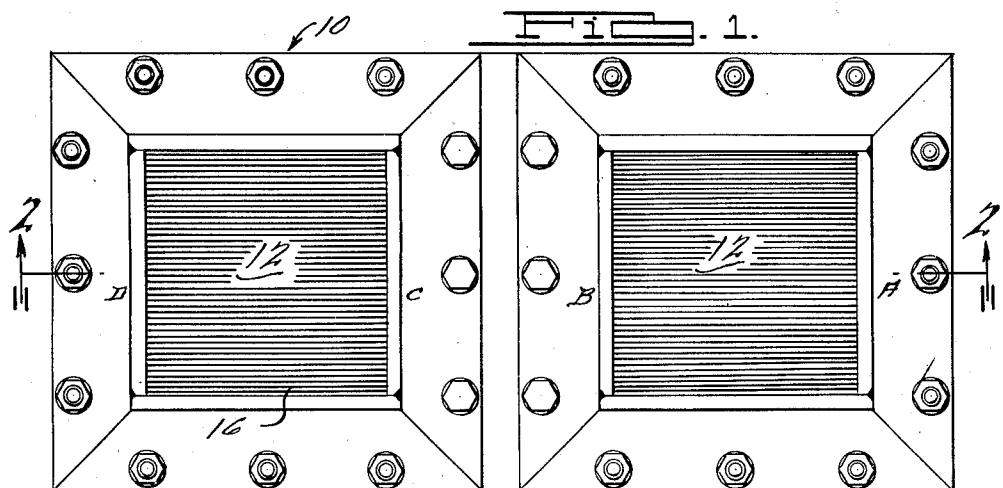
A. J. SLEMMONS

2,945,680

HEAT EXCHANGER

Filed April 28, 1955

7 Sheets-Sheet 1



INVENTOR.
Arthur J. Slemmons.
BY
Hansen and Hansen
ATTORNEYS.

July 19, 1960

A. J. SLEMMONS

2,945,680

HEAT EXCHANGER

Filed April 28, 1955

7 Sheets-Sheet 2

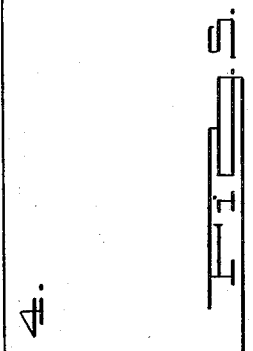
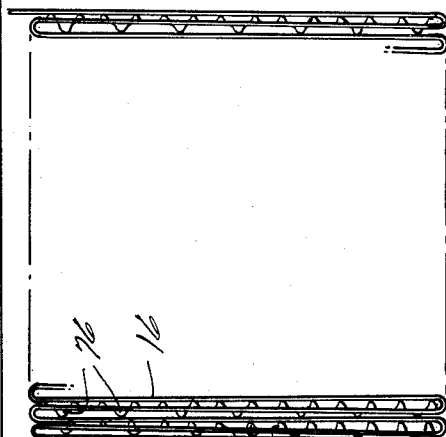
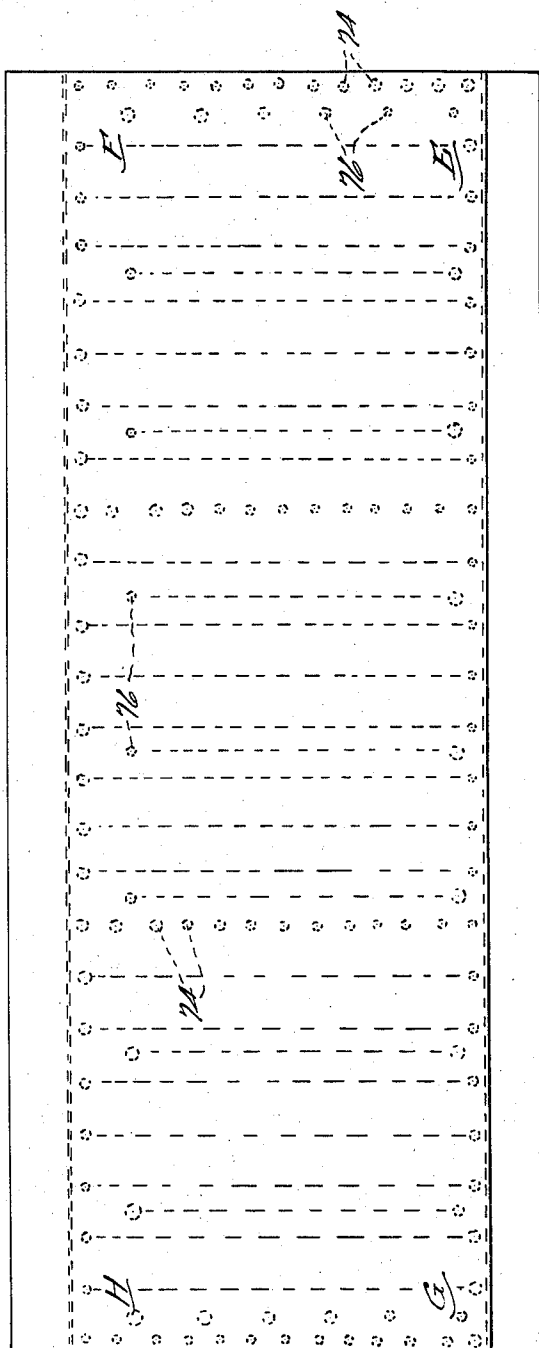


FIG. 4.

INVENTOR.
Arthur J. Slemmons

BY

Hansen and Hansen

ATTORNEYS

July 19, 1960

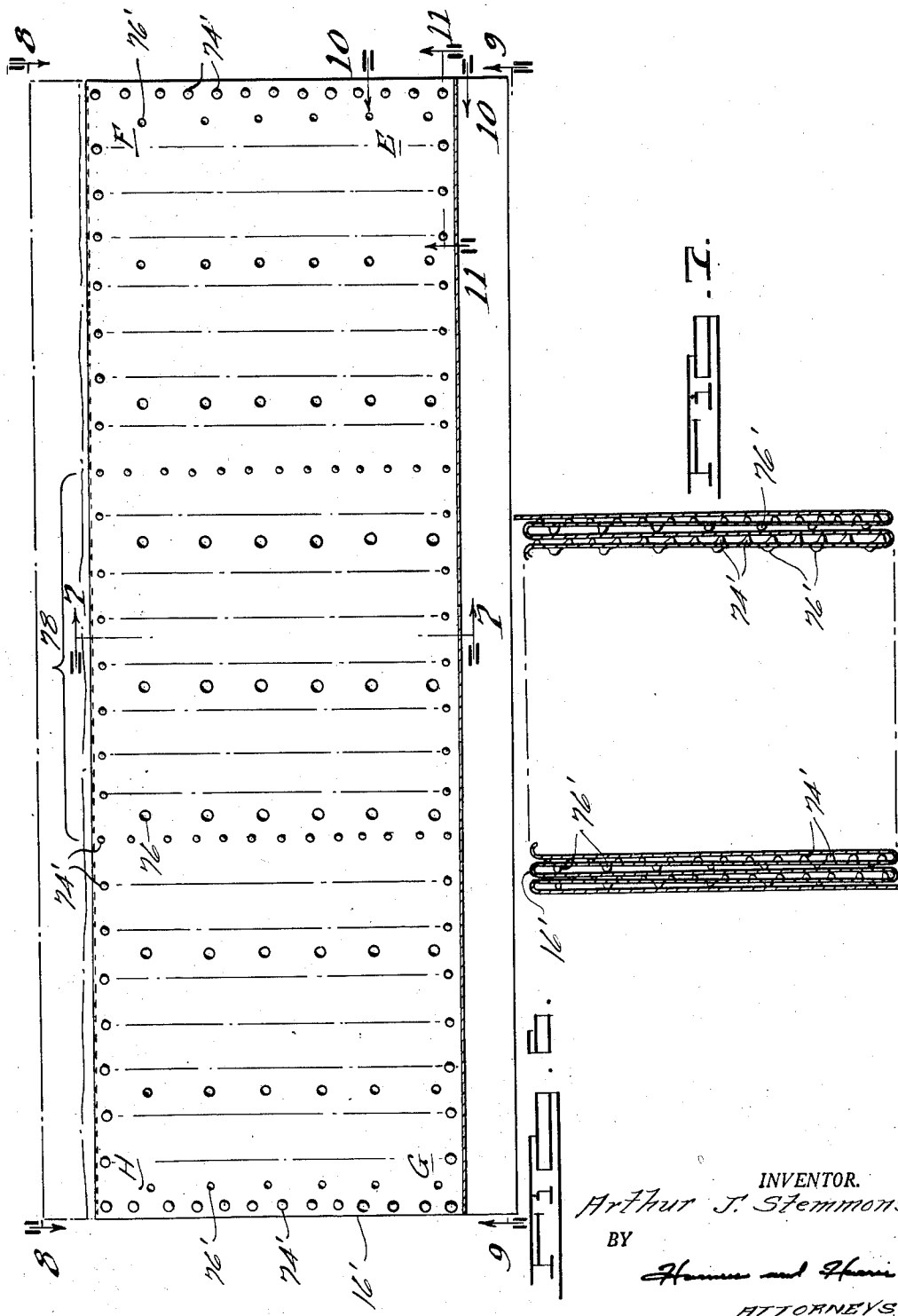
A. J. SLEMMONS

2,945,680

HEAT EXCHANGER

Filed April 28, 1955

7 Sheets-Sheet 3



July 19, 1960

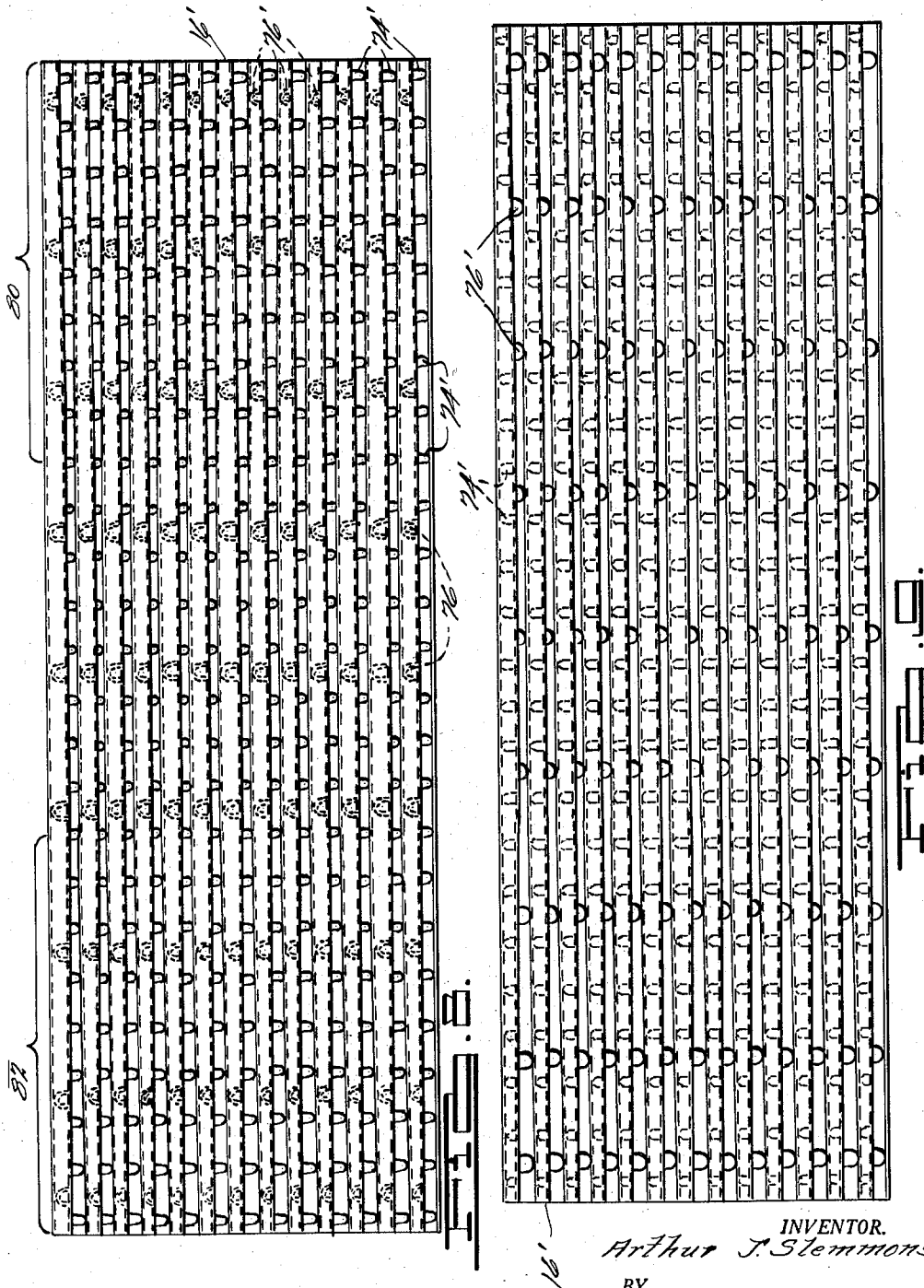
A. J. SLEMMONS

2,945,680

HEAT EXCHANGER

Filed April 28, 1955

7 Sheets-Sheet 4



INVENTOR.

Arthur J. Slemmons

BY

Hammann and Spawie

ATTORNEYS.

July 19, 1960

A. J. SLEMMONS

2,945,680

HEAT EXCHANGER

Filed April 28, 1955

7 Sheets-Sheet 5

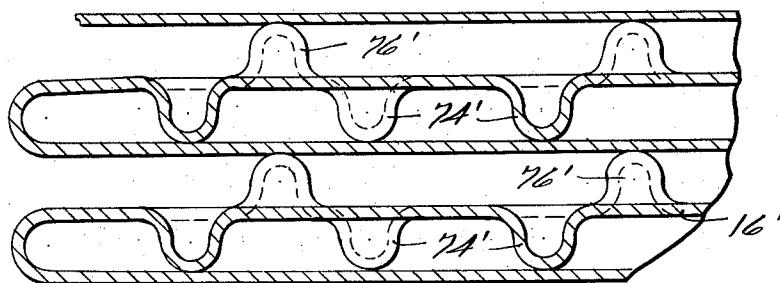


FIG. 10.

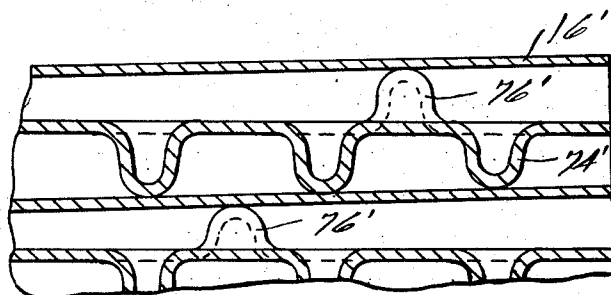


FIG. 11.

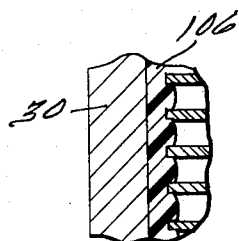


FIG. 12.

INVENTOR.
Arthur J. Slemons
BY
Hansen and Hansen
ATTORNEYS

July 19, 1960

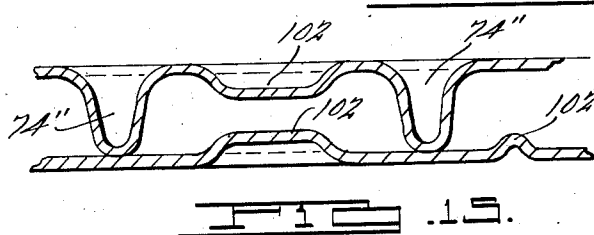
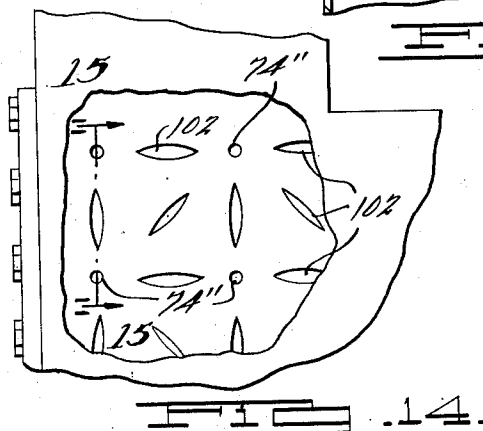
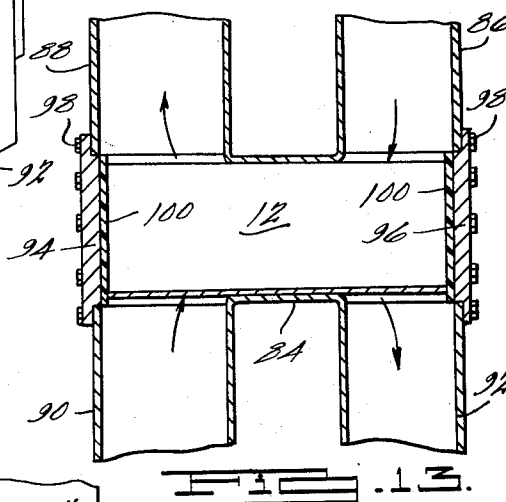
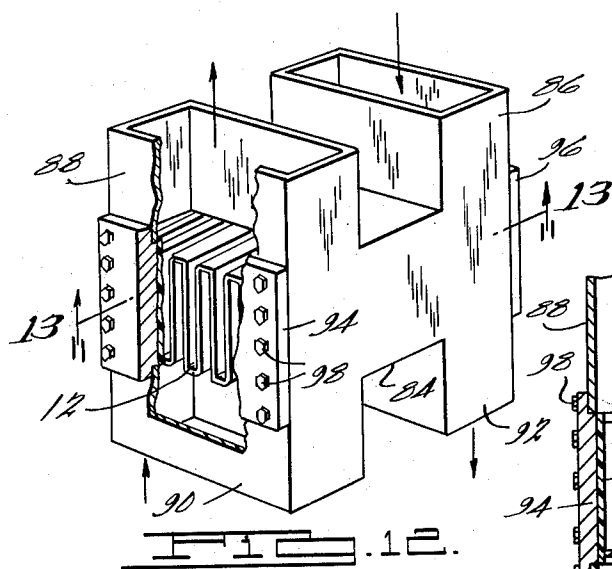
A. J. SLEMMONS

2,945,680

HEAT EXCHANGER

Filed April 28, 1955

. 7 Sheets-Sheet 6



INVENTOR.
Arthur J. Slemmons
BY
Shannon and Shinn
ATTORNEYS

July 19, 1960

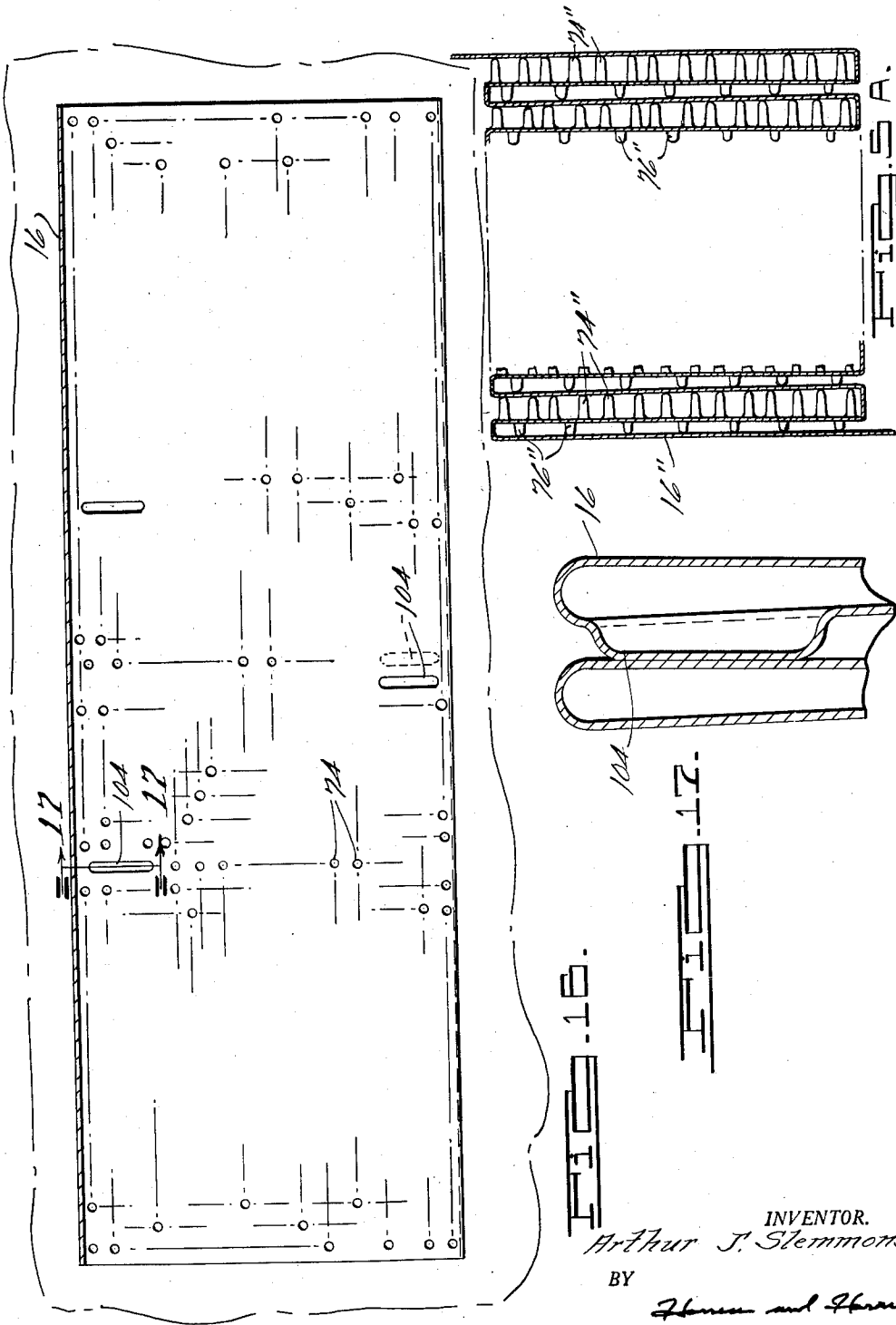
A. J. SLEMMONS

2,945,680

HEAT EXCHANGER

Filed April 28, 1955

7 Sheets-Sheet 7



INVENTOR.
Arthur J. Slemons
BY
Hansen and Horan
ATTORNEYS.

1

2,945,680

HEAT EXCHANGER

Arthur J. Slemmons, Birmingham, Mich., assignor to Chrysler Corporation, Highland Park, Mich., a corporation of Delaware

Filed Apr. 28, 1955, Ser. No. 504,628

14 Claims. (Cl. 257—245)

My invention relates generally to heat exchanger apparatus and more particularly to a new and improved heat exchanger core structure capable of accommodating the flow of fluid media of different temperatures.

The core structure of my instant invention is particularly adapted to be used with gaseous fluid mediums for effecting a transfer of thermal energy from the higher temperature gas to the lower temperature gas and it may be readily employed as a core for an air conditioning device for buildings, for the passenger compartments of various types of vehicles, or for similar applications.

According to a principal feature of my invention, the core structure above mentioned is comprised of a single pleated or folded metal sheet in which the individual folds function as separate gas conduits for conducting cool and warm gases, each of the conduits communicating with external gas ducts or the like. I contemplate that the cool and the warm gases may have different pressures so that a pressure differential will exist over the folded core sheet. The core structure of my instant invention is adapted to separate the cool gases from the warm gases by means of a single primary heat transfer surface which results in more efficient heat transfer.

According to the disclosed embodiments of my instant invention, the core structure is formed with a substantially rectangular cross section and the high pressure gases enter and leave the core structure at separate portions of one side of the rectangular structure while the low pressure gases enter and leave separate portions of the opposite side. Heretofore, considerable difficulty has been experienced with such rectangular core structures of known construction in efficiently utilizing the gas passages located at the corner portions of the structure. However, the core structure of my instant invention eliminates these shortcomings and it substantially eliminates undesirable stagnation areas throughout the entire paths followed by the high and the low pressure gases.

The provision of a heat exchanger of the type briefly described above being a principal object of my instant invention, it is a further object of my invention to provide a heat exchanger having a core of seamless construction to reduce manufacturing cost, to reduce the overall physical dimensions and to improve its durability and strength.

It is a further object of my instant invention to provide a new and improved heat exchanger as above mentioned, wherein the individual pleats or folds of the core structure are separated by suitable spacer means to maintain an optimum spacing between the folds.

It is a further object of my instant invention to provide a heat exchanger apparatus as set forth in the preceding objects wherein the space defined by adjacent folds define separate passages for accommodating the flow of cool and of warm gases and wherein means are provided for controlling the path of the gas flow between the folds to effect a uniform distribution of the gases over substantially the entire heat transfer surfaces.

It is another object of my instant invention to provide a heat exchanger apparatus as set forth above wherein

2

means are provided for increasing the rigidity of the individual folds of the core structure.

It is another object of my instant invention to provide a heat exchanger apparatus having a plurality of spaced sheets adapted to accommodate the flow of cool and warm gases therebetween, as above described, wherein the magnitude of the spacing between adjacent sheets is varied to define tapered gas passages, said tapered construction being effective to improve the distribution of the gaseous media flowing through the gas passages.

It is a further object of my instant invention to provide a heat exchanger apparatus as set forth in the preceding object wherein the longer gas flow paths through the structure are formed with a larger area than that of the shorter paths.

It is a further object of my instant invention to provide a heat exchanger apparatus as set forth in the preceding object wherein the inlet portions for the gas flow paths are formed with an increased cross sectional area of tapered configuration.

It is a further object of my invention to provide a heat exchanger apparatus which includes a core structure of convenient size and in which the core structure may be readily removed from the assembly for servicing.

It is a further object of my instant invention to provide a heat exchanger apparatus which is characterized by its relatively low manufacturing cost and by its improved operating efficiency.

Other objects and features of my invention will readily become apparent from the following particular description and from the accompanying drawings wherein:

Figure 1 is a plan view of the heat exchanger apparatus of my instant invention;

Figure 2 is a cross sectional elevation view of the apparatus shown in Figure 1 and is taken along section line 2—2 of Figure 1;

Figure 3 is a sectional view of the heat exchanger apparatus taken along section line 3—3 of Figure 2;

Figure 4 is a detail view showing one side of one form of the core structure of my instant invention which is adapted to be used in the assembly of Figures 1, 2, and 3;

Figure 5 is an end view of the core structure of Figure 4 as viewed in the direction of the arrow 5 in Figure 4;

Figure 5A is an end view similar to Figure 5, showing a modified form of the core structure;

Figure 6 is a side view of another form of the core structure of my instant invention, this other form also being adapted to be used in the assembly of Figures 1, 2, and 3;

Figure 7 is a cross sectional view through the center of the core structure of Figure 6 and is taken along the section line 7—7 of Figure 6;

Figure 8 is a top view of the core structure shown in Figure 6 as viewed from the plane of the section line 8—8 of Figure 6;

Figure 9 is a bottom view of the core structure of Figure 6 as viewed along the plane of the section line 9—9 of Figure 6;

Figure 10 is an enlarged end view of the core structure of Figure 6 and is taken along the section line 10—10 of Figure 6;

Figure 11 is an enlarged cross sectional view of a portion of the core structure of Figure 6 and is taken along section line 11—11 of Figure 6;

Figure 12 shows a second type of casing which may be used for enclosing either of the core structures of Figure 1 or 6 and it further shows a means for conveniently removing and installing the core structure within the casing;

Figure 13 is a cross sectional view of the assembly of Figure 12 and is taken along section line 13—13 of Figure 12;

Figure 14 is a partial sectional view of the casing of Figure 12 showing reinforcing projections formed on the folds or pleats of the core structure, said projections being interposed between the dimples shown in Figures 4 to 11;

Figure 15 is a sectional view taken along section line 15—15 of Figure 14 showing the construction of the reinforcing projections and the dimples of the individual pleats of the core structure shown in Figure 14;

Figure 16 is a side view of another modified form of the core structure in which flow directing darts or baffles are formed in the individual pleats of the core structure together with the dimples of the type shown in Figures 6 and 14;

Figure 17 is a partial sectional view of the core structure of Figure 16 showing one side of a flow directing dart of Figure 16; and

Figure 18 shows a modification of the assembly of Figures 1, 2, and 3 including an alternate means for securing the core structure at its ends to the inner sides of the outer casing.

Referring first to Figures 1, 2, and 3 I have shown a suitable fixture or casing 10 for enclosing the core structure 12 of my instant invention. It is apparent from the views of Figures 1, 2, and 3 that the core structure 12 is formed with a rectangular cross section and that it is enclosed on each of its four sides by a suitable steel envelope 14. It may be seen from Figures 1 and 3 that the body portion of the core structure 12 is made up of a single pleated sheet, the individual pleats or folds being identified by numeral 16. One end of the pleated sheet for the core structure 12 may be brazed or otherwise suitably secured to one side of the steel envelope 14, as shown at 18 in Figure 3, while the other side thereof may be similarly secured to the opposite wall of the envelope 14, as shown at 20. The depth of the envelope 14 is substantially greater than the depth of the core structure 12 so that a portion of the former extends upwardly for a convenient distance from the centrally disposed core structure 12, as shown at 22, while another portion 24 extends below the core structure 12 for approximately the same distance. A peripheral flange 26 may be secured to the lower portion 24 of the envelope 14 by welding or by any other suitable means.

The sub-assembly of the envelope 14 with its internally bonded core structure 12 may be fitted within a rectangular box structure 28. This box structure 28 may be comprised of an inner rectangular wall portion 30 and a surrounding rectangular wall portion 32, the inner wall portion 30 being adapted to contact and to position the sub-assembly comprised of the envelope 14 and the core structure 12. A laterally extending flange is secured to the top and to the bottom of the wall portion 28 as shown at 34 and 36. A top cover plate 38 is positioned over the upper end of the rectangular box structure 28 and a lower cover plate 40 is positioned over the lower end of the box structure 28. A low pressure gas inlet opening 42 and a low pressure gas outlet opening 44 are formed in the upper cover plate 38 and a high pressure gas inlet opening 46 and a high pressure gas outlet opening 48 are formed in the lower cover plate 40, said openings being best seen in Figure 2. Suitable gas ducts are secured to the upper portion of the assembly, as shown at 50 and 52, and they communicate with the inlet opening 42 and the outlet opening 44 respectively. Similar ducts 54 and 56 are secured to the lower cover plate 40, and they communicate with the inlet opening 46 and the outlet opening 48 respectively. The ends of each of the ducts 50, 52, 54, and 56 are transversely flanged as shown at 58, 60, 62, and 64, respectively. The flange 34, the cover plate 38 and the flanged portions of the ducts 50 and 52 are suitably bolted together by bolt means 63 about the peripheral edge of the assembly, and other bolt means 65 are provided for securing the duct flanges to the center portion of the top cover plate 38.

The flanges 62 and 64 for the other ducts 54 and 56

respectively, are secured to the lower cover plate 40 and to the flange 36 for the rectangular box structure 28 by suitable bolt means 66, said bolt means being disposed about the peripheral edge of the assembly as shown. Other bolt means 68 may be provided as shown, for securing the duct flanges 62 and 64 to the center portion of the lower cover plate 40.

A suitable packing material 70 may be interposed between the upper cover plate 38 and the upper edge of the core structure 12 and it may extend transversely across the interior of the rectangular box structure 28. Similarly, other suitable packing material 72 may be interposed between the lower cover plate 40 and the bottom of the core structure 12 and it may extend transversely across the width of the interior of the box structure 28.

It is apparent from the foregoing that the duct 50, the opening 42, opening 44 and the duct 52, together with the opening defined by the adjacent folds 16 of the core structure 12 on one side of the pleated sheet of the core structure, are adapted to define a continuous low pressure gas passageway, the direction of the flow being from right to left through the core structure 12 as indicated by the arrows shown in Figure 2. Similarly, the duct 54, the opening 46, the opening 48 and the duct 56, together with the opening defined by the adjacent folds 16 of the core structure 12 on the opposite side of the associated pleated plate, define a high pressure gas passageway which is adapted to accommodate the flow of gases from the left to the right, as indicated by the arrows of Figure 2. The counterflow above described is to be preferred over a unidirectional flow for the reason that the heat transfer characteristics are greatly improved when the core structure 12 is utilized in this manner. It is apparent that the cooler gases are separated from the warmer gases by a single thickness of the pleated plate of the core structure 12 and the thermal energy of the warmer gases may thereby be readily transferred to the cooler gases in an efficient manner as the gases traverse through the core structure 12.

Referring next to Figures 4 and 5, I have illustrated one form of the core structure of my instant invention in more particular detail. As previously mentioned, the core structure illustrated in Figures 4 and 5 may be readily used in a fixture or casing of the type illustrated in Figures 1, 2, and 3. It may be seen that the individual folds 16 are formed from a single continuous sheet to form a heat transfer surface of considerable area, the individual folds or pleats 16 being disposed in closely adjacent relationship. Alternate ones of the individual folds or pleats 16 are formed with a plurality of dimples 74 which function as separators for maintaining a predetermined clearance between the folds. The low pressure gas passages defined by the individual folds or pleats 16 open at the top of the core structure 12, as seen in Figure 5, and the dimples 74 are situated therein. The high pressure gas passages defined by the folds or pleats 16 are situated in alternate relationship with respect to the low pressure passages above mentioned and they are substantially void of the dimples 74. However, these high pressure passages do contain widely spaced projections 76 which function as spacers for the adjacent folds defining each of the individual high pressure gas passages. The dimples 74 are provided for the purpose of preventing a collapse of the adjacent folds or pleats 16 by reason of the differential in the pressure of the gases on either side of the pleated sheet of the core structure 12, while the spacer projections 76 are provided for maintaining a predetermined clearance between the adjacent folds or pleats 16 of the high pressure gas passages during the formation of the core structure 12. By preference, the spacer projections 76 and the dimples 74 are formed in the same fold or pleat 16, while the adjacent fold or pleat 16 is free of any such indentations. The spacer projections 76 and the dimples 74

extend in the opposite directions, as shown, but I contemplate that the spacer projections 76 could also be formed in the pleats which are free of the dimples 74, in which case the projections 76 and the dimples 74 would extend in the same direction.

The dimples 74 and the spacer projections 76 may be readily formed by means of a rolling operation. The apparatus used in such an operation may include a pair of rollers through which a continuous strip of heat conductive material is fed and one part of the periphery of one of the rollers may be formed with projections for producing the dimples and spacer projections while the other roller may be provided with mating recesses.

An important feature of my invention resides in the tapered cross section of the high pressure gas passages and the low pressure gas passages, as best seen in Figure 5. It is apparent from an inspection of Figure 5 that the inlet and outlet openings for the high pressure gas passages and the inlet and outlet openings for the low pressure gas passages are narrower than the portions of the passages situated within the interior of the core structure. More specifically, the adjacent folds which define the low pressure gas passages are closer together at the top side of the core structure 12, as viewed in Figure 4, than they are at the bottom side thereof, and the adjacent folds defining the high pressure exhaust passages are closer together at the bottom side of the core structure 12, as viewed in Figure 5, than they are at the top side thereof. Accordingly, the dimples 74 are formed with a progressively increasing height so as to define the above described tapered opening and similarly the spacer projections 76 are provided with a progressively increasing height for the same purpose.

Referring again to Figure 1, I have identified opposite edges of the low pressure inlet opening 42 and of the low pressure outlet opening 44 by the letters A, B, C, and D. It will be apparent that the portion of the low pressure air which enters the inlet opening 42 adjacent the edge A will tend to be discharged from the outlet opening 44 adjacent the edge D while the low pressure air which enters the inlet opening 42 adjacent the edge B will tend to be discharged from the low pressure outlet opening 44 adjacent the edge C. It is therefore apparent that the length of the path of the former portion of the inlet air will be longer than the length of the path followed by the latter portion. If the pressure drop along the path from edge B to edge C is less than the pressure drop along the path from edge A to edge D, then a larger portion of the air will follow the shorter path. This undesirable flow distribution would tend to reduce the operating efficiency of the heat exchanger since the effective heat transfer area would be considerably reduced. However, the core structure 12 of my instant invention compensates for the tendency of the low pressure air to assume such an unbalanced flow pattern by reducing the magnitude of the pressure drop per unit length in the longer path as compared to the pressure drop per unit length in the shorter path. This adjustment in the relative magnitudes of the total restriction to flow in the various paths followed by the low pressure air is accomplished by reason of the tapered spacing of the adjacent folds or pleats 16 which define the low pressure gas passage through core structure 12.

The same reasoning applies to the high pressure gas passage through the core structure 12. It may be observed from Figure 5 that the portions of the folds or pleats 16 defining the relatively long high pressure gas flow paths are spaced wider than the portions thereof which define the relatively short high pressure gas flow paths. The substantially equalized total flow restriction of the various flow paths through the core structure 12 tends to provide a uniform flow pattern across both sides of the heat transfer surfaces and this in turn greatly improves the operating efficiency of the unit.

It the two fluid media employed with the heat exchanger

core structure of my instant invention are possessed of greatly different physical characteristics such as viscosity or density, or if one of the fluid mediums is supplied in quantities much greater than that of the other fluid medium, it is desirable to provide a fluid flow passage of larger cross sectional area for the medium with the relatively high viscosity or density or the medium which is supplied at a relatively greater rate. I have therefore designed a modified core structure as shown in Figure 5A which comprises a pleated sheet as in the previously described embodiment, the individual pleats forming gas passages of tapered configuration. Alternate ones of the gas passages of the structure of Figure 5A define a portion of a common gas flow conduit and the spacing between the individual pleats is such that one of the gas passages has a larger effective cross sectional area than the other.

The core structure of Figure 5A may also be provided with dimples and spacer projections as in the previously described embodiment, as indicated at 74' and at 76' respectively. The individual pleats of the core structure of Figure 5A are identified by numeral 16'.

As an alternative, the density of the dimples in one gas passage may be increased or decreased if desired for the purpose of respectively providing a lesser or a greater effective cross sectional area.

Referring next to Figures 6 through 11, I have disclosed a second form of the core structure of my instant invention which is similar in many respects to the above-described core structure shown at Figures 4 and 5. It may be observed that the center portion of the core structure 12, as shown in Figures 6 and 7, is substantially the same as the core structure in Figures 4 and 5, said center portion comprising substantially a middle one-third of the length of the core structure 12 as identified by numeral 78. The core structure 12 of Figures 6 through 11 may also be mounted in the fixture or casing, as shown in Figures 1, 2, and 3, and it may be observed that the low pressure passages contain dimples 74' while the high pressure gas passages contain projections 76', said dimples and projections respectively corresponding to the above-described dimples 74 and projections 76 of Figures 4 and 5. It may be observed that the low pressure passages and the high pressure passages of this second embodiment are also formed with a tapered cross sectional area so as to equalize the magnitudes of the total restriction to flow in the relatively long and the relatively short gas flow paths as the high pressure and low pressure gases pass through the core structure 12.

Referring more particularly to Figure 8, it may be seen that the portions 80 of the folds or pleats 16' which define the low pressure gas inlet openings and the portions 82 of the folds or pleats 16' which define the low pressure gas outlet openings are each tapered so that the spacing between the folds 16' at the outer edge A of the low pressure gas inlet opening 42 and the outer edge D of the low pressure gas outlet opening 44 are respectively greater than the inner edge B of the inlet opening 42 and the inner edge C of the outlet opening 44, said edges being identified in Figure 1 as previously mentioned. This latter tapered configuration tends to further encourage the low pressure gases to follow the relatively longer gas flow paths while passing through the interior of the core structure 12. This latter characteristic arises by reason of the accompanying reduction in the pressure drop per unit length in the relatively longer air flow paths with respect to the pressure drop per unit length in the relatively shorter air flow paths. It is thus seen that the characteristics of the previously described core structure of Figures 4 and 5 are common to the core structure of Figures 6 through 11, but in addition the core structure of Figures 6 through 11 incorporates this further improvement and thus the gas flow distribution pattern is even more completely equalized.

Referring next to Figure 9, it may be seen that the portions of the folds or pleats 16' defining the high pres-

sure gas passage adjacent the high pressure gas inlet opening 46 and adjacent the high pressure gas passage outlet opening 48 are also tapered from a maximum at the outer edges to a minimum at the inner edges. Such a tapered configuration of the inlet and outlet openings for the high pressure gas passages in the core structure 12 tends to also provide a more nearly uniform flow distribution pattern for the high pressure gases.

The amount of the taper of the inlet and outlet openings for the high pressure gas passages and for the low pressure gas passages is preferably formed so that it will compensate for and equalize the amount of the taper of the folds or pleats 16' as viewed in Figure 7, the edges of the individual folds or pleats 16' at either of the ends of the core structure 12 thereby being substantially equally spaced and parallel to each other. This feature is illustrated in the enlarged sectional view of Figure 10 which is taken along section line 10—10 closely adjacent one of the ends of the core structure 12, as shown in Figure 6.

For the purpose of more particularly illustrating the tapered configuration of the outlet opening for the high pressure gas passage through the core structure 12, reference may be made to Figure 11 in which a small portion of this opening is shown with an enlarged scale. It may be observed that the spacing of the folds or pleats 16' at the outermost end are equally spaced and that the low pressure gas passages become progressively smaller as they approach this outer edge. The high pressure gas passages become progressively larger as they approach this outer edge, as previously mentioned. However, it is pointed out that the effective cross sectional area of the high pressure passages defined by the folds or pleats 16' does not increase at the expense of the effective cross sectional area of the low pressure passages since this reduction in the spacing between the folds or pleats 16' defining the low pressure passages occurs only in that portion of the core structure 12 which is not efficiently utilized by the low pressure gases. In other words, only a very small percentage of the low pressure gases entering the top side of the core structure 12 shown in Figure 6 will enter the corner region of the core structure 12 which is identified by the letter E in Figure 6. On the other hand, a substantial percentage of the high pressure gases leaving the bottom openings in the core structure 12, as shown in Figure 6, will traverse the corner region E as identified in Figure 6.

Similarly the low pressure passage inlet openings defined by the folds or pleats 16' at the top of the core structure 12 of Figure 6 progressively increase in size until they reach a maximum at the right end of the core structure when viewed in Figure 6. The amount of this increase is obtained at the expense of the high pressure passages in the upper corner region F as identified in Figure 6. It is emphasized, however, that the portion of the high pressure gases passing through the core structure 12 which enters the corner region F is relatively small whereas the percentage of the low pressure gases traversing the corner region F is relatively high. It is thus seen that the form of my instant invention illustrated in Figures 6 through 11 makes efficient use of the otherwise less useful corner portions of the rectangular core structure and the percentage of heat recovery from the relatively warm gases for a given volume of the core structure is greatly increased for this reason. The corner portions identified by the letters G and H in Figure 6 are similarly formed so that the high pressure gas inlet openings in the corner region G are enlarged at the expense of the portions of the low pressure passage in this corner region, while the low pressure outlet openings in the corner region H are increased at the expense of the portions of the high pressure passages in this corner region H.

Referring next to Figures 12 and 13, I have illustrated another type of casing which may be used to enclose

either of the core structures previously described and it may comprise a substantially rectangular box portion 84 having a low pressure gas inlet duct 86 and a low pressure outlet duct 88 formed thereon at its upper side. Similarly, a high pressure gas inlet duct 90 and a high pressure gas outlet duct 92 may be formed on the bottom side of the central rectangular box portion 84. A core structure 12 of the type illustrated in Figure 4 and in Figures 6 through 11 may be mounted within the central rectangular box portion 84 as illustrated in Figure 12. For convenience in removing and installing the core structure 12, the lateral ends of the central rectangular box portion 84 are formed with rectangular openings which may be covered by suitable cover plates as illustrated in Figures 12 and 13 at 94 and 96. Cover plates 94 and 96 may be secured to the casing structure by means of bolts 98 and leakage around the ends of the folds or pleats of the core structure 12 may be prevented by applying a suitable packing material 100 between the end closure plates 94 and 96 and the adjacent edges of the core structure 12.

In operation, the low pressure gases may enter the duct 86 and may traverse the core structure 12 through the low pressure passages defined by the individual folds or pleats of the core structure 12 and may then be exhausted out of the duct 88. High pressure gases may enter the duct 90 and traverse the core structure 12 through the remaining passages defined by the individual folds or pleats of the core structure 12 and they may then be exhausted out of the duct 92.

A modified construction of the individual pleats or folds of the core structure of my instant invention is shown in Figures 14 and 15. For convenience, the core structure as illustrated in Figures 14 and 15 is mounted within a casing of the type shown in Figures 12 and 13. Alternate ones of the individual folds of the pleated sheet which comprises a body portion of the core structure of my instant invention are provided with spacer dimples 74'' which are adapted to maintain a predetermined clearance between the individual pleats. A plurality of ribs 102 are formed in the pleats between the spacer dimples 74'' in a manner similar to that shown. The height of each of the ribs is preferably substantially less than the height of the dimples 74'' and the length of each of the ribs 102 is preferably less than the shortest distance between any two adjacent dimples 74''. The pattern assumed by the projections 102 shown in Figure 14, includes diagonally positioned projections as well as vertical and horizontal projections. Although I prefer to form the projections 102 with the pattern illustrated in Figure 14, I contemplate that various other patterns may also be used with success.

The projections 102 in each of the pleats of the core structure are adapted to rigidify the individual pleats as well as the composite assembly in order to prevent excessive bending of the sheet material of which the core structure is formed, to prevent collapse of the pleats by reason of the pressure differential across the same and to facilitate the manufacturing operation. The dimpled sheet as well as the adjacent undimpled sheets may be formed with such rigidifying projections 102, as illustrated in the cross sectional view of Figure 15.

Referring next to Figures 16 and 17, I have illustrated a further improvement which may be applied to any of the aforementioned constructions of the core structure of my instant invention. However, for purposes of illustration, I have applied this further improvement to the core structure of Figures 4 and 5. The improvement in the core structure of Figures 16 and 17 resides in the formation of a system of flow directing darts or baffles 104 which may be formed on each of the individual pleats 16 of the core structure. The darts 104 are preferably formed in a transverse direction and one such dart is positioned adjacent the inner edge B of the low pressure gas inlet opening while another is placed adjacent the inner edge C of the pressure gas outlet

opening. Other darts 104 may be positioned substantially at the center of the individual pleats 16 adjacent the bottom side of the core structure. By preference, each of the darts 104 is aligned with a row of spacer dimples 74 and replaces a plurality of the spacer dimples in that row. As best seen in Figure 17, the darts or baffles 104 are formed with a varying height in order to allow for the taper between the adjacent pleats, said taper providing for gas passages of variable width as previously described. Darts or baffles 104 are preferably formed in the dimpled pleat, but I contemplate that they could also be formed in the adjacent undimpled sheets.

It is apparent from an inspection of Figure 16 that the darts or baffles 104 are effective to alter the flow pattern of the low pressure gases as they progress from the low pressure gas inlet opening at the right side of the figure to the low pressure gas outlet opening at the left side of the figure. The total length of the path followed by the low pressure gases while traversing through the low pressure gas passages is therefore considerably increased because of the presence of the baffles 104. Also the baffles 104 tend to direct the low pressure gases to the remote corner regions E and G as identified in Figure 6 and they thereby tend to uniformly distribute the low pressure gases to a still further degree.

Similar darts or baffles 104 may be provided adjacent the inner edges of the inlet and outlet openings for the high pressure gas passages and within the central portion of high pressure gas passages at the top side of the core structure as viewed in Figure 16. These latter darts or baffles function in the manner previously described to distribute the high pressure gases to the remote corners of the core structure and to increase the total effective length of the path followed by the high pressure gases as they travel through the core structure.

In Figure 18 I have shown an alternate way in which the core structure 12 may be secured to the end walls of the casing or fixture 10 as shown in Figures 1, 2, and 3. The ends of the pleated sheet of which the core structure 12 is comprised is preferably brazed to the surrounding steel envelope 14 as previously described in the description of the casing of Figures 1, 2, and 3. However, in the embodiment of Figure 18, the ends of the individual pleats of the core structure 12 are inserted in a suitable packing or matrix material 106 as shown, said matrix material being effective to prevent leakage or bypassing of the gases around the ends of the pleats. Such a construction would eliminate the brazing operation and would provide a satisfactory seal in most instances.

Although I have particularly described various preferred embodiments of my invention, I contemplate that other variations may also be included within the scope of my invention as defined by the following claims.

I claim:

1. A heat exchanger core structure comprising a pleated sheet, the individual pleats of said sheet forming a plurality of adjacent heat transfer surfaces, said pleats substantially defining a regular hexahedron with a plurality of gas flow passages interposed between the adjacent surfaces thereof, a first conduit means defined by alternate ones of said passages on one side of said pleated sheet, a second conduit means defined by the other passages on the other side of said pleated sheet, the entrance and exit portions of said first conduit means being located on one side of said hexahedron adjacent opposite ends thereof, the entrance and exit portions of said second conduit means being located on the opposite side of said hexahedron adjacent opposite ends thereof, the spacing between the adjacent heat transfer surfaces defining said alternate passages varying from a minimum at said one side to a maximum at the opposite side, the spacing between the adjacent heat transfer surfaces defining said other passages varying from a maximum at said one side to a minimum at the opposite side, each of said passages being closed along the side

at which the spacing of the associated heat transfer surfaces are a maximum.

2. The combination as set forth in claim 1 wherein the entry and exit openings at said one and said opposite sides vary in width from a minimum at the central portion of said core to a maximum near the end portions thereof.

3. A heat exchanger for transmitting thermal energy from one moving body of fluid to another comprising a folded sheet of heat conductive material, the individual folds of said sheet defining adjacent fluid flow passages, alternate ones of said passages defining a first conduit means for conducting relatively warm gases, the other passages defining a second conduit means for conducting relatively cool gases, said folded sheet forming a core of substantially rectangular cross section having a pair of opposed sides and first and second end portions, the entrance and exit openings for said alternate passages being located at one of said opposed sides, the entrance and exit openings for the other passages being located at the other of said opposed sides, said folds extending longitudinally from one of said end portions to the other, the spacing between the adjacent folds defining said openings increasing from a minimum near the center portion of said core to a maximum at said end portions, said entry and exit openings for each conduit means being upstream and downstream, respectively, of the region of minimum spacing between the adjacent folds of the associated conduit means.

4. The combination as set forth in claim 3 wherein the spacing of the adjacent folds defining each of said passages is smaller at the side of said core at which the associated entrance and exit openings are located than at the other side.

5. The combination as set forth in claim 4 wherein the folds defining each of said passages are substantially evenly spaced and parallel to each other in the vicinity of each of said core end portions.

6. A heat exchanger for transmitting thermal energy from one moving body of fluid to another comprising a folding sheet of heat conductive material, the individual folds of said sheet defining adjacent fluid flow passages, alternate ones of said passages defining a first conduit means for conducting relatively warm gases, the other passages defining a second conduit means for conducting relatively cool gases, said folded sheet forming a core of substantially rectangular cross section having a pair of opposed sides and first and second end portions, the entrance and exit openings for said alternate passages being located along one of said opposed sides, the entrance and exit openings for the other passages being located along the other of said opposed sides, the spacing of the adjacent folds defining each of said passages being smaller at the side of said core at which the associated entrance and exit openings are located than at the other side, the spacing between the adjacent folds defining said openings increasing from a minimum near the center portion of said core to a maximum at said end portions, dimples formed in alternate ones of said folds extending into the passages defining one of said conduit means for maintaining a predetermined clearance between the individual folds of the passages defining these same passages, said dimples being formed with a variable height and being arranged in a relatively dense pattern, and flow directing baffles formed in at least one of said passages at one side of said core adjacent the entrance and exit openings of the conduit means associated therewith, said baffles being adapted to direct the gases flowing through the associated passage toward the side of said core which is opposite from the passage entrance and exit openings.

7. The structure as set forth in claim 6 wherein said baffles are formed in the folds containing said dimples and are elongated in a direction substantially transverse to said core.

8. A heat exchanger core comprising a continuous,

pleated sheet, the pleats of said sheet defining two groups of elongated passages, each of said groups defining fluid paths of varying lengths therethrough, the fluid medium passing through one of said groups of passages being separated from the fluid medium passing through the other of said groups of passages by said sheet, the entrance and exit portions for one group of passages being located on one side of said core and the entrance and exit portions for the other group of passages being located on another side of said core, the pleats of the passages of each of said groups diverging in the directions from the regions of the shorter flow paths to the regions of the longer flow paths and generally transversely of the direction of fluid flow along said paths, the pleats of each group also diverging from said side of the core containing the entry and exit openings of said group.

9. A heat exchanger comprising a core having first and second conduit means for separate fluids, said core including a plurality of layered flow passages partitioned by walls of heat conductive material closely spaced with respect to their surface areas and extending substantially from end to end and from side to side of said core, alternate flow passages defining said first conduit means, the remaining flow passages defining said second conduit means, the flow passages of said first conduit means having entry and exit openings spaced endwise of said core at one side of the latter, the flow passages of said second conduit means having entry and exit openings spaced endwise of said core at the opposite side of the latter, the spacing between juxtaposed walls of said first conduit means being a minimum adjacent said one side and increasing to a maximum adjacent said opposite side, also the spacing between juxtaposed walls of said second conduit means being a minimum adjacent said opposite side and increasing to a maximum adjacent said one side, thereby to achieve decreasing resistance to flow with increasing length of the flow path between said entry and exit openings.

10. In a heat exchanger, a core comprising a pleated sheet of heat conductive material defining a plurality of layered flow passages partitioned by walls extending substantially from end to end and from side to side of said core, alternate flow passages defining a first conduit means, the remaining flow passages defining a second conduit means, the flow passages of said first conduit means having entry and exit openings adjacent opposite ends of said core at one side of the latter, the flow passages of said second conduit means having entry and exit openings adjacent opposite ends of said core at the opposite side of the latter, the spacing between juxtaposed walls of said first conduit means being a minimum adjacent said one side and increasing to a maximum adjacent said opposite side, also the spacing between juxtaposed walls of said second conduit means being a minimum adjacent said opposite side and increasing to a maximum adjacent said one side, thereby to vary the spacing between said walls generally transversely of the direction of flow to achieve decreasing resistance to flow with increasing length of the flow path between said entry and exit openings.

11. A heat exchanger comprising a core having first and second conduit means for separate fluids, said core including a plurality of layered flow passages partitioned by walls of heat conductive material closely spaced with respect to their surface areas and extending substantially from end to end and from side to side of said core, alternate flow passages defining said first conduit means, the remaining flow passages defining said second conduit means, the flow passages of said first conduit means having entry and exit openings spaced endwise of said core

at one side of the latter, the flow passages of said second conduit means having entry and exit openings spaced endwise of said core at the opposite side of the latter, the spacing between juxtaposed walls of said first conduit means being a minimum in the region adjacent said one side between the associated entry and exit openings and increasing in the directions toward said entry and exit openings and the opposite ends and also toward said opposite side, the spacing between juxtaposed walls of said second conduit means being a minimum in the region adjacent said opposite side between the associated entry and exit openings and increasing in the directions toward said entry and exit openings and the opposite ends and also toward said one side.

12. A heat exchanger comprising a core having first and second conduit means for separate fluids, said core including a plurality of layered flow passages partitioned by walls of heat conductive material closely spaced with respect to their surface areas and extending substantially from end to end and from side to side of said core, alternate flow passages defining said first conduit means, the remaining flow passages defining said second conduit means, the flow passages of said first conduit means having entry and exit openings spaced endwise of said core at one side of the latter to effect generally U-shaped flow paths of varying lengths extending into the latter passages from said entry opening to said exit opening, the flow passages of said second conduit means also having entry and exit openings spaced endwise of said core at the opposite side of the latter to effect generally U-shaped flow paths of varying lengths extending into the latter passages from the last named entry opening to the last named exit opening, the walls of each flow passage diverging in the directions from the regions of the shorter flow paths to the regions of the longer flow paths and generally transversely of the direction of the fluid flow along said paths.

13. A heat exchanger comprising a core having separate flow passages for separate fluids and partitioned from each other by walls of heat conductive material, each flow passage having spaced entry and exit openings, and means effecting curved fluid flow paths of varying lengths within each flow passage from its entry opening to its exit opening comprising the walls of each flow passage diverging in the directions from the regions of the shorter flow paths to the regions of the longer flow paths and generally transversely of the direction of fluid flow along said paths.

14. In a heat exchanger according to claim 10, the spacing between the juxtaposed walls of both the first and second conduit means at the region intermediate the associated entry and exit openings and adjacent the side of the conduit means having the entry and exit openings increasing toward said opposite ends, and the spacing between the juxtaposed walls of both the first and second conduit means at the region intermediate the associated entry and exit openings and adjacent the side of the conduit means remote from its entry and exit openings decreasing toward said opposite ends.

References Cited in the file of this patent

UNITED STATES PATENTS

785,580	Shiels et al.	Mar. 21, 1905
1,636,958	Harter	July 26, 1927
2,019,351	Lathrop	Oct. 29, 1935
2,081,678	Rosenblad	May 25, 1937
2,288,061	Arnold	June 30, 1942
2,321,110	Shipman	June 8, 1943
2,596,008	Collins	May 6, 1952
2,613,920	Flint	Oct. 14, 1952