Dec. 13, 1966 T. P. NICHOLSON 3,291,206

HEAT EXCHANGER PLATE

Filed Sept. 13, 1965 4 Sheets-Sheet 1

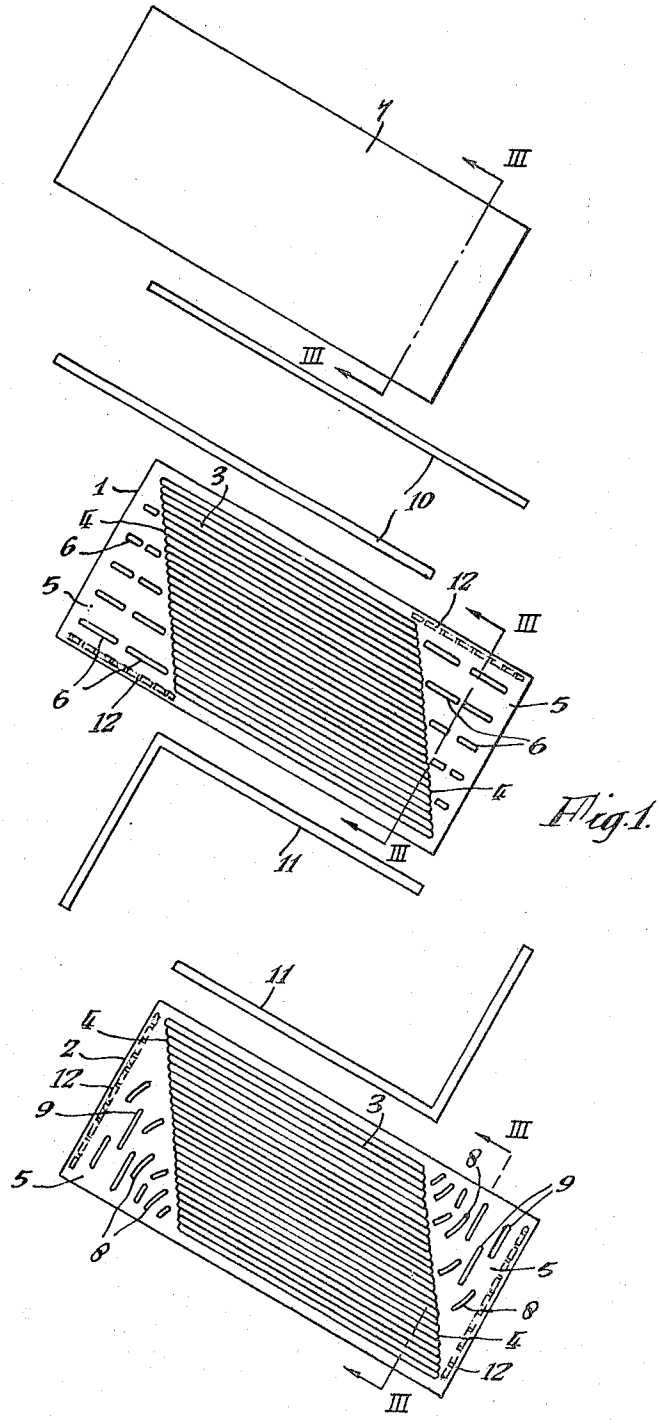


Fig. 1.

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HEAT EXCHANGER PLATE

Filed Sept. 13, 1965 4 Sheets-Sheet 2

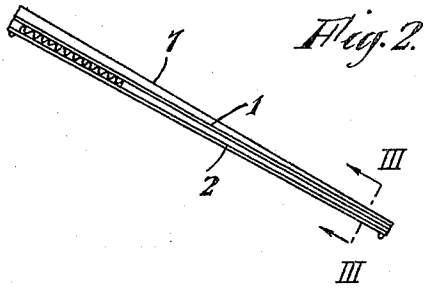


Fig. 2.

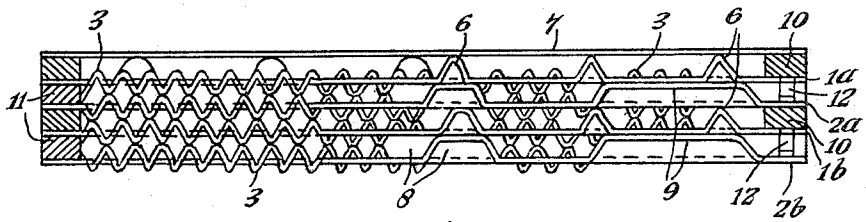


Fig. 3.

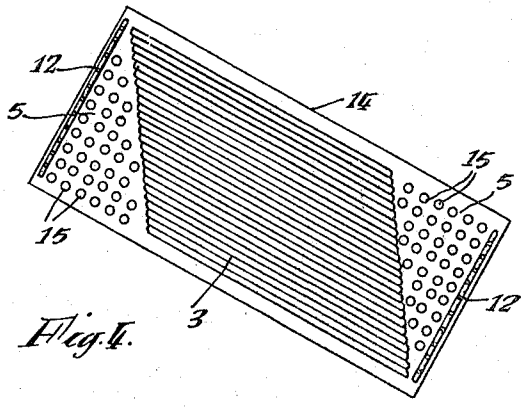


Fig. 4.

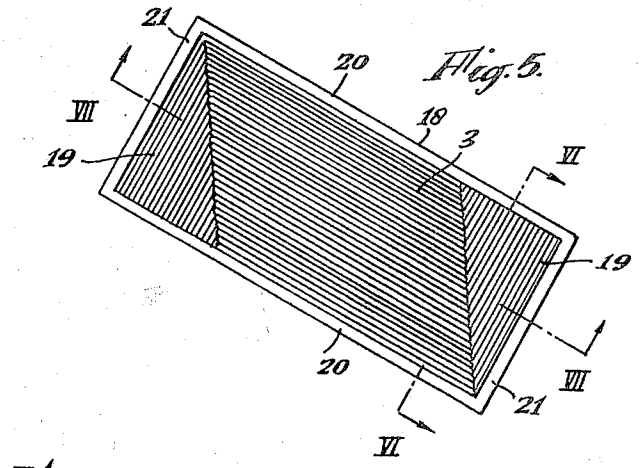

21
20
18
3
19
VII
VI
19
20
21
VII
VI

Fig. 5.

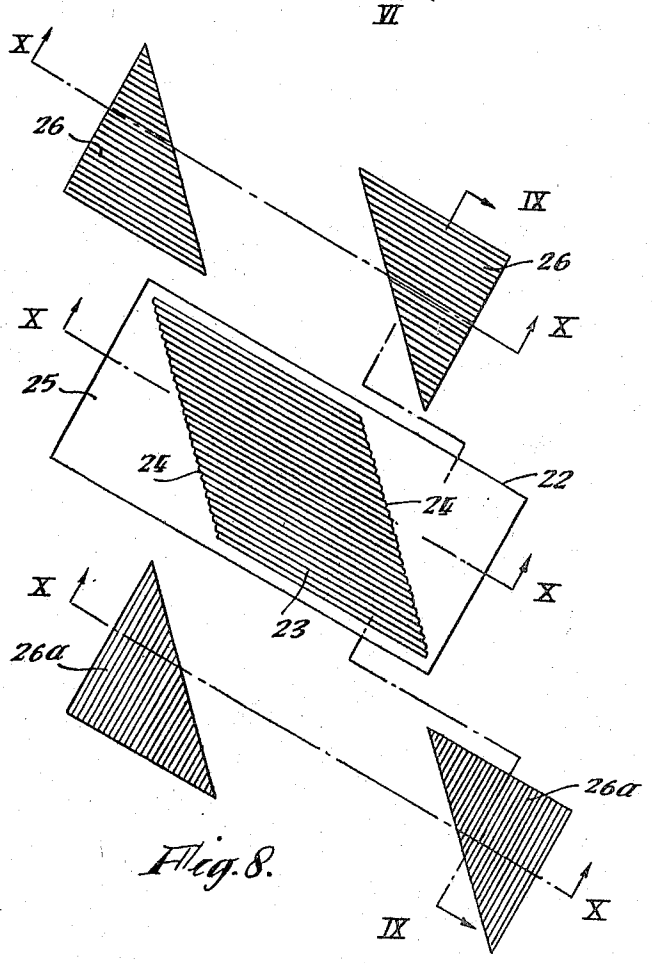

X
26
IX
26
X
X
25
24
24
22
X
23
26a
26a
X
IX

Fig. 8.

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HEAT EXCHANGER PLATE

Filed Sept. 13, 1965 4 Sheets-Sheet 4

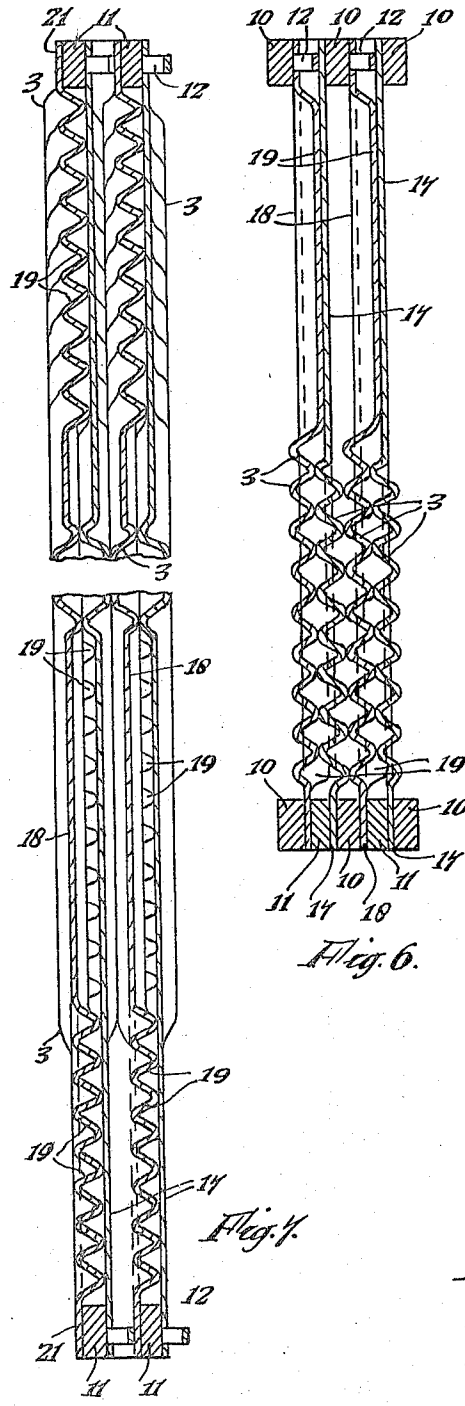


Fig. 4.

Fig. 6.

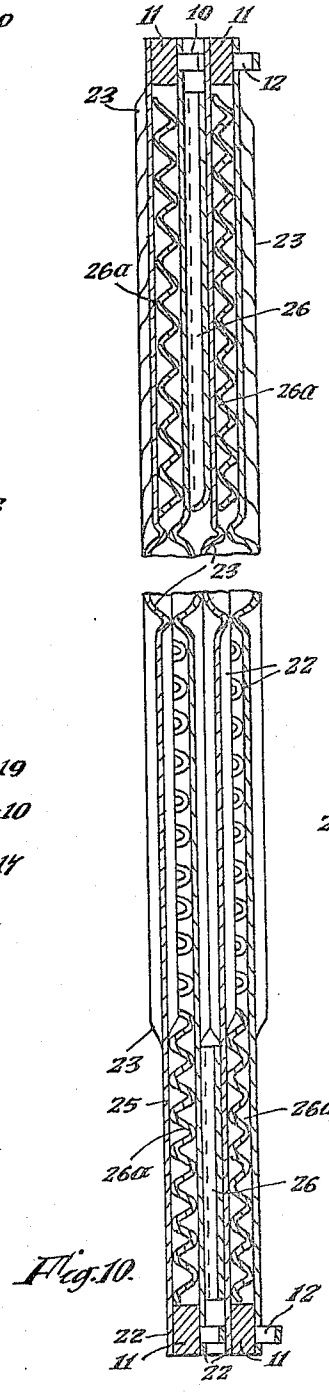


Fig. 10.

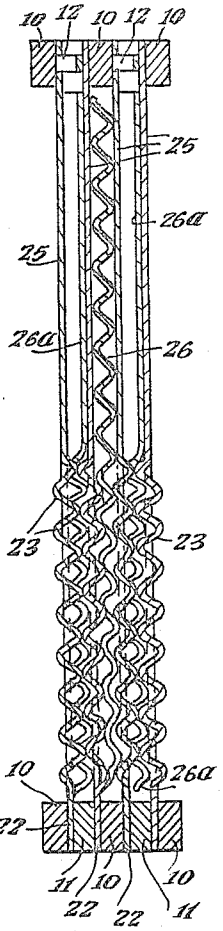


Fig. 9.

United States Patent Office 3,291,206 Patented Dec. 13, 1966

3,291,206

HEAT EXCHANGER PLATE

Terence Peter Nicholson, Craigmillar, Stocksfield, Northumberland, England

Filed Sept. 13, 1965, Ser. No. 486,982
8 Claims. (Cl. 165—166)

This application is a continuation-in-part of my application Serial No. 257,707, filed February 11, 1963, now abandoned and relates to heat exchangers of the type wherein channels for the flow of fluids between which heat exchange is to occur are formed and separated by a plurality of plates (hereinafter called a "heat exchanger of the stated type").

The invention has for objects to provide improved forms of corrugated plates from which heat exchangers of the above-stated type can be constructed, and improved heat exchangers so constructed.

Another object of the invention is to provide improved forms of corrugated plates which are adapted for assembly in the construction of a heat exchanger so that each plate constitutes a primary element for exchange of heat between two fluids passing one on each side of the plate. The plates provided by the invention are thereby distinguished from many types of corrugated plate known in the art, which serve as secondary heat exchange elements, the function of which is solely to conduct heat from one fluid passing on both sides of the corrugated plate to flat plates between opposed faces of which the corrugated plate is sandwiched, said flat plates serving as the primary heat exchange elements between said one fluid and another fluid passing on both sides of further corrugated plates in contact with the other faces of said flat plates.

According to the invention, a plate for use as a primary heat exchange element in the construction of a heat exchanger of the stated type is rectangular with two parallel, narrow, flat margins and a zone between said margins comprising continuous corrugations integrally from in the plate and having alternate half waves projecting on opposite sides of the median plane of said plate, the corrugations extending longitudinally parallel to said margins and terminating short of each end of the plate on two parallel, oblique lines, one of said oblique lines extending from adjacent the end of one of said flat margins to an intermediate point in the length of the other of said margins, and the other of said lines extending obliquely from adjacent the end of said other margin to an intermediate point in the length of said one margin, each of said oblique lines and a narrow, flat margin of the adjacent end of the plate defining one of two triangular end zones of the plate.

A rectangular plate with corrugations as aforesaid enables a heat exchanger to be constructed by assembling a plurality of the plates in a pile with their oblique bands of corrugations congruently disposed, so that each plate serves as a primary heat exchange element (i.e. has one of two fluids in direct contact with one surface and the other fluid in direct contact with its other surface) the termination of the corrugations at said triangular end zones on both sides of the plate enabling the provision of inlet and outlet openings for one fluid laterally and for the other fluid longitudinally at said end portions.

In one form of corrugated plate which affords excellent resistance to possible deformation of the plates, when assembled as a primary heat exchange element in a heat exchanger wherein the fluids at opposite sides of each plate are under widely different pressures, in the zones at each end of the plate embossments may be formed on the plate of one side of said plane of the margins at both ends.

The aforesaid embossments may be thimbles, the term

"thimble" being intended to define an individual embossment which is conical, pyramidal, semi-ovoid or hemispherical, or alternatively each of said embossments may be a short length of a corrugation, or the like, in the material of the plate, rising from a base located at said plane of the margins. A plurality of ranks such as thimbles may be formed in alignment with some of the longitudinal corrugations so as to extend across the width of the zone at the end of the plate. Alternatively, short corrugations in the end zone may comprise some which are transverse and some which extend in arcuate loci form one lateral margin of said zone, tending towards the longitudinal direction nearer to the ends of the continuous longitudinal corrugations.

In an alternative mode of producing rectangular plates according to the invention with end or lateral inlet and outlet channels, as required, each plate may be provided with an oblique band of continuous longitudinal corrugations projecting from both sides of its plane, the triangular end zones being left plane, corresponding triangular portions of wholly corrugated sheet metal being welded to the surfaces of said plane end zones. Evidently, said triangular portions will be disposed with their corrugations extending longitudinally to provide end inlet and outlet channels, and extending transversely to provide lateral inlet and outlet channels; when said plane end zones have the form of right-angled isosceles triangles, identical triangular corrugated portions may be employed, and simply disposed before welding with their corrugations extending longitudinally or laterally.

In the construction of a heat exchanger with corrugated or otherwise embossed plates as aforesaid, such plates may be assembled in juxtaposition with the ridges of their opposed corrugations in mutual lengthwise contact, spacer elements having a thickness equal to the total depth of corrugation of one plate being interposed between flat marginal portions of said plates.

Another object of the present invention is to provide adaptations of the plates as aforesaid more particularly for the production of annular heat exchangers, wherein the median plane of each plate is radial or substantially radial to the axis of the heat exchanger.

To this end, the invention further provides plates as aforesaid wherein the depth of the corrugations increases progressively from one end to the other of each plate. Since in an annular heat exchanger there may be a very large number of plates, for example, 300–400, the progressive increase of depth may be very slight, and equivalent to an angle of no more than 2°.

Embodiments of heat exchanger plates, in accordance with the invention, will be described by way of example with reference to the accompanying diagrammatic drawings, wherein:

FIG. 1 is an exploded view of a group of plates and spacers,

FIG. 2 is a lateral view of the same assembled,

FIG. 3 is a transverse section, on an enlarged scale, on the lines III—III of FIGS. 1 and 2,

FIGS. 4 and 5 are face views of two alternative forms of plate,

FIG. 6 is a transverse section on the line VI—VI of FIG. 5,

FIG. 7 is a longitudinal section on the line VII—VII of FIG. 5,

FIG. 8 is an exploded view of components of another form of plate,

FIG. 9 is a transverse section, on the line IX—IX of FIG. 8, and

FIG. 10 is a longitudinal section on the line X—X of FIG. 8.

FIGS. 1–3 of the drawings show two variants of an embossed heat exchanger plate according to the invention, assembled as the first pair of a regular series or pile with a flat exterior plate. As shown in FIG. 2, the spaces between each two plates may be tapered so that the heat exchanger has a sector form capable of association with others into a completely annular heat exchanger as will hereinafter be described. Evidently, as an alternative, the plates may be parallel so that the heat exchanger unit is a cuboid block.

Each of the embossed plates **1** and **2** is rectangular, and has a series of longitudinal corrugations **3** extending across the width of the plate and terminating at oblique lines **4** extending approximately from diagonally opposite corners of the plate, so as to leave triangular end zones **5** with their apices at said opposite corners. In each of the plates **2** and **3** the corrugations may be of any suitable form which at any transverse line project equally and alternately on opposite sides of the median plane of the plate. The corrugations may be triangular so that when two plates are abutted they afford diamond section passages, or may be trapezoidal to afford hexagonal passages, or may be sinusoidal so that the passages are approximately circular.

In the plate **1**, which is intended to provide a longitudinal pass for fluid between end inlet and outlet openings, in each end zone **5** the plate is embossed on one side with short longitudinal corrugations **6** in ranks distributed over the width of the end zone. These short corrugations have a height equal to the total height of the corrugations **3** on both sides of the plate **1**, so that in a series of alternate plates **1** and **2** the corrugations **6** support the end zone of the overlying plate. Thus, as shown in FIG. 3, the corrugations **6** of the plate **1***a* abut and support a flat exterior plate **7**, while the corrugations **6** of plate **1***b* abut and support portions of the end zones **5** of the overlying plate **2***a*.

In the plate **2** as shown in FIG. 1, which is intended to provide a longitudinal pass for fluid between lateral inlet and outlet openings, each end zone **5** is provided with short corrugations including arcuate corrugations **8** which serve to divert fluid from the longitudinal to the lateral course, or vice versa, and transverse straight corrugations **9** which direct the fluid laterally. Like the corrugations **6** in the end zones of the plate **1** the corrugations **8** and **9** of the plate **2** have a height equal to the total height of the corrugations **3** on both sides of the same plate **2**; thus, as seen in FIG. 3, the corrugations **8** (which are shown partly in transverse section and partly in elevation) and the corrugations **9** (which are shown in transverse section) of the plates **2***a* and **2***b* respectively abut and support the end zones of the overlying plates **1***a* and **1***b*.

In the assembly of alternate plates **1** and **2** and the flat exterior plate **7**, spacing strips are suitably located between portions of the margins of the several plates. Where end inlet and outlet openings are to be provided, as between the plates **1***a* and **7** and the plates **1***b* and **2***a* in FIG. 3, and also of course between the plate **2***b* and the underlying plate of the series **1** and so on, the spacer strips **10** are straight and extend along the full length of both sides of the two plates. Where lateral inlet and outlet openings are to be provided, as between the plates **1***a*, **2***a* and **1***b*, **2***b* in FIG. 3, the spacer strips **11** are of L-form so that each extends across the margins of one end of the pair of plates, and from that corner of each plate which is closely approached by the corrugations **3**, along one side of the plate to the other end of the adjacent corrugation, so as to leave open the side of each triangular end zone **5**.

For supporting the margins of the plates at the inlet and outlet openings, they are provided across each of these openings with a series of arch-form projections **12**, in each plate on the side opposite the projections **6** or **8**, **9** respectively in the end zones, as shown, for example, in FIG. 3 on the plates **1***a* and **1***b* wherein these projections **12** are located at the sides of triangular end zones. Likewisein the plates **2** the arch-form projections **12** are located across the end margins of the end zones **5** to support end inlet and outlet openings. These arch projections afford very little restriction of the area of the opening, since only the edges of said arched portions are presented to the flow of fluid, which can pass inside as well as outside the arches.

When a mode of assembly of the plates with spacer strips as described is employed for the construction of a sector form heat exchanger unit or a completely annular heat exchanger, it is not necessary that each of the plates should be strictly in a plane radical to the axis of said unit or heat exchanger. This enables the advoidance of a disadvantage which would follow from the necessity to make the L-form spacer strip **11** with tapering thickness if the plates **1** and **2** between which they are located were to be mutually inclined as shown in FIG. 2. Assuming that the angle between the underside of the plate **7** and the underside of the nearest plate **2** were to be 4°, while maintaining this angularity between the plates **7** and **2**, the intermediate plate **1** may be located parallel to the plate **2** by the provision of L-form spacers **11** having uniform thickness, the radially extending straight spacer strips **10** between the plates **1** and **7** having said taper of 4°.

FIG. 4 shows another form of heat exchanger plate **14** according to the invention, having a similar oblique band **3** of corrguations and triangular end zones **5** in which are located longitudinally and transversely extending ranks of thimbles **15**. Since this arrangement of thimbles will permit flow of fluid either longitudinally or laterally, a heat exchanger having end inlet and outlet openings for one fluid and lateral inlet and outlet openings for another fluid may be constructed from an assembly of one single type of plate **14**. The thimbles **15** are made to project entirely on one side of the plate and have a height equal to the total height of the corrugations **3** on both sides of the plate (like the short corrugations **6**, or **8**, **9** of the plates **1** and **2** as shown in FIG. 3); in this latter case it may be desirable to provide on each plate **14** a series of arch-form projections **12** as shown in FIG. 4 extending across the intended inlet or outlet opening, although this necessitates ultimately two differently finished types of plate **14**.

FIGS. 5, 6 and 7 show yet another form of plate **18** having an oblique series of longitudinal corrugations **3**, between narrow, flat, lateral margins **20** and triangular end zones which are wholly occupied by transversely extending corrugations **19**, except for narrow transverse margins **21**. As shown more clearly in FIGS. 6 and 7, to construct a heat exchanger unit from plates of this kind it is necessary to assemble the plates **18**, in each of which the transverse corrugations **19** are located on one side of the plane of the margins and have a height equal to the total depth of the corrugations **3** on both sides of the plate, in alternation with plates **17** (FIG. 5, 6 and 7) which have similar longitudinal corrugations **3** but no corrugations in their end zones. Thus, when the plates **17**, **18** are assembled into a unit with pairs alternately of L-form spacer strips **11** across the transverse margins **21** and along parts of the lateral margins **20** between those sides of the plates from which the transverse corrugations **19** project, and straight spacer strips **10** between the other pairs of plates, the unit is adapted to provide alternately passes for one fluid with end inlet and outlet openings and passes for the other fluid with lateral inlet and outlet openings through mutually abutting pairs of the transversely corrugated portions **19**. In order to support the margins of the inlet and outlet openings the plates **17**, **18** may be provided, like the plates **1** and **2** of FIG. 1, with arch-form projections **12** suitably located and as above described.

In order to avoid the necessity for providing two different plates, such as the plates **1** and **2** of FIGS. 1 and 3, or the plates **17**, **18** of FIGS. 5–7, the alternative may be adopted of providing as shown in FIG. 8 a single from of basic plate **22** (which is the equivalent of the plate **17**) provided with an oblique band of corrugations alternately projecting on both sides of the plate and terminating at lines which are at an angle of 45° to the length of the plate, leaving plane end zones **25** each of which has the form of a right-angled isosceles triangle. Corresponding triangular portions **26** or **26***a* of wholly corrugated sheet metal are welded to the surfaces of the plane end zones **25**. As indicated in FIGS. 9 and 10, on alternate plates **22** of a pack said triangular portions **26** are disposed with their corrugations extending longitudinally to provide end inlet and outlet openings. On the corresponding side of an adjacent plate triangular portions **26***a* are disposed with their corrugations extending transversely to provide lateral inlet and outlet openings. The total height of the corrugations in the portions **26**, **26***a* is equal to the projections of the corrugations **23** from the surfaces of both sides of the plate **22** so that when two plates are abutted the mutually registering longitudinally extending corrugations **23** are in contact at their ridges and the longitudinally corrugated portions **26** and the transversely corrugated portions **26***a* support the superposed plane end zones of the plates **22**. A plurality of plates **22** thus arranged can be assembled into a heat exchanger unit with the aid alternately of longitudinal spacer strips **10** and L-form spacer strips **11** as described with reference to FIGS. 1–3.

In the construction of heat exchangers or units thereof with plates and spacer strips as hereinbefore described, after assembly in a suitable jig the components can be permanently united by soldering or brazing over the areas where the sides of the spacer strips **10**, **11** are superposed, and at the corners where end and lateral openings converge, i.e. at the corners to which an end opening on one side of each plate and a lateral opening on the other side of the same plate both extend.

As can be seen from each of the transverse sections, FIGS. 3, 6 and 9, in a heat exchanger comprising a pile of plates assembled with spacer strips, the plates may be arranged so that the peaks of the longitudinal corrugations in each two adjacent plates abut one another. This provides for the mutual supporting of the plates when two fluids passing, either in co-current or counter-current movement, one on each side of each plate, are at substantially different pressures. The arrangement also provides, over the area of the congruent oblique bands of longitudinal corrugations in the superimposed plates, a series of individual, parallel passages which may be hexagonal, rhomboidal or substantially ovoid, according to the form of the corrugations; this arrangement may be achieved with a pile of plates, in which the band of longitudinal corrugations extending between the lateral margins is identical in the plates and comprises a number of complete waves, e.g. sinusoidal waves, so that when alternate plates are turned end for end, peaks of the corrugations in the two plates are opposed, and troughs are likewise opposed.

Evidently, the invention affords means for the construction of a variety of heat exchangers, of annular form, and in various box-like forms. Further, heat exchangers constructed of plates according to the invention may be made in various sizes according to the required duty. For example, an annular air preheater assembly for a gas turbine may be constructed of thin plates having a radial dimension of 6″ and an axial dimension of about 2–3″, the inner annular surface having a diameter of about 4–12″ and the outer annular surface consequently having a diameter of about 16–24″. At the other end of the range, a heat exchanger according to the invention may be provided, for example, for preheating of combustion air or condensation of steam in industrial power plant, and may, for example, be made of steel plates of relatively substantial thickness, and have a diameter up to 30 feet; such plates may be made substantially in the manner described with reference to the accompanying drawings and welded together with suitable spacing elements and/or manifolds for the construction of the heat exchangers.

For convenience of assembly, an annular heat exchanger may be constructed from portions of sector form, the outer plates of each sector being flat so that when two such plates are abutted together no passage is afforded between them.

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

1. In a heat exchanger, a plurality of noncommunicating fluid passages for two fluids separated by a series of stacked rectangular plates which are operative as primary heat exchange elements, said rectangular plates having two parallel narrow flat margins and a zone between said margins comprising continuous corrugations integrally formed in the plate and having alternate half waves projecting on opposite sides of the median plane of said plate, the corrugations extending longitudinally parallel to said margins and terminating short of each end of the plate on two parallel, oblique lines, one of said oblique lines extending from adjacent the end of one of said flat margins to an intermediate point in the length of the other of said margins, and the other of said lines extending obliquely from adjacent the end of said other margin to an intermediate point in the length of said one margin, each of said oblique lines and a narrow, flat margin of the adjacent end of the plate defining one of two triangular end zones of the plate said plate having formed and distributed over each of said end zones, on one side of the plate, a plurality of embossments each having a height equal to the total height of said longitudinal corrugations.

2. A heat exchanger as claimed in claim **1**, wherein said embossments in said plate are short corrugations disposed in longitudinal ranks distributed over the width of the end zone.

3. A heat exchanger as claimed in claim **1**, wherein said embossments in said plate comprise short corrugations, some of which are disposed transversely to said longitudinal corrugations, and some of which are arcuate, each having one end directed towards the lateral margin of the end zone and the other end nearer to the ends of said longitudinal corrugations tending towards the longitudinal direction.

4. A heat exchanger as claimed in claim **1**, wherein said embossments in said plate comprise a plurality of thimbles located in ranks aligned with some of said longitudinal corrugations and distributed over the width of the end zone.

5. A heat exchanger as claimed in claim **1**, wherein said embossments in said plate are formed integrally in the plate and extend over the whole area of each of said end zones and comprise a plurality of corrugations which extend transversely to said longitudinal corrugations from the defining oblique line of said zone to the inner side of the flat lateral margin of said zone.

6. A rectangular plate for use as a primary heat exchange element in the construction of a heat exchanger of the stated type, with two parallel narrow flat margins and a zone between said margins comprising continuous corrugations integrally formed in the plate and having alternate half waves projecting on opposite sides of the median plane of said plate, the corrugations extending parallel to said margins and terminating short of each end of the plate on two parallel, oblique lines, one of said oblique lines extending from adjacent the end of one of said flat margins to an intermediate point in the length of the other of said margins, and the other of said lines extending obliquely from adjacent the end of said other margin to an intermediate point in the length of said one margin, each of said oblique lines and a narrow, flat margin of the adjacent end of the plate defining one of

two integral flat triangular end zones of the plate in the plane of said narrow margins, and triangular portions of wholly corrugated sheet metal welded on one side of the plate to the surface of each end zone, the total depth of the corrugations of said triangular portions being equal to the projections of the corrugations from the surfaces of both sides of the plate.

7. A heat exchanger as claimed in claim 6, wherein each of said triangular portions is disposed with its corrugations longitudinally aligned with the integral longitudinal corrugations of the plate.

8. A heat exchanger as claimed in claim 6, wherein each of said triangular portions is disposed with its corrugations transverse to the integral longitudinal corrugations of the plate.

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