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Shore

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[54] **HEAT EXCHANGERS**

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[52] **U.S. Cl.** **165/12,** 165/84, 165/166

[51] **Int. Cl.** **F28d 11/06**

[58] **Field of Search** 165/1, 83, 92, 12, 166, 165/84

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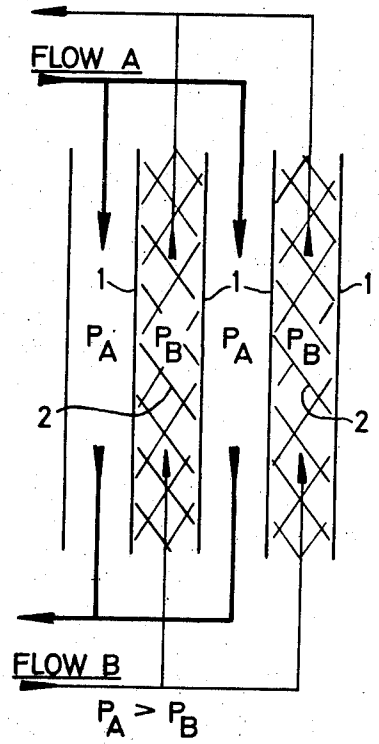
Primary Examiner—Charles Sukalo

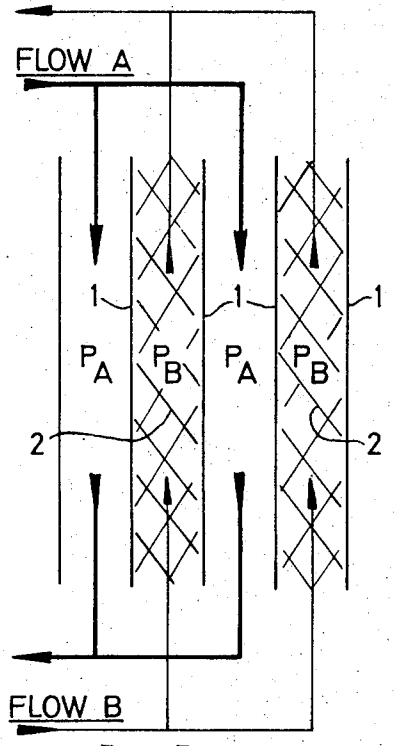
Attorney, Agent, or Firm—Christel & Bean

[57] **ABSTRACT**

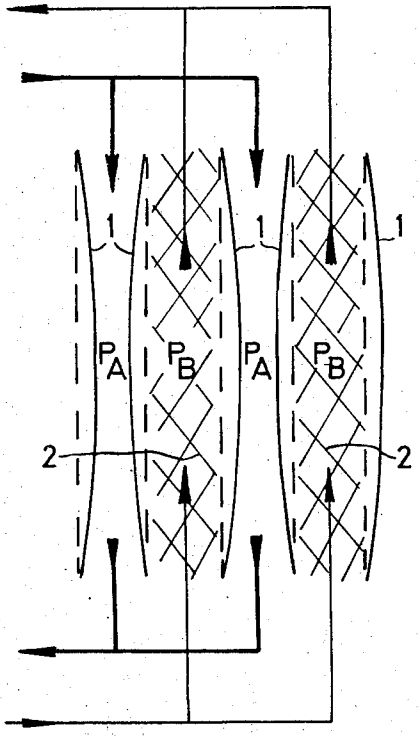
A heat exchange apparatus and method of using it comprising periodically flexing flexible flat heat transfer plates so as to vary the cross section of the flow space, thereby achieving turbulence which promotes improved heat transfer. The variation in cross section may be obtained mechanically or through varying the pressure of the medium on one side of the plate.

9 Claims, 10 Drawing Figures





$P_A > P_B$ FIG.1.



$P_A < P_B$ FIG.2.

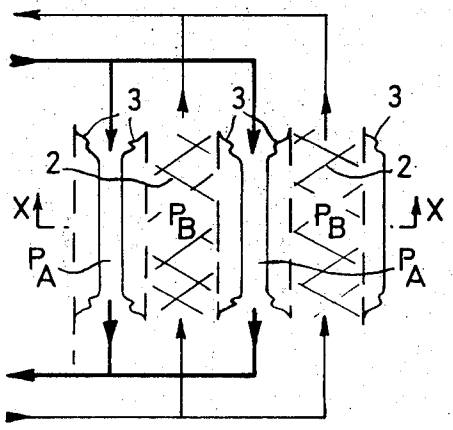
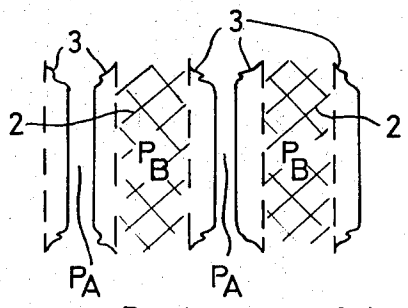


FIG. 3.



$P_A < P_B$ FIG.4.

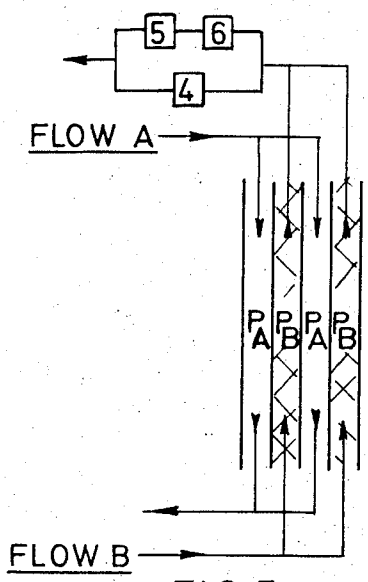


FIG. 5.

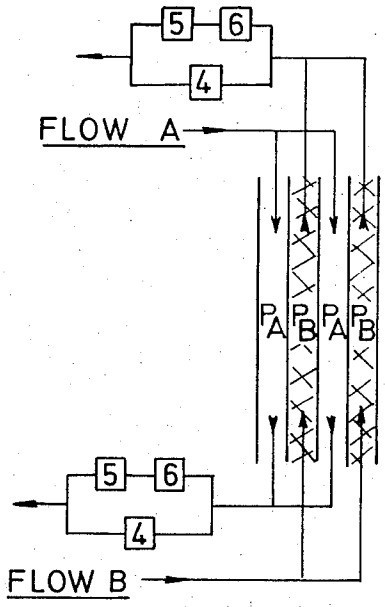


FIG. 6.

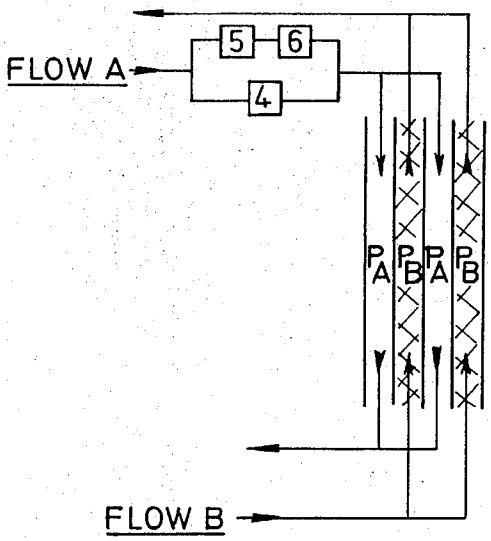


FIG. 7.

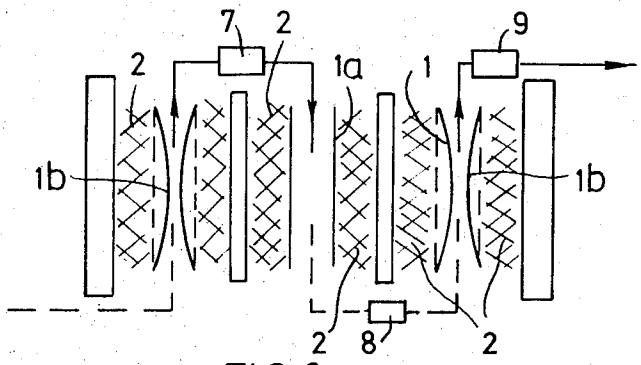


FIG.8.

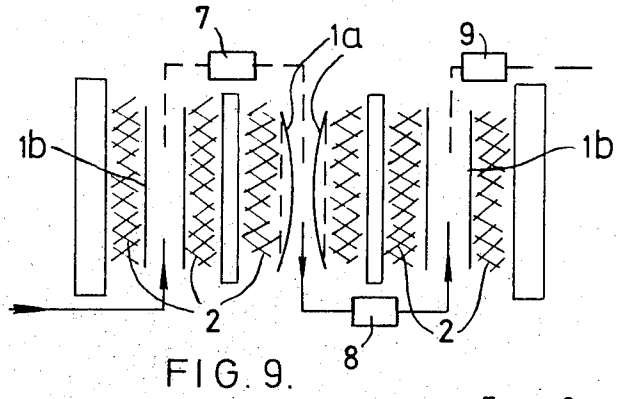


FIG. 9.

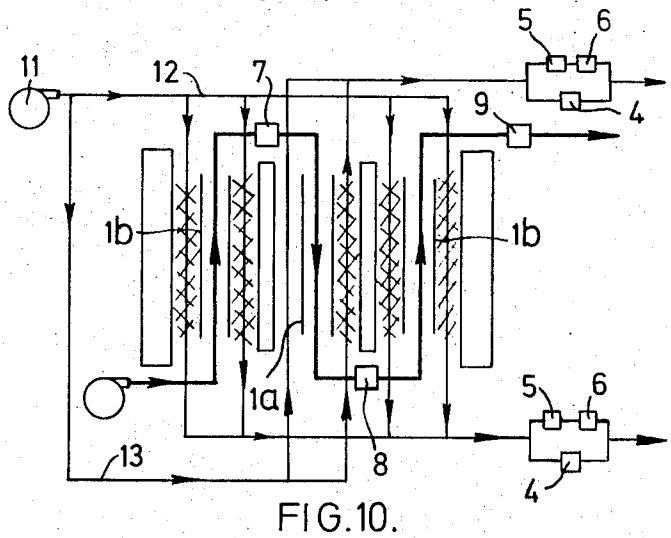


FIG.10.

HEAT EXCHANGERS

This invention relates to heat exchangers of the type comprising at least one flow space in which a liquid heat transfer medium to be treated flows as a thin substantially flat film, the flow space being bounded on at least one side of the film by a heat transfer plate also partially defining a flow space for a second heat transfer medium.

Such a heat exchanger may be of the gasketed plate type in which successive flow spaces are defined between plates in spaced face-to-face relationship and bounded by gaskets which also serve to control flow of the media from and to supply and return ducts for the media, which ducts are generally formed by aligned apertures in the plates.

Alternatively, the heat exchanger may be of the type in which the plates are welded together into cells each comprising a group of flow spaces and headers for the supply and discharge of the heat transfer media.

In the gasketed plate type of heat exchanger, which is currently in widespread use, there is a tendency towards larger plates. When, as is usual, the plates are of stainless steel or other metal or alloy, and are formed with patterns of turbulence promoting corrugations or other formations, the cost of press tools an presses for the formation of the plates becomes very high. It will be appreciated that the turbulence promoting formations also have a function in stiffening the plates to inhibit deformation under operating pressure, and crossing of the corrugations, or the cooperation of other formations is also used to provide interplate support to prevent deformation of the plates, and that such function becomes more necessary in the conventional heat exchangers as the size of the plates increases.

The present invention represents a break with these conventional types of heat exchanger in that controlled flexing of the plates is introduced to provide turbulence and promote heat transfer.

It has previously been proposed to provide flexible plates with spacer elements which extend only part way across a flow space when the plates are undeflected and to deflect the plates one way or the other. The purpose was to enable deposits of impurities, such as fibrous material, building up on the spacer elements to be removed by switching channels as and when required. In other respects, the operation was conventional.

The invention consists in a method of heat treating a first liquid heat transfer medium comprising passing it in a comparatively thin flat film into a flow space, bounded on at least one side by a flexible flat heat transfer plate, and cyclically flexing the plate to vary the cross section of the flow space, while passing a second medium in heat transfer relationship with the first medium through the said heat transfer plate.

The present invention further consists in a heat exchanger of the type comprising at least one flow space for passage of a first liquid heat transfer medium in the form of a comparatively thin flat film, the or each flow space being bounded on at least one side by a substantially flat heat transfer plate which serves partially to define a flow space for a second heat transfer medium, and means for cyclically flexing the flat heat transfer plate to five cyclic variation in the cross section of the or each flow space for the first heat transfer medium.

Thus, the expensive press tools for complex shapes of turbulence promoting corrugations are avoided.

Also, the flexing of the plate itself enables satisfactory heat transfer to be obtained with very viscous materials which cannot be made turbulent by the conventional turbulence-promoting ridges. Such viscous materials are normally treated in a so-called swept surface heat exchanger, and a heat exchanger according to the invention, with a comparatively small number, even down to one, of flow passages of the viscous material can provide a satisfactory heat transfer.

The cyclic flexing of the plates may be such as to give almost total displacement of the liquid medium in the flow space so that only very thin films are left at certain instants of the cycle, followed by an increase in section and a increase of the flow. The displacement action of the flow channel, by providing velocities other than in the normal direction of flow, improves the distribution.

The objections to previous forms of flat plate heat exchanger has been that heat transfer is inferior to that of plates having turbulence promoting corrugations unless the plates are very close together, and this leads to poor distribution across the flow space and possible blockage by fouling or suspended solids. Cyclic flexing overcomes these problems.

In the second medium flow spaces a support system may be provided, for example an expanded metal or plastic mesh. The heat exchanger would thus consist of thin flat plates which may be regarded as flexible membranes. The product flow channels being free of internal encumberance, while the second medium flow spaces contain a support grid or mesh. The product flow plates may be welded or all the plates may be sealed by rubber or asbestos gaskets. In the case of a gasketed design, external and internal support of the gasket may be provided. Gasket grooves may be accommodated in the plate, and this will require only a limited press action at the periphery of the plate surface, or it may be provided by support frames placed between each of the thin flat plate membranes.

If required a mesh or other compressible support system may also be incorporated in the flow spaces for the product median, although this would reduce the amount of flexure available. On the other hand, it would increase the inherent turbulence in the flow system.

It will be seen that by flexing the plates to vary the flow section, the frequency and amplitude of the variations can be chosen so as to cause variations in the flow and affect the velocity distribution, the holding efficieny, and also the heat transfer.

Under certain circumstances, the flexing of the plate can be made to provide a pumping action, particularly in a multi-pass heat exchanger having connector grids between the passes. The flexing of the plate may be by external hydraulic pressure or by mechanical means. For the case of external hydraulic pressure, this may be applied from the flow spaces for the second medium. The pumping action provided may replace or supplement the pump for the medium in question.

The flexible heat transfer surface may be much thinner than that used in conventional pressed plate heat exchanger design. The flexible material may be a metal or a single or laminated plastic film, using materials such as polyvinylchloride, polypropylene or polytetrafluorethylene. Although the thermal conductivity of

such plastics materials is low, the membrane type plates may be sufficiently thin as to offer an economic solution compared with conventional metallic pressed plates.

Where plastics material plates are employed, either the thickness or the modulus of elasticity employed adjacent to the plates edges may be so as to ensure that the displacement action is uniform across the width of the flow channel.

Changes in the modulus of elasticity may be effected by irradiation of the polymer material in local areas.

For the specific problem of dealing with very viscous fluids, the invention may be employed with advantage in a single flow channel. In this case the service fluid i.e., the other medium, will be passed through chambers on one or both sides of the heat transfer channel. By varying the pressure in the chambers a pumping action will be provided, while at the same time providing conditions for good heat transfer.

The invention will be further described with reference to the accompanying drawings, in which:

FIG. 1 and 2 are diagrams illustrating the construction and operation of one form of heat exchanger according to the invention;

FIG. 3 is a view similar to FIG. 2 of a modified form of heat exchanger;

FIG. 4 is a section on the line X—X of FIG. 3;

FIGS. 5, 6 and 7 illustrate three forms of pressure control for use in heat exchangers;

FIGS. 8 and 9 are diagrams to illustrate a pumping effect in a multi-pass heat exchanger; and

FIG. 10 is a diagram showing a pressure control system in a multi-pass heat exchanger.

Referring first to FIGS. 1 and 2, there is shown a group of plates 1 defining flow spaces PA and PB for two heat media, namely the product and a service fluid respectively. The service fluid flow spaces PB are packed with a support grid or mesh 2. In the condition shown in FIG. 1, the pressure of the product is somewhat greater than that of the service fluid, so that the plates are flattened against the support grid 2, so that the nominal flow section in the product flow spaces is maintained.

An example of this design concept uses stainless steel plates having a heat transfer surface measuring 36 inches × 60 inches. The plates are spaced one-eighth inch apart and sealed at their periphery by conventional rubber gaskets. One or more non-return valves are provided to ensure that the product only flows out of the discharge side of the product flow channel. To reach the condition of FIG. 2, a super-pressure in excess of 2 p.s.i. is applied to the service fluid chambers, causing a displacement in the product channel equivalent to a reduction in spacing of the plates by one-tenth inch. To ensure the maintenance of an adequate flow channel of the product side during the filling part of the cycle, it is preferred to maintain a super-pressure of at least 2 p.s.i. between the product channel and the service fluid channels. Thus, the pressure variation between the two channels swings from −2 p.s.i. to +2 p.s.i. The frequency of pressure change depends upon the product, its viscosity, and whether or not it is saturated with gas. Depending upon the materials of construction and the heat transfer problem, the frequency of pressure change would be between 0.1 and 2 cycles/second.

Air or gas should be excluded from the system as the compressibility will absorb the pressure pulses and limit the effect on the plates themselves.

When using plates of uniform stiffness, the plates 1 tend to bow out from their flat condition (shown in dashed lines in FIG. 2) so that their maximum deflection is only achieved at the centre region of the plates. In order to get a greater deflection over a major area of the plate, the plates may be provided with a weakened area 3 at the edges, as shown in FIGS. 3 and 4. In this form, the plates act as diaphragms, and the whole region away from the edges moves as a substantially flat zone bodily towards the adjacent plate, away from the rest position shown in dashed lines, so that there is a greater volume reduction in the flow space.

FIG. 5 illustrates one mode of achieving cyclic variation of the hydraulic conditions by cyclic throttling on the output side of the service fluid flow space PB. This is achieved by the use of a throttling system consisting of parallel arms comprising respectively an adjustable valve 4 and an adjustable valve 5 in series with an on-off valve 6. This three valve system has the advantages of allowing control of the pressure level by means of the adjustable valves, avoiding complete shut-off when the valve 6 is closed, and allowing control of the pressure differential.

FIG. 6 shows an arrangement in which a system of valves 4, 5 and 6 is arranged in the output sides of both the product and service fluid flow spaces PA and PB.

As shown in FIG. 7, it is also possible to have the throttling system of valves 4, 5 and 6 in the inlet side of either or both flow systems. It is also possible to throttle the output side of the product flow stream.

FIGS. 8 and 9 illustrate how cyclic variation of pressure on one side of the heat exchanger can exert a pumping action on the other side. The plates 1 are shown as constituting a downward pass 1*a* flanked by two upward passes 1*b*. Only one product flow passage of each pass is shown, although it will be appreciated that each pass could consist of a number of flow passages in parallel. Non-return valves 7, 8 and 9 are provided.

When the pressure is high in the service fluid side of the upward passes 1*b* and low in that of the downward pass 1*a*, product flows through the non-return valves 7 and 9, while the non-return valve 8 is closed. Upon reversal of the pressure condition, so that the system moves from the FIG. 8 condition to that of FIG. 9, non-return valve 8 opens and non-return valves 7 and 9 close, so that product flows into the upward passes and out of the downward pass in a forward direction. The product is thus pumped successively through the non-return valves 7, 8 and 9 by the cyclic pressure variation in the service fluid sides taking plate 180° out of phase.

FIG. 10 illustrates a simple form of control system for operating a multi-pass heat exchanger as described with reference to FIGS. 8 and 9. A pump 11 for the service fluid feeds two service fluid inlet lines 12 and 13 for the upward and downward passes 1*b* and 1*a* respectively, and the outlet lines for the service fluids are provided with variable throttling systems comprising three valves 4, 5 and 6 as described with reference to FIG. 5. A product pump 14 is provided to ensure that the first upward pass 1*b* is filled. The on-off valves 6 operate out of phase to achieve the pumping action

previously described. The pulse levels set by the adjustable valves **4** and **5** in the throttling systems may be automatically adjusted in accordance with the pressure levels prevailing in the opposed product flow channels by suitable control equipment is desired. With multi-pass operation, there could be sufficient stages, and also sufficient pressure differential, to cause total blockage of the flow passage in successive stages of the equipment, thus providing a pumping action which is comparable with a peristaltic pump.

In the case of the single heat transfer passage, or a pair of passages arranged back to back there is also the possibility of providing the compression of the flow channel by mechanical means such as the roller in a peristaltic pump design, although it will be appreciated that this would limit the heat transfer to one wall of the flow chamber.

Even such a simple design would provide in comparison with the swept surface heat exchanger, a much bigger heat transfer area at a lower cost per square foot.

Various modifications may be made within the scope of the invention.

I claim:

1. A heat exchanger of the type comprising at least flow space for passage of a first liquid heat transfer medium in the form of a comparatively thin flat film, each flow space being bounded on at least one side by a substantially flat heat transfer plate which serves partially to define a flow space for a second or another heat transfer medium, means for periodically flexing said plate to give periodic variation in the cross section of one or more flow spaces, and a support system in the second medium flow space.

2. A heat exchanger as claimed in claim **1**, in which the flow spaces are sealed by gaskets.

3. A heat exchanger as claimed in claim **1**, in which the flexing of the heat transfer plate is achieved by mechanical means operatively connected to said plate.

4. A heat exchanger as claimed in claim **1**, in which said means for flexing said plate includes means for varying the hydraulic pressure of the medium on one side of said plate.

5. A heat exchanger as claimed in claim **4**, in which the hydraulic pressure is the differential pressure between the flow spaces for the first and second heat transfer media and means is provided for cyclically varying this differential pressure.

6. A heat exchanger as claimed in claim **5**, in which the cyclically varying means comprises a throttling system in at least one of said flow streams.

7. A heat exchanger as claimed in claim **6**, in which the throttling system comprises two arms in parallel, one arm containing an adjustable valve, and the other arm containing an adjustable valve in series with an on-off valve.

8. A heat exchanger as claimed in claim **3**, in which the heat transfer plates to be flexed are weakened at the edges.

9. A heat exchanger as claimed in claim **1**, of a multi-pass type, comprising a non-return valve between each two passes.

* * * * *