July 18, 1967 E. I. VALYI 3,331,435

HEAT EXCHANGER WITH SINTERED METAL MATRIX

Filed Oct. 11, 1965 3 Sheets-Sheet 1

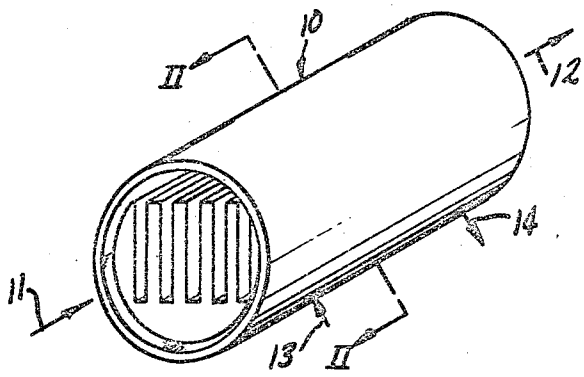


FIG - 1

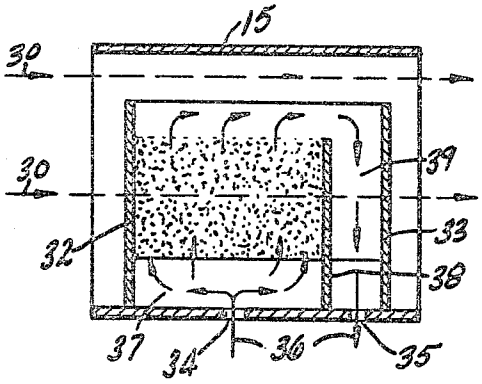


FIG - 3

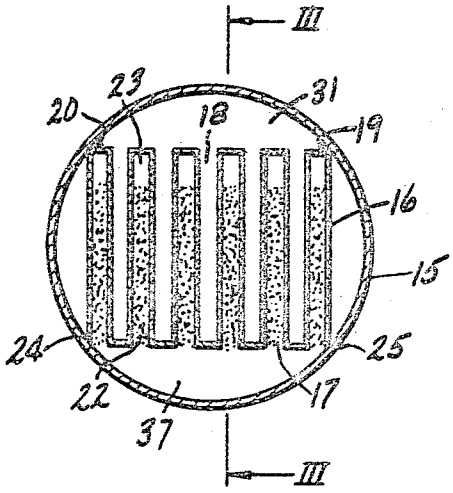


FIG - 2

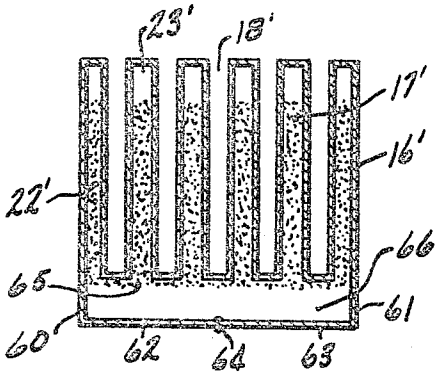


FIG - 8

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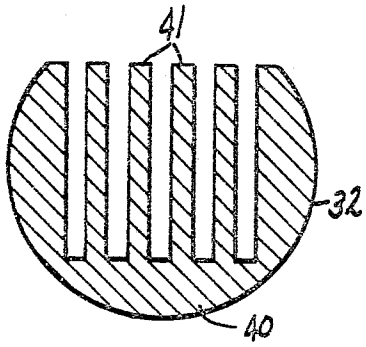


FIG - 4

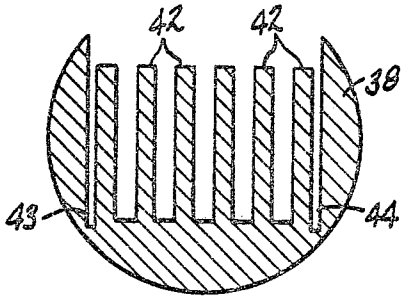


FIG - 5

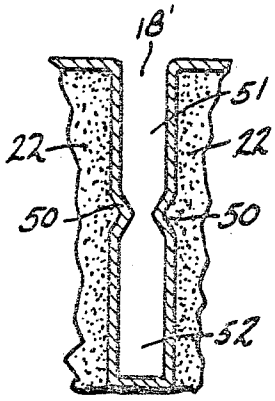


FIG - 6

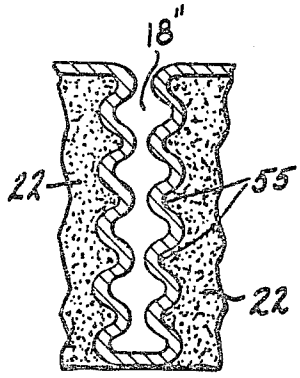


FIG - 7

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HEAT EXCHANGER WITH SINTERED METAL MATRIX

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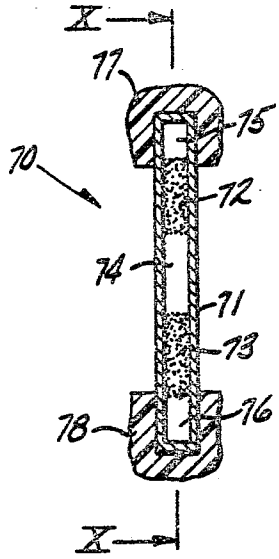


FIG-9

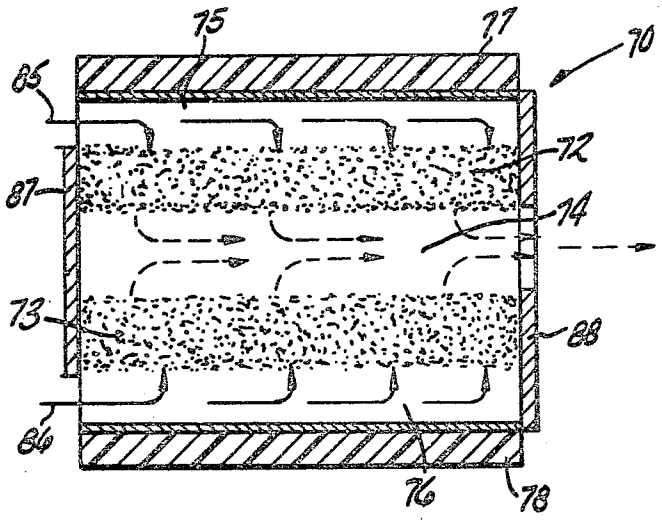


FIG-10

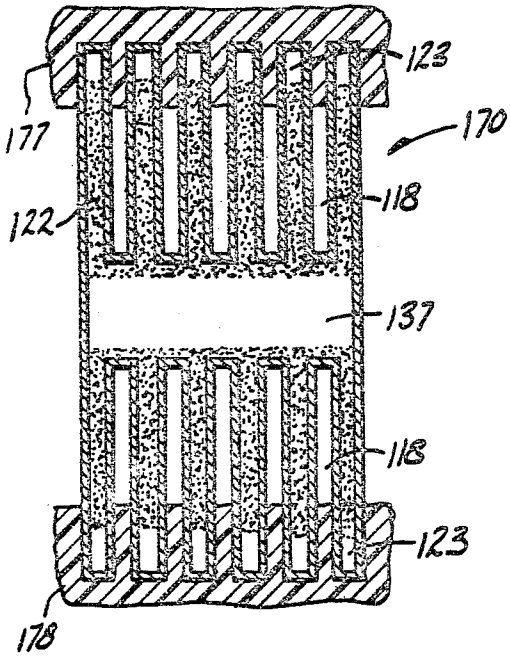


FIG-11

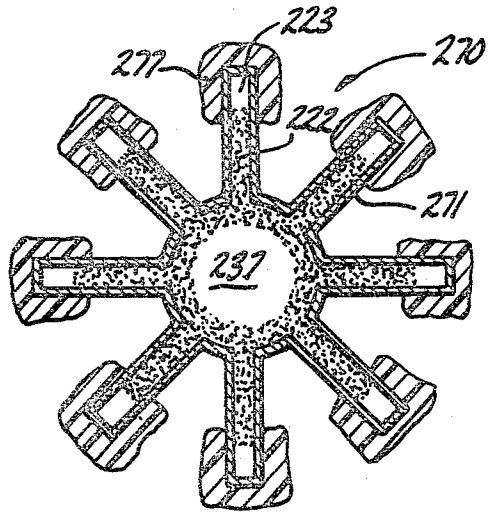


FIG-12

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3,331,435

HEAT EXCHANGER WITH SINTERED METAL MATRIX

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Filed Oct. 11, 1965, Ser. No. 494,329
4 Claims. (Cl. 165—135)

This application is a continuation-in-part of my copending application Ser. No. 482,242, filed Aug. 24, 1965.

This invention relates generally to heat exchangers, and more particularly to a novel heat exchanger having a body of pervious material therein, particularly adapted for use as an evaporator.

As is known in the heat exchange art, the greatest heat exchange is achieved by providing the maximum possible area of heat exchange surface across which the desired heat exchange may take place. Various devices have been employed to so increase the area such as, for example, fins or corrugations across which pass the media between which the heat exchange is to take place. However, it has been found that greatly increased heat transfer surfaces can be achieved by instead employing a body of pervious material, or a porous body having interconnected voids, conductively joined to a solid metal member. Such a body of pervious material presents a large exposed surface area for heat exchange purposes combined with the high heat conductivity of the solid member, as well as other advantages to be discussed shortly.

By the instant invention there is provided a heat exchanger having a unique configuration and arrangement of such a pervious body within a heat exchanger resulting in greatly increased heat exchange properties. The concept of the instant invention may be employed in heat exchangers of any desired shape, but is particularly adapted to tubular heat exchangers functioning as evaporators.

In the concept of the instant invention there is provided a heat exchanger in which not only the heat exchange area is increased but the flow of one of the media is directed in a plurality of passages between a series of pervious bodies through which flow the second medium. The advantages resulting from such a flow are achieved by the provision of a plurality of spaced-apart pervious bodies within a formed strip. By a particular construction of the strip and the pervious bodies, to be discussed hereinafter, space is provided within the heat exchanger to serve as guide channels for each of the heat exchange media resulting in the desired flow.

It is accordingly an object of this invention to provide a heat exchanger which is compact and yet capable of high efficiency and low pressure drop.

It is a further object of this invention to provide such a heat exchanger having bodies of pervious material joined therein by a metallic bond.

It is a still further object to provide such a heat exchanger adapted for use as an evaporator.

Additional objects and advantages will become apparent to those skilled in the art from a consideration of the details of several specific embodiments illustrated in the drawings, in which:

FIGURE 1 is a perspective view of a heat exchanger embodying the general concepts of this invention;

FIGURE 2 is an axial cross-section of the heat exchanger of FIGURE 1, taken along the line II—II thereof;

FIGURE 3 is a longitudinal cross-section of the heat exchanger of FIGURE 1, taken along the lines III—III of FIGURE 2;

FIGURE 4 is a frontal view of one of the header plates employed in the heat exchanger of FIGURE 1;

FIGURE 5 is a frontal view of a second header plate employed in the heat exchanger of FIGURE 1;

FIGURE 6 is an exploded view of a portion of a first modification of the heat exchanger of FIGURE 1;

FIGURE 7 is an exploded view of a portion of a second modification of the heat exchanger of FIGURE 1;

FIGURE 8 is a cross-sectional view similar to FIGURE 2, illustrating a third modification of the heat exchanger of FIGURE 1;

FIGURE 9 is a cross-sectional view of a heat exchanger according to this invention particularly adapted for use as an evaporator;

FIGURE 10 is a cross-sectional view of the heat exchanger of FIGURE 9, taken along the line X—X thereof;

FIGURE 11 is a cross-sectional view of another embodiment of an evaporator according to this invention; and

FIGURE 12 is a cross-sectional view of still another embodiment of an evaporator according to this invention.

An exemplary heat exchanger according to this invention is shown in FIGURE 1, and is designated generally by **10**. A first heat exchange medium, for example the medium to be employed in heating or cooling, is introduced into the heat exchanger **10** at one end thereof, as shown by the arrow **11**, and exits from the opposite end thereof in the direction of the arrow **12**. A second heat exchange medium, for example the medium to be cooled or heated, enters the heat exchanger **10** through any suitable fitting in the direction of the arrow **13**, is circulated through the heat exchanger, and exits through a suitable fitting in the direction of the arrow **14**. It will be obvious that any desired media might be employed in the instant heat exchanger; for example, the medium introduced at **11** may be water, and that introduced at **13** may be oil.

The construction of the heat exchanger **10** is shown in detail in FIGURES 2 and 3. Referring first to FIGURE 2, it may be seen that the heat exchanger **10** comprises a tube **15** in which there may be situated a metal strip **16**, folded as shown in FIGURE 2 to provide a plurality of cavities **17** and passages **18**, for reasons to become evident shortly. The folded metal strip may be secured within the tube in any desired method, as by brazing throughout its entire length along the edges indicated at **19** and **20**. As can be seen in FIGURE 3, the strip **16** extends along substantially the full length of tube **15**.

Within each of the cavities **17** there is situated in heat transfer relationship with the strip **16** a pervious body **22**. It will be seen that the pervious body **22** occupies all of the cavity **17** in which it is contained except for a void **23** at one end thereof, for reasons also to become evident shortly. It will also be noted that the strip **16** may rest upon the tube **15** at edges **24** and **25** opposed to the attached edges **19** and **20**. These ends **24** and **25** need not be attached to the tube **15**.

Referring now to FIGURE 3 of the drawings, the function of the structure previously described will be appreciated. A first heat exchange medium may flow through the tube **15** in the direction of the dashed line arrows **30**, it being evident that any desired fittings may be employed at opposed ends of the tube **15**. The flow of this first heat exchange medium is restricted to the open space **31** above the metal strip **16**, see FIGURE 2, and the passages **18**. Entry into the cavities **17** is prevented by header plates **32** and **33** at opposed ends of strip **16**, to be described in detail shortly.

Considering now the flow of the second heat exchange medium, it will be seen in FIGURE 2 that such medium is introduced into the heat exchanger through a suitable opening **34** in the wall of tube **15**, and exits through a

similar opening 35. The medium enters through opening 34 and, flowing in the direction of the solid line arrows 36, disperses throughout a space 37 below the cavities 17, thence through the cavities 17 collecting at the upper ends 23 thereof, thence out through the outlet opening 35. To expedite the flow of this medium from the heat exchanger, a header plate 38, to be described in detail shortly, is provided to form a manifold space 39 for collecting the medium flowing from the voids 23. Any desired fittings may of course be provided at openings 34 and 35 for external flow of the second heat exchange medium.

Referring now to FIGURES 4 and 5, the specific construction of the header plates will be seen. FIGURE 4 illustrates the construction of the header plate 32; header plate 33 is identical in construction and it will be evident that all description of header plate 32 is equally applicable to the header plate 33. The header plate 32 consists of a non-pervious sheet having a solid portion 40 around a portion of the periphery thereof and a plurality of projecting teeth 41 centrally thereof. Referring momentarily to FIGURE 2, it will be evident that the solid portion 40 and projecting teeth 41 are of a configuration to seal off all of the area within tube 15 other than the passages 18 and space 31.

Referring now to FIGURE 5, the header plate 38 is similar to the header plate 32 except that the projecting teeth 42 here terminate short of the upper ends of the cavities 17, see FIGURE 2. It will be evident that this construction seals off all of the area within the tube 15 other than passages 18, space 31, and the voids 23 at the upper ends of channels 17. The width of the teeth 42 may be so dimensioned as to be closely received within channels 17; slits 43 and 44 are provided to receive the outermost edges of strip 16. Alternatively, the area of heater plate 38 to the left of slit 43 and the right of slit 44—and the corresponding areas of header plates 32—may be deleted so that the spaces to the left and right of strip 16 may also be employed for flow of a heat exchange medium. It is to be understood that the header plate 38 illustrated is only one means of preventing flow of the heat exchange medium passing through the pervious bodies 22 directly into the channel 39. Thus, any means of sealing off the areas of the pervious bodies illustrated to be in contact with the header plate 38 will suffice. For example, a suitable resinous sealing compound may be applied to such areas.

Referring again to FIGURE 3, it will be seen that the header plates just described assure the desired flow of the heat exchange media. Header plate 32 seals off the strip 16 except at the passages 18, thus forcing the heat exchange medium 15 to flow through the passages 18 and in the upper space 31. Header plate 33 serves a similar function in sealing off the opposite end of the strip 16. Header plate 38 serves to seal off the cavities 17 except at the upper portions thereof, thus assuring that the heat exchange medium flowing through the pervious bodies 22 will have a ready path for exit from the heat exchanger.

By the flow indicated, the heat exchange advantages obtained will be appreciated. By virtue of the plurality of passages through the strip 16 the two heat exchange media are in heat exchange relationship along a greatly increased surface area. Additionally, the heat exchange media flowing through the pervious bodies 22 is exposed to a materially increased area for heat exchange by virtue of the multitudinous paths which the heat exchange medium must take in passing through the pervious bodies. As will be indicated shortly, the pervious bodies are in heat exchange relationship with the cavities and accordingly also in heat exchange relationship with the medium flowing through the passages between the cavities.

The form of the strip 16 illustrated in FIGURE 2 is merely exemplary, it being evident that the cross-section thereof may be altered as desired. Two modifications which have been found to be especially advantageous are illustrated in FIGURES 6 and 7 of the drawings, which

are exploded portions of strips analogous to strip 16 of FIGURE 2, illustrating one passage between two cavities containing pervious bodies 22. By the particular construction of the modified channels 18' and 18'', the heat transfer may be materially increased while providing additional rigidity to the walls of the channels. As show for example in FIGURE 6, the channel 18' may be divided into two parts by providing an indentation 50 in each side of the passage wall 18', as by embossing, resulting in an upper passage 51 and a lower passage 52.

Similarly, a greater number of divisions of the passage 18 may be effected by providing in the walls of the passage 18 a greater number of indentations 55, see FIGURE 7. These indentations may be easily achieved, as by any standard corrugating procedure of the strip 16 prior to bending it in the shape illustrated.

It will be evident that either of the modifications just discussed may require modification of the header plates to conform to the cross-section of the strip. Alternatively, the embossments or corrugations may be interrupted in the areas where the header plates are to be applied.

As indicated hereinbefore, the application of this invention to a tubular heat exchanger is merely exemplary. Thus, the strip 16 may be suitably modified to form a unitary heat exchanger apart from any surrounding tube, and employed for example by simple immersion in any suitable container. This application is illustrated in FIGURE 8, wherein it will be seen that structure analogous to structure of the strip of FIGURE 2 is indicated by the same reference character primed. Thus, the strip 16' is formed with a plurality of cavities 17' and passages 18', with pervious bodies 22' and voids 23' situated in the cavities 17'. Here, however, the outermost side walls of the strip 16' are extended downwardly, as at 60 and 61, bent inwardly, as at 62 and 63, and joined together in any suitable manner, as at 64. The pervious bodies 22' may be discrete, or they may be joined together, as at 65. At a lower portion of the strip 16', a large void 66 is formed to distribute the heat exchange medium in the same manner as the space 37 of FIGURE 2.

It will be evident that provision of suitable openings in the lower end of the strip 16', analogous to openings 34 and 35 in FIGURE 3, and addition of appropriate manifolds, analogous to 32, 33 and 38 in FIGURE 3, will allow for circulation of a heat exchange medium in the same manner as described hereinbefore. The resulting heat exchanger may then be used alone, or in assembly with other similar modules, as by immersion in the second heat exchange medium.

Considering now the manner in which a heat exchanger as described above may be produced, production of the heat exchanger of FIGURE 1 will be taken as exemplary, it being understood that suitable modification of the steps indicated will result in the modification of FIGURES 6, 7 and 8. It is to be noted that various combinations of metals may be utilized in forming the heat exchangers according to the instant invention; and accordingly the solid portions and the pervious body may be of the same metal or alloy, or the pervious structure and the solid member may be comprised of different compositions. For example, both the pervious body and solid portions may be formed of the same stainless steels, coppers, brasses, carbon steels, aluminums or various combinations thereof. As will be evident, the ultimate use of the resultant structure determines the specific combination of alloys to be employed.

The pervious bodies may be produced by a process wherein particles, usually spherical, are poured by gravity into an appropriately shaped confined space and usually vibrated to cause the particles to compact uniformly. As is obvious, the choice of particle size will largely determine the size of openings in the resulting pervious bodies. The bodies of particles so packed are then treated in accordance with any of the well known metallurgy prac-

tices—e.g., sintering, welding, brazing or soldering employing an appropriate coating—to produce in each body a metallic bond between the particles. Thus, there is provided pervious bodies whose bulk density, or apparent density, is but a fraction of the density of the metal or alloy from which the particles are obtained. Furthermore, such process results in a metallic bond between the pervious bodies and solid material around the bodies.

Thus, the particles may be poured into the formed strip 16 and joined in place by any of the metallurgy practices noted above. A particularly advantageous method of forming the voids 23 is to pour the particles into the formed strip 16, with the header plates 32 and 38 in place, while the assembly is oriented in a position rotated 180° from the position shown in FIGURE 2. The volume of particles poured into each of the cavities 17 may be so calculated that when the strip 16 is returned to the position shown in FIGURE 2 the desired voids 23 at the upper ends of cavities 17 are achieved. The resulting body may then be metallurgically treated, resulting in a metallic bond (1) between the various particles of each of the bodies, (2) between each of the bodies 22 and the walls of the cavities 17 in which they are positioned, (3) between each of the bodies 22 and the header plates 32 and 38, and (4) between the strip 16 and the header plates 32 and 38. Header plate 33 may then be similarly attached.

The resulting assembly may, if so desired, then be inserted into the tube 15 and joined in place. While it is shown in FIGURE 2 that the lower edges 24 and 25 rest upon the interior walls of the tube 15, this is not required and these lower ends may be spaced from the wall if so desired. Similarly, the resulting assembly may be one of a number of similar modules put together within a single conduit, such as a larger tube, to achieve greater heat exchange capacity. This may be done by joining a number of modules in side-by-side relationship, or by orienting one such module atop the other. In the latter expedient, two modules may be brought together with their ends having the voids 23 in contact, such that the passages 18 of each are in communication. The voids 23 of each may remain separate from the voids 23 of the other, or corresponding voids 23 may be joined as by providing an opening in the upper wall of each of the cavities 17.

As will be obvious to those skilled in the art, the indicated flow of the heat exchanger media achieved by the instant device attains a high degree of heat exchange with a minimum of pressure drop. The medium within the pervious bodies distributes over the entire pervious structure in a uniform manner over a greatly increased heat exchange surface. The construction of the pervious bodies will be dictated by the contemplated use of the exchanger dependent upon such factors as the thermal conductivity, specific heat, viscosity, and corrosive nature of the fluid, the presence of clogging solids in the fluids, and tolerable pressure drops.

It is to be understood that the concepts indicated above are not limited to the particular configurations illustrated. For example, a tube need not be exclusively employed; any desired shape of exchanger may be provided, with the inner structure shaped accordingly to fit. Furthermore, the strip may be of any desired cross-section, any number of heat exchange media may be employed, the exchanger may be used for either heating or cooling, and the direction of flow of the heat exchange media may take a variety of patterns. While the flow directions indicated above have been found to be the most desirable, the direction of flow of either or both of the heat exchange media may be reversed if so desired. Additionally, the heat exchange media may be either liquid or gaseous, and thus the instant structure may serve as a liquid to liquid heat exchanger, a condenser, or an evaporator.

The adaptability of the instant invention to a structure for use as an evaporator is illustrated in FIGURES 9–12 of the drawings, and it is this structure which forms the basis of this continuation-in-part application.

Referring now to FIGURES 9 and 10, a basic form of evaporator according to this invention is indicated at 70 and comprises a conduit 71 having therein two pervious bodies 72 and 73. As may be best seen in FIGURE 9, the pervious bodies are so secured within the conduit 71 as to leave a central passage, or void, 74, and additional passages, or voids, 75 and 76, for reasons to become evident shortly. The conduit 71 may be formed in any desired manner, as by reshaping a round tube, or suitably shaping and joining sheet material; the pervious bodies 72 and 73 may then be positioned within the conduit 71 in a manner analogous to that disclosed hereinbefore. Surrounding the voids 75 and 76 exteriorly of the conduit 71 are secured two bodies of insulation 77 and 78, respectively, which may be, for example, of foamed plastic.

Referring now to FIGURE 10, which is a cross-sectional view of the evaporator 70 of FIGURE 9 taken along the line X—X thereof, the functioning of the evaporator 70 will be evident. It is to be understood that the evaporator 70 in use will be in heat exchange relationship with a first heat exchange medium exteriorly of the conduit 71. The second heat exchange medium, that to be evaporated, may be introduced into the conduit 71 from one end thereof into the voids 75 and 76, in the direction of the solid-line arrows 85 and 86, respectively. The second heat exchange medium will then flow through the pervious bodies 72 and 73 in heat exchange relationship with the first heat exchange medium in the same manner as indicated hereinbefore. During such flow, the second heat exchange medium may be made to change state, e.g., from a liquid to a vapor state. The vapor is then collected within the void 74 and may exit from the conduit 71 at an opposite end thereof. To achieve the flow indicated, the structure illustrated in FIGURE 10 includes a header plate 87 secured to one end of the conduit 71 for closing off the entire end other than the voids 75 and 76, and a second header 88 secured at the opposite end of the conduit 71 appropriately apertured to seal off the entire end except for the void 74, the header plates 87 and 88 cooperating with appropriate fittings, not shown. Obvious alternatives of the header structure illustrated include closing off one end entirely, and providing the header at the opposite end with appropriate apertures for entry to the voids 75 and 76 and exit from the void 74 at the same end of the evaporator 70.

The functioning of the bodies of insulation 77 and 78 will now be apparent. Such insulation functions to insulate the second heat exchange medium from the first heat exchange medium during flow within the passages 75 and 76, and accordingly prevents premature heating, and premature boiling, of the second heat exchange medium. Clearly, the flow indicated may be reversed, with the sizes of the voids 74, 75 and 76 appropriately dimensioned to receive the expected flow. Where a reversed flow is desired, the insulation would of course instead be secured to the conduit 71 in a position to surround the void 74.

In FIGURE 11 there is illustrated an evaporator structure 170 analogous in form to the heat exchanger illustrated in FIGURES 1 and 8 of the drawings. Essentially, the evaporator 170 may comprise two of the heat exchangers thereshown joined end-to-end so as to form a plurality of passages, or voids, 123 at opposite ends of two groups of pervious bodies 122 separated by a central passage, or void, 137. Accordingly, the construction may be effected in the manner indicated hereinbefore, as by appropriately joining the portions 60 and 61 of two of the heat exchangers illustrated in FIGURE 8. The passages 123, in association with suitable bodies of insulating material 177 and 178, and the passage 137 may then function in the same manner as the passages 75, 76 and 74, respectively, of the evaporator 70 of FIGURE 9. The

passages **118**, analogous to the passages **18** of FIGURE 2 and **18'** of FIGURE 8, may then serve to pass the first heat exchange medium through the evaporator **170** in the same manner as is illustrated with respect to the heat exchanger of FIGURES 1 and 8.

Clearly, the instant evaporator may take any desired configuration. One further modification is illustrated in FIGURE 12 of the drawings, and comprises an evaporator **270** formed in a manner analogous to the evaporator **170** of FIGURE 9 except that the pervious bodies **222** are arranged within a conduit **271** radially around a central passage, or void, **237**. Again, a passage, or void, **223** and associated body of insulating material **277** is provided in connection with each of the pervious bodies **222** for the same reasons indicated with respect to the evaporators of FIGURES 9 and 11. The flow of the second heat exchange medium in the evaporator **270** will be analogous to that within the evaporator **170** and, as was the case with the evaporator of FIGURE 9, may be reversed if so desired. Obviously, for the evaporators of FIGURES 11 and 12 the header plates analogous to header plates **32** and **38** of FIGURES 4 and 5 will have to be modified to match the configuration of the cross-section of the evaporator.

It is to be understood that any of the evaporators illustrated in FIGURES 9, 11 and 12 may be positioned within a surrounding conduit transmitting the first heat exchange medium in the same manner as is illustrated with respect to the heat exchanger of FIGURE 1. It is also to be understood that the pervious bodies employed in the evaporators here disclosed achieve the same heat exchange results and advantages as those indicated hereinbefore with respect to the heat exchangers of FIGURES 1 and 8.

While several specific embodiments of this invention have been shown and described, they are to be understood as for the purpose of illustration only and that various changes and modifications may be made in the disclosed articles and method without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. An evaporator structure, comprising

(A) conduit means adapted to convey a medium to be evaporated,

(B) a pervious heat transfer body within said conduit means substantially filling said conduit means cross-section,

(C) at least one void within said pervious body on the upstream side for controlled flow of said medium, and

(D) insulating means exteriorly of said conduit means surrounding said void to prevent heat transfer while said medium is in said void.

2. An evaporator structure, comprising

(A) conduit means for conveying a first heat exchange medium to be evaporated in heat exchange relationship with a second heat exchange medium exteriorly of said conduit means,

(B) at least one pervious heat transfer body associated with said conduit means in heat exchange relationship therewith substantially filling said conduit means cross-section,

(C) at least one void within said pervious body on the upstream side for controlled flow of said medium, and

(D) means associated with said conduit means for insulating said void from said second heat exchange medium,

whereby said first heat exchange medium passes through said pervious body in heat exchange relationship with said second heat exchange medium but is insulated therefrom while in said void.

3. A heat exchanger according to claim **2** wherein said conduit means includes a plurality of passages therein for flow of said first heat exchange medium therethrough.

4. An evaporator structure, comprising

(A) first conduit means for conveying a first heat exchange medium,

(B) second conduit means within said first conduit means for conveying a second heat exchange medium to be evaporated, said second conduit means including

(1) a plurality of passages allowing for flow of said first heat exchange medium therethrough,

(2) a plurality of pervious heat transfer bodies substantially filling said conduit means cross-section, each of said pervious bodies being juxtaposed adjacent one of said passages,

(3) at least one void within each of said pervious bodies on the upstream side for controlled flow of said second heat exchange means,

(C) insulating means exteriorly of said second conduit means surrounding each of said voids,

whereby said second heat exchange medium passes through said pervious bodies in heat transfer relationship with said first heat exchange medium flowing in said passages, but is insulated from said first heat exchange medium while in said void, thereby being capable of changing phase.

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