July 3, 1962 W. HRYNISZAK 3,042,382

PLATE TYPE HEAT EXCHANGERS

Filed Oct. 27, 1958 6 Sheets-Sheet 1

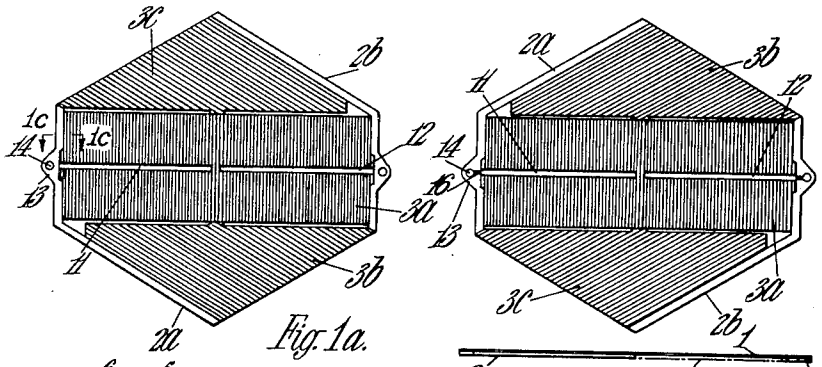



Fig. 1a.




Fig. 1b.



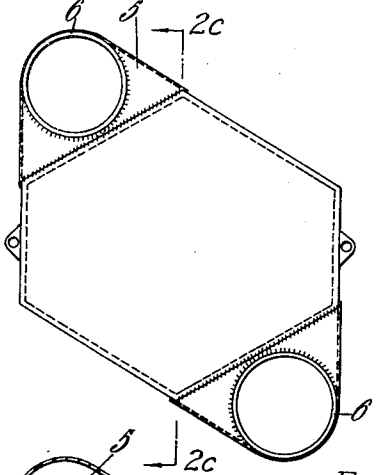




Fig. 2b.

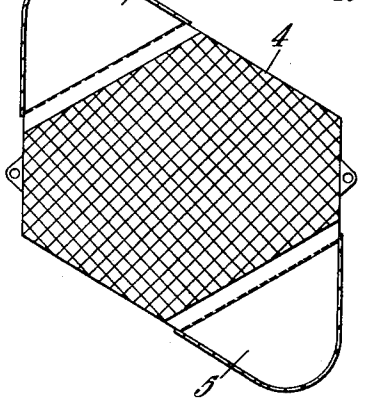



Fig. 2d.

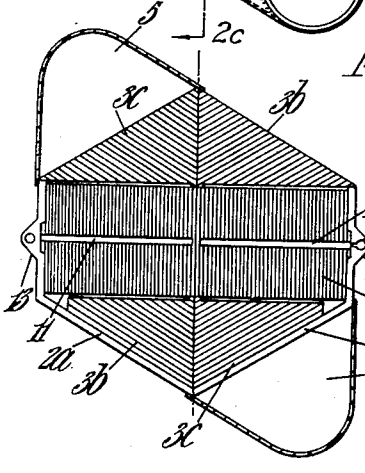



Fig. 2c.

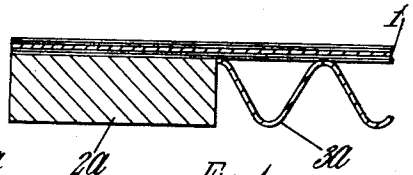



Fig. 1c.

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PLATE TYPE HEAT EXCHANGERS

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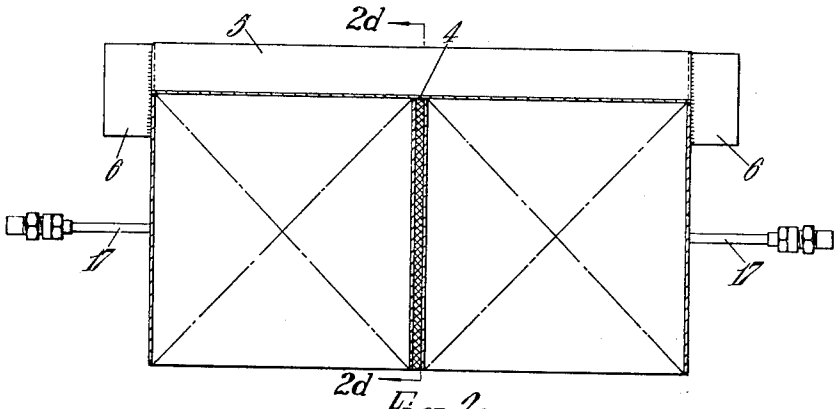



Fig. 2c.

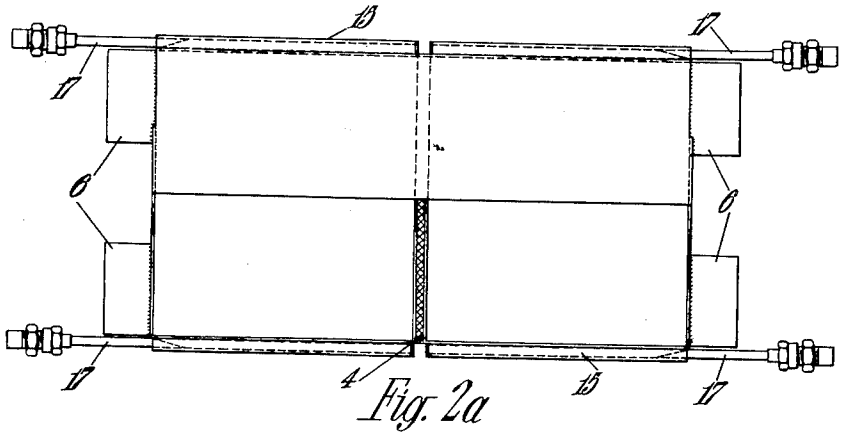



Fig. 2a

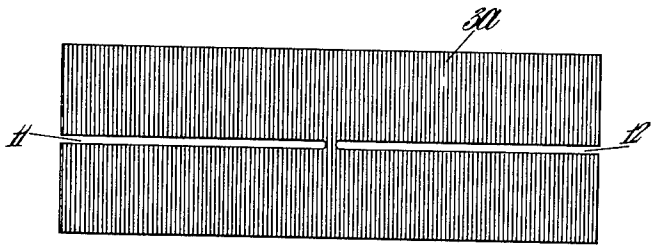



Fig. 6.

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Filed Oct. 27, 1958 6 Sheets-Sheet 3

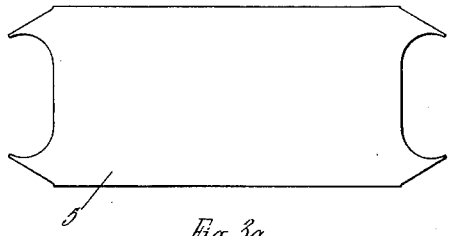



Fig. 3a.

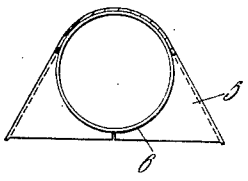



Fig. 3c.

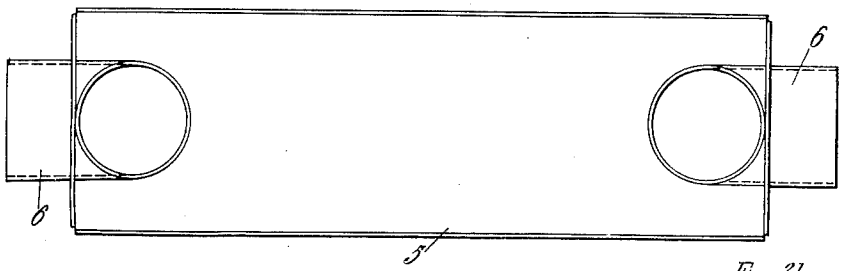



Fig. 3b.

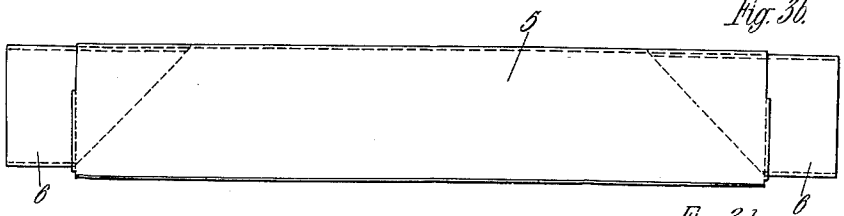



Fig. 3d.

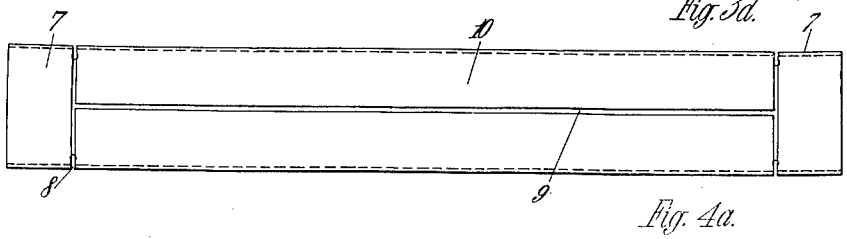



Fig. 4a.

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PLATE TYPE HEAT EXCHANGERS

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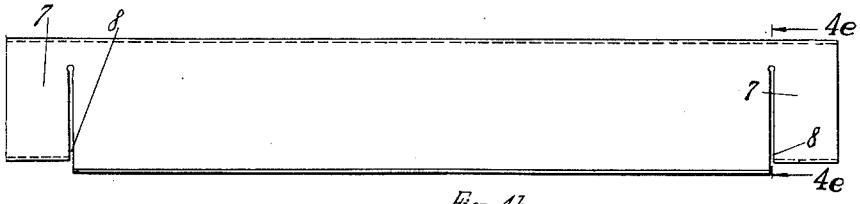



Fig. 4b.

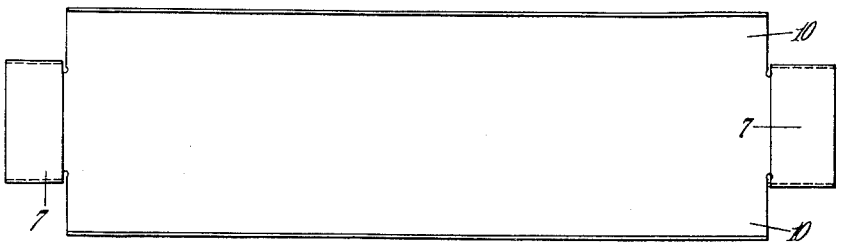



Fig. 4c.

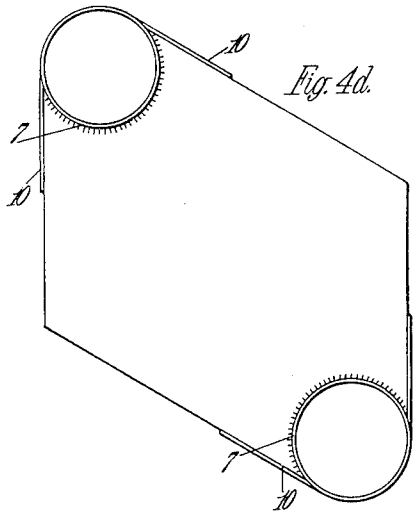



Fig. 4d.

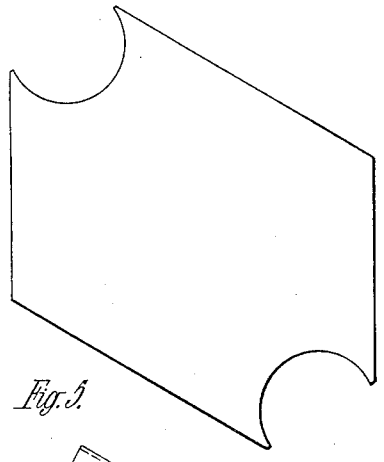


Fig. 5.

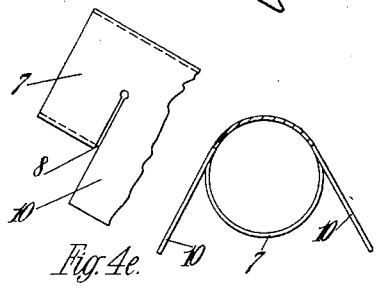



Fig. 4e.

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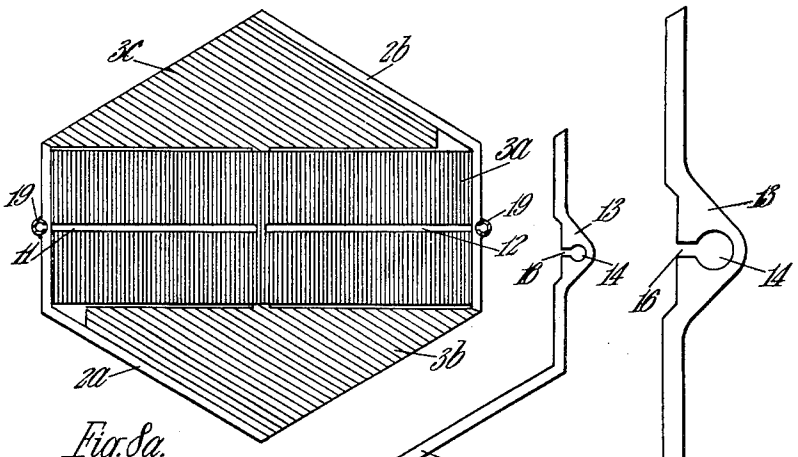



Fig. 8a.




Fig. 7b.

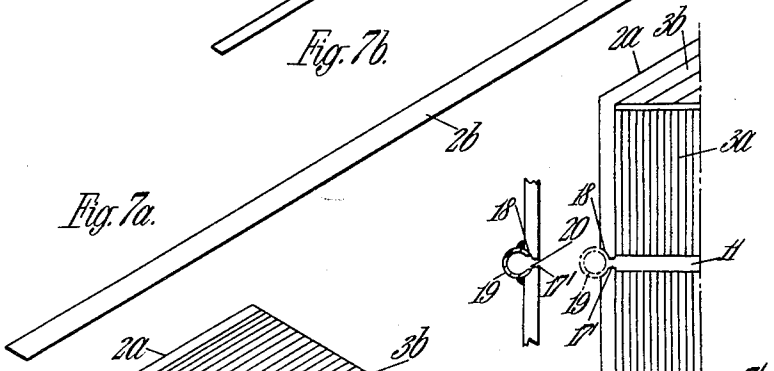



Fig. 7a.




Fig. 8e.

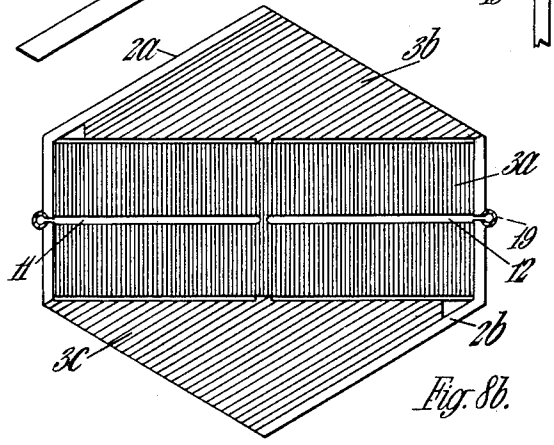



Fig. 8b.

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Filed Oct. 27, 1958 6 Sheets-Sheet 6

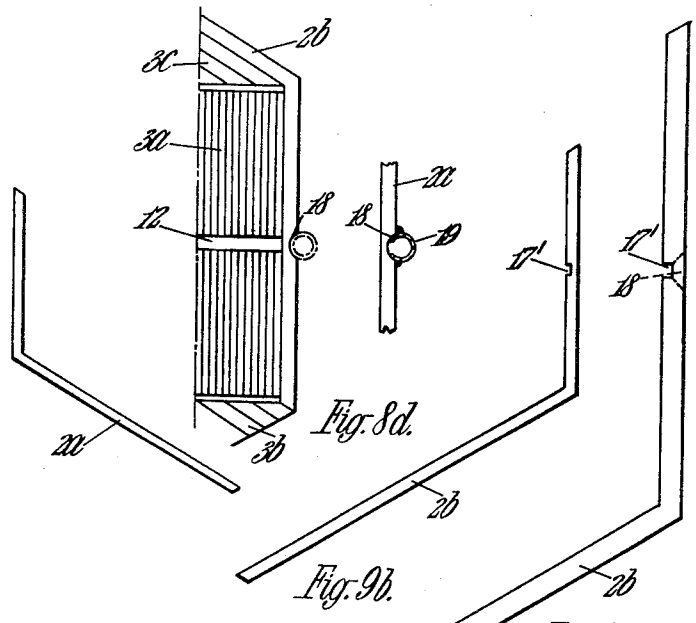



Fig. 8d.

Fig. 9b.

Fig. 9a.

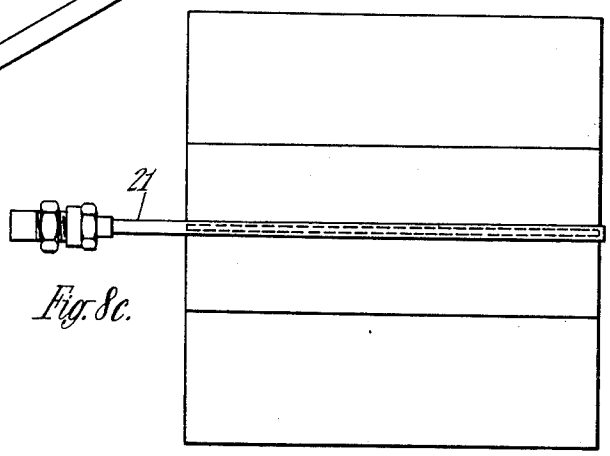



Fig. 8c.

United States Patent Office

3,042,382
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3,042,382

# PLATE TYPE HEAT EXCHANGERS

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Filed Oct. 27, 1958, Ser. No. 774,571
Claims priority, application Great Britain Oct. 31, 1957
1 Claim. (Cl. 257—245)

This invention relates to plate type heat exchangers of the kind comprising one or more heat exchange elements which elements comprise a series of spaced sheets separated from one another by side wall elements which form a flow channel, the inlets and outlets of which are displaced from the main direction of flow through said channel and such that the outlets and inlets of adjacent channels are staggered with respect to one another, said flow channels being subdivided into a plurality of flow channels by corrugated inserts between said spaced sheets. It relates especially but not exclusively to heat exchangers including heat exchange elements according to British Patent No. 718,991, that is to say in which the paths for hot fluid and cold fluid are separate, and in which heat transfer takes place through a wall separating the hot fluid and cold fluid, the heat exchanger consisting of one or more heat exchange elements, each element comprising a number of cells arranged in the form of a column or stack, each cell consisting of a flat base sheet and side walls which define a flow channel all of said side walls in the element being of identical shape and such that inlet and outlet openings to and from each cell are formed, which openings are angularly displaced from the line of direction of the flow channel, said side walls being inverted in adjacent cells thereby causing the inlets and outlets of one cell to be angularly displaced from those of an adjacent cell thus allowing for separate inlets and outlets for the hot and cold fluids respectively and allowing them to flow in counterflow with respect to one another in alternate cells, said flow channel being subdivided into a number of flow paths by means of a corrugated strip providing an increased heat transfer surface and structurally strengthening the cell, and in which the side walls of each cell are two in number and the corrugations of the corrugated strip are parallel and straight throughout their entire length.

The element of that British patent was adapted for easy construction and for positioning in a casing in ducts to which the heat exchanging fluids could be led.

When such elements are located in a series of such ducts in a casing not only is the weight of the heat exchanger increased by a certain amount of material which does not assist heat transfer, but in cases where the heat exchanging fluids are at substantially different pressures it has been found that difficulties arise in preventing leakage in the duct containing the element between inlets and outlets for said fluids especially across the contacting faces of element and duct.

The main object of the present invention is to provide improved means for conveying the heat exchanging fluids to and from said heat exchange elements.

In British Patent No. 732,977 is described means whereby elements which may be in accordance with British Patent No. 718,991 located in ducts as described above, can be cleaned regularly and automatically, but the devices described therein are not applicable to the construction of elements in accordance with the present invention as set out in the statements of invention below and a further object of this invention is to provide means for cleaning at regular intervals the passages of a heat exchange element incorporating the improved means for conveying the heat exchange fluid to and from the element as set out in the statements of invention below.



A further object is to provide means whereby two or more of said elements can be operated together.

The invention consists in a plate type heat exchanger comprising one or more heat exchange elements which elements comprise a series of spaced sheets separated from one another by side wall elements which form a flow channel the inlets and outlets of which are displaced from the main direction of flow through said channel and such that the outlets and inlets of adjacent channels are staggered with respect to one another, said flow channels being subdivided into a plurality of flow channels by corrugated inserts between said spaced sheets in which element ducts for the heat exchanging fluids are welded or otherwise bonded to the element inlets and outlets.

The invention also consists in a plate type heat exchanger in which the paths for hot fluid and cold fluid are separate, and in which heat transfer takes place through a wall separating the hot fluid and cold fluid, the heat exchanger consisting of one or more heat exchange elements each element comprising a number of cells arranged in the form of a column or stack, each cell consisting of a flat base sheet and side walls which define a flow channel, all of said side walls in the element being of identical shape and such that inlet and outlet openings to and from each cell are formed, which openings are angularly displaced from the line of direction of the flow channel, said side walls being inverted in adjacent cells thereby causing the inlets and outlets of one cell to be angularly displaced from those of an adjacent cell thus allowing for separate inlets and outlets for the hot and cold fluids respectively and allowing them to flow in counterflow with respect to one another in alternate cells, said flow channel being subdivided into a number of flow paths by means of a corrugated strip providing an increased heat transfer surface and structurally strengthening the cell, and in which the side walls of each cell are two in number and the corrugations of the corrugated strip are parallel and straight throughout their entire length, the characteristic feature according to the present invention being that the element ducts for the heat exchanging fluids are welded or otherwise bonded to the element inlets and outlets.

The invention also consists in a plate type heat exchanger in accordance with either of the preceding two paragraphs in which only ducts for high pressure fluid are welded or otherwise bonded to the element.

The invention also consists in a plate type heat exchanger in accordance with any of the preceding three paragraphs in which the ducts are formed by curved sheets which are welded to the element adjacent the inlets and outlets the said sheets forming an enclosed space with openings at opposite faces thereof into which tubular ducts are fitted.

The invention also consists in a plate type heat exchanger in accordance with any of the preceding four paragraphs in which the ducts are formed by forming a longitudinal slot in a tubular duct for a distance intermediate its ends, forming slots in a circumferential direction for a distance equal to half the circumference of the duct at each end of the longitudinal slot, the portion of the duct bonded by the slots being opened up and welded to the element so as to form a duct having tubular portions at each end thereof and a portion of domed cross-section in between.

The invention also consists in a plate type heat exchanger in accordance with any of the preceding five paragraphs in which two or more elements are arranged in alignment each separated by a heat insulating mem-

ber the aligned members having common inlet and outlet ducts.

The invention also consists in a plate type heat exchanger in accordance with any of the preceding six paragraphs in which the corrugated sheet in each flow channel is in two parts spaced from each other in the direction of flow, a slot being formed in each side of the element opening into said spaces between the corrugated sheet and a duct welded to the element each side thereof and having an opening in one side therein in communication with said spaces so that cleaning fluid may be introduced into each flow channel.

The invention also consists in plate type heat exchangers substantially as described below with reference to the accompanying drawings in which:

FIGURES 1*a* and 1*b* show the form of alternate flow channels of a heat exchange element used in accordance with one form of the invention;

FIGURE 1*c* is a part section on line **1***c*—**1***c* of FIGURE 1*a* to a larger scale;

FIGURE 2*a* is a plan view of two elements in axial alignment and showing a ducting arrangement used in accordance with one form of the invention;

FIGURE 2*b* is an end elevation of FIGURE 2*a*;

FIGURE 2*c* is a section on line **2***c*—**2***c* of FIGURE 2*b*;

FIGURE 2*d* is a section on line **2***d*—**2***d* of FIGURE 2*c*;

FIGURE 2*e* is a section through the aforesaid element, one half showing details of one flow channel and the other half details of an adjacent channel;

FIGURES 3*a*, 3*b*, 3*c* and 3*d* respectively show details of one form of duct arrangement used in accordance with the invention;

FIGURES 4*a*, 4*b*, 4*c* and 4*d* respectively show details of an alternative form of duct arrangement used in accordance with the invention;

FIGURE 4*e* is a section, on line **4***e*—**4***e* of FIGURE 4*b*;

FIGURE 5 is a view of a modified form of end plate;

FIGURE 6 is a view of a centre corrugated sheet used in accordance with one form of the invention;

FIGURES 7*a* and 7*b* show details of a side wall used in accordance with one form of the invention;

FIGURES 8*a*, 8*b*, 8*c*, 8*d* and 8*e* respectively show details of a cleaning arrangement of the flow channels;

FIGURES 9*a* and 9*b* show details of a side wall in accordance with the construction of FIGURE 8.

In carrying the invention into effect in the forms illustrated by way of example and referring first of all to FIGURES 1*a*–1*c*, a heat exchange element is built up of a series of spaced sheets **1** (FIGURE 1*c*) of hexagonal shape separated by side walls **2***a*, **2***b*, to form a flow channel between each pair of sheets. As can be seen from FIGURES 1*a* and 1*b* the side walls lie along edges of the sheets and, in the spaces enclosed by the said side walls, are arranged corrugated sheets which divide the flow channel up into a number of smaller channels for the flow of heat exchanging fluid.

The corrugated sheets comprise a centre sheet **3***a* and inlet and outlet corrugated sheets **3***b* and **3***c* respectively. The side walls **2***a*, **2***b* are arranged so that the inlets and outlets are displaced from the direction of flow through the centre sheet **3***a* and accordingly the corrugations in the sheets **3***b* and **3***c* are disposed at an angle to the corrugations of sheet **3***a* as can be seen in FIGURES 1*a* and 1*b*.

The heat exchange element is built up by having flow channels of the form shown in FIGURE 1*a* alternating with flow channels of the type shown in FIGURE 1*b*, so that flow channels for hot fluid alternate with channels for cold fluid.

To complete an element end plates of similar shape to the spaced sheets but slightly thicker are added at each end of the element. In one example the spaced sheets **1** are 0.0028" thick and the end plates 0.048" thick.

When such heat exchange elements are to be subjected to high temperatures of the order of 600° C. and also to a pressure difference it is often advisable to use two elements in axial alignment with each other separated by a heat insulating pad, for example of asbestos, rather than a single element, so as to keep the length of an element within desirable limits. It has been found, in this respect, that the best length for an element, under these temperature conditions and when a pressure difference exists between the heat exchange fluids, is of the order of six inches and with the thickness of sheets envisaged this would mean about 150 flow channels in each element.

FIGURE 2*a* shows a plan view of two elements in axial alignment and incorporating ducts for conducting one of the heat exchange fluids to and from the two elements. While a duct can be used for both fluids it is only necessary to have the duct arranged for the fluid at the higher pressure.

FIGURE 2*b* shows an end elevation of the elements showing the general shape of the element and attached ducts.

FIGURE 2*c* is a section on line **2***c*—**2***c* of FIGURE 2*b*, but the cross section through the flow channels is not shown. In this view the elements can be seen separated axially by a pad **4** of asbestos.

FIGURE 2*d* shows a section on line **2***d*—**2***d* of FIGURE 2*c* and is a section through the asbestos pad **4**.

FIGURE 2*e* is in two parts, the left hand side being a section through a flow channel of the type shown in FIGURE 1*a*, whilst the right hand side shows a section through a flow channel of the type shown in FIGURE 1*b*.

FIGURES 3*a*—3*d* show details of the form of duct incorporated in the element of FIGURES 2*a*—2*e*. It consists of a plate **5** of the shape shown in FIGURE 3*a* which is bent into the shape shown in plan, and elevation and side elevation in FIGURES 3*b*, 3*c* and 3*d* respectively, to form a circular opening for pipes which are then welded to the plates at each end thereof.

To form the duct assembly, plate **5** and the attached pipes **6**, are then welded or otherwise bonded to the inlet and outlet for high pressure fluid as can be seen in FIGURES 2*a*, 2*b* and 2*c*.

As will be clear from FIG. 1*a*, the placement of the side walls **2***a* and **2***b* is such as to allow opening for flow of fluid between the upper left and lower right opposite sides of the hexagonally shaped cell, while in the cell shown in FIG. 1*b*, the placement is such as to allow flow between the upper right and lower left opposite sides of the hexagonal cell. The ducting for the high pressure fluid (FIGS. 2*b*, 2*e*, 2*a*) is positioned with relation to the stack of cells (alternately of the type shown in FIG. 1*a* and of the type shown in FIG. 1*b*) so as to provide for flow of the high pressure fluid through cells of the type shown in FIG. 1*a* between the two ducts **5** as shown in FIG. 2*e*.

An alternative duct arrangement is shown in FIGURES 4*a*—4*e*. In this form a duct **7** has radial and axial slits **8** and **9** respectively cut in it (see FIGURES 4*a* and 4*b*) intermediate its ends and the slit portions are then opened out as shown in FIGURE 4*c* to form two flap portions **10** (see FIGURE 4*c*), which are subsequently welded to the inlet and outlet of the element as shown in FIGURE 4*d*.

With this latter form of duct both end plates in the case of a single element or if two elements are axially aligned the two extreme end plates, must be modified as shown in FIGURE 5 to allow the welding of duct **7** to the element.

The invention also provides for the cleaning of such elements in a simple way.

Referring to FIGURE 1*a* the centre sheet 3*a* has slits **11** and **12** cut in it which stop short of each other in the centre of the sheet so that the resulting shape of the

sheet is rather like a letter H. This can be seen more clearly by reference to FIGURE 6 which shows the form of the centre sheet 3*a*. The side walls 2*a*, 2*b* have a projection 13 (see FIGURES 7*a* and 7*b*) in which is formed a hole 14. Similarly each spaced sheet has a projection which coincides with projection 13 when the element is assembled so that a continuous duct 15 (see FIGURE 2*a*) is formed, down each side of the element. In alternate sets of side walls as shown in FIGURES 7*a*—7*b* a slit 16 is cut so that when in position in the element the slit 16 puts the duct 15 in communication with the slits 11 and 12 in the centre sheet 3*a*. Cleaning air or fluid is then passed periodically through ducts 15 through connection 17 (FIGURE 2*a*) from which ducts it enters the corrugations and removes dust and other particles deposited there. Normally it is sufficient to clean only the low pressure side as on the high pressure side the passages are virtually self cleaning. If desired however, the cleaning fluid can be passed through all the flow channels instead of only alternate ones by simply forming slits 16 in the side walls of each flow channel.

In an alternative cleaning arrangement shown in detail in FIGURES 8*a*—8*e* and 9*a* and 9*b* each side wall is provided with a notch 17 and then after the element has been assembled and brazed together a milling cutter is used to cut out a further notch 18 of circular shape which opens into the notch 17. Into the notch 18 is welded a pipe 19 having a longitudinal slit 20 coinciding with the notch 17. This pipe 19 is then connected to a supply of cleaning air or cleaning fluid through connection 21 (FIGURE 8*c*).

If it is desired to clean only the low pressure side of the channels for one heat exchange fluid then, as before, all that is necessary is for the side walls of alternate flow channels only, to have notches 17 cut in them.

I claim:

A heat exchanger comprising an assembly of hexagonally shaped flat sheets, side walls spacing said sheets, each side wall having two portions at an angle to each other, each side wall lying along adjacent sides of a hexagonal sheet at opposite corners thereof, a rectangular shaped corrugated sheet disposed between each pair of sheets with the two shorter edges lying parallel to two



opposed parallel portions of the side walls and the corrugations running parallel to said shorter edges, the corrugations between each pair of sheets being parallel to one another and the side walls being disposed in adjacent pairs of sheets to provide inlets and outlets for a flow channel between one pair of sheets which are displaced from those for the flow channel between an adjacent pair of sheets, inlet and outlet means for conducting one heat exchanging fluid to the inlets and from the outlets of alternate flow channels and inlet and outlet means for conducting another heat exchanging fluid to the inlets and from the outlets of the remaining flow channels, the inlet and outlet means for at least one said fluid comprising inlet and outlet headers for the inlets and outlets for that heat exchanging fluid, one header being on the inlet face and the other on an outlet face of the heat exchanger, said headers consisting of tubular members having a slot formed therein for a distance intermediate their ends, and slots formed in a circumferential direction for a distance equal to half the circumference of the members at each end of the longitudinal slot, the portion of the duct bounded by the slots being open at the side thereof facing the said slots and having side portions continuing the duct wall remote from the said slots, means joining the said side portions to the heat exchanger to form a header having tubular portions at each end thereof and a portion of domed cross-section in between, and end plates at each end of the heat exchanger which seal the ends of the domed portions of the duct and to which the tubular ends of the duct are bonded.

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