Jan. 23, 1968 F. A. BURNE ETAL 3,364,951

HEAT EXCHANGER

Filed April 22, 1965 2 Sheets-Sheet 1

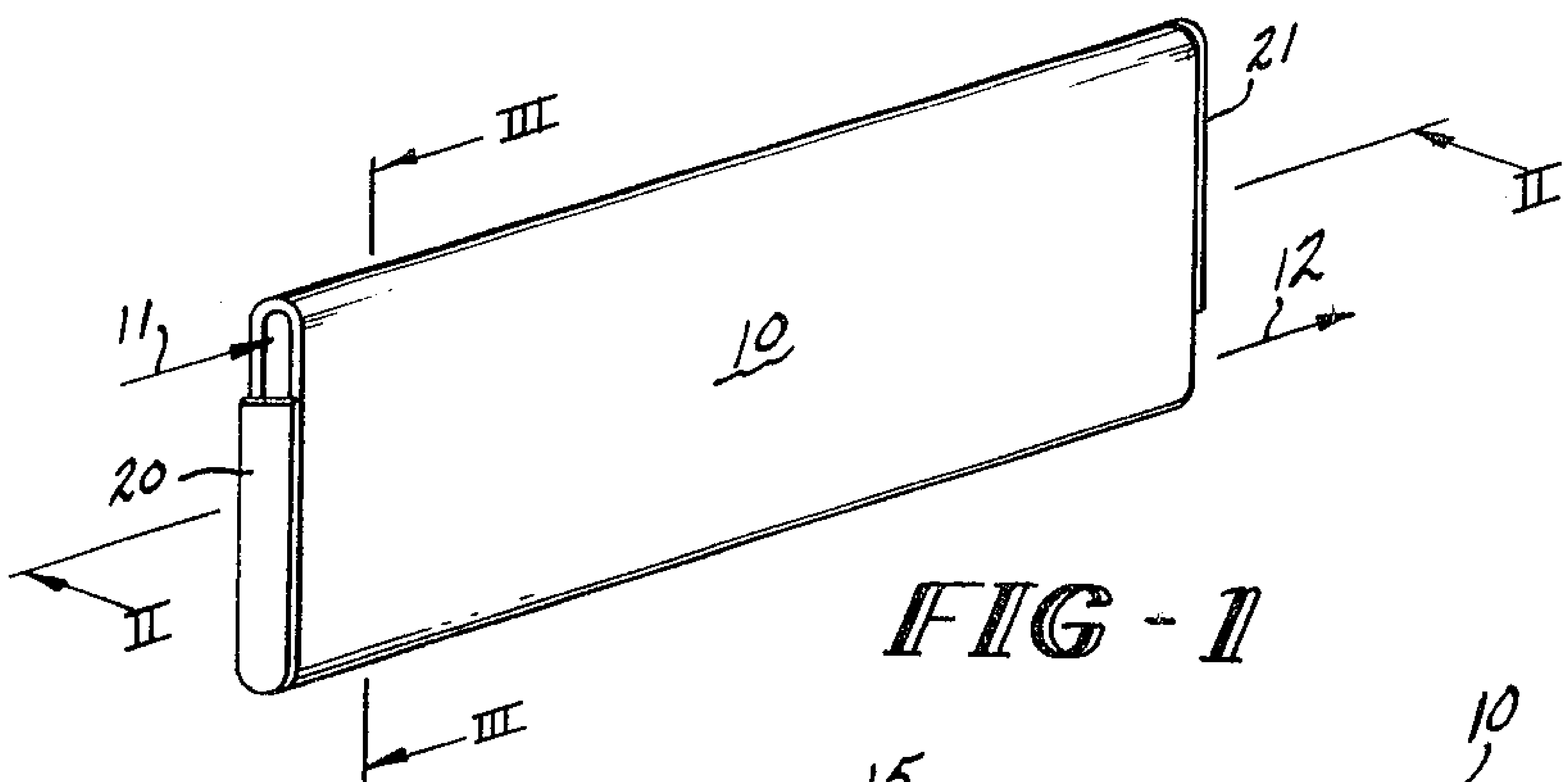

FIG-1

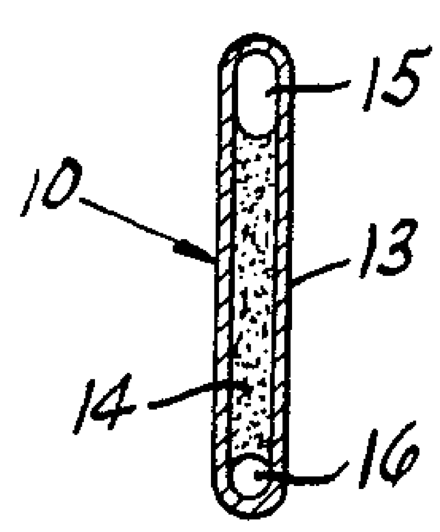

FIG-3

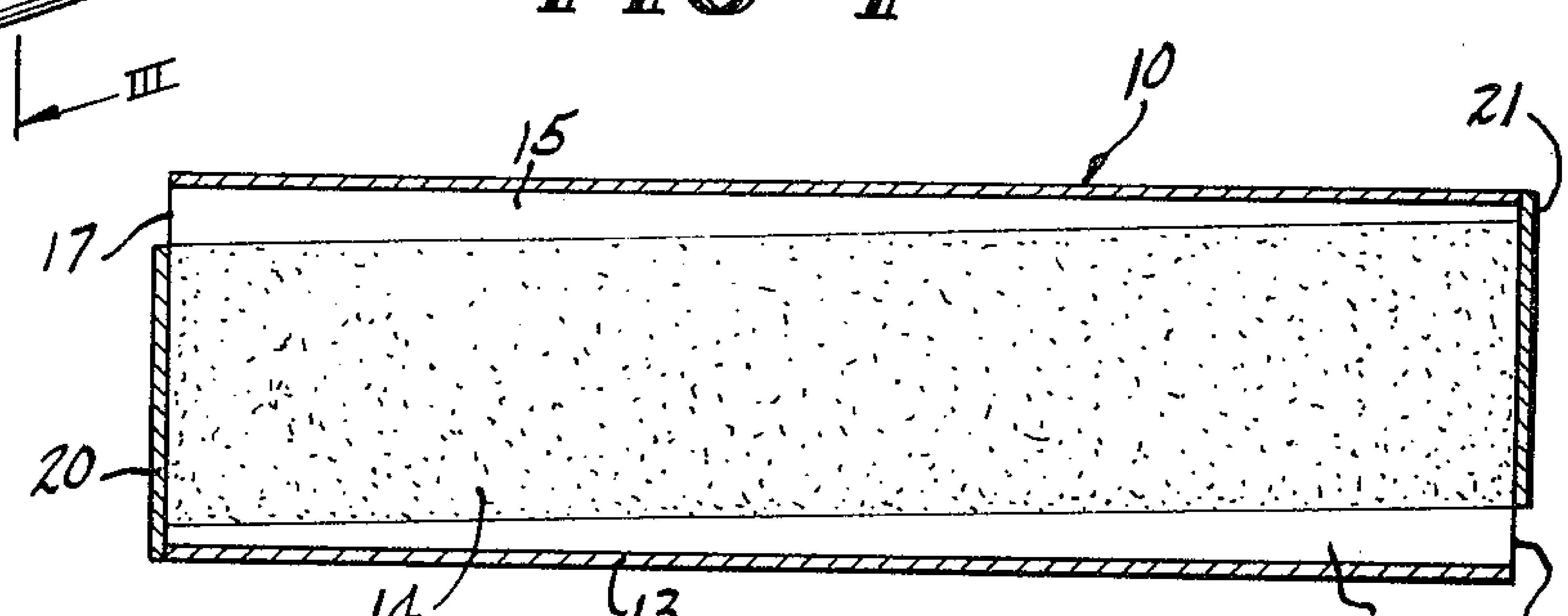

FIG-2

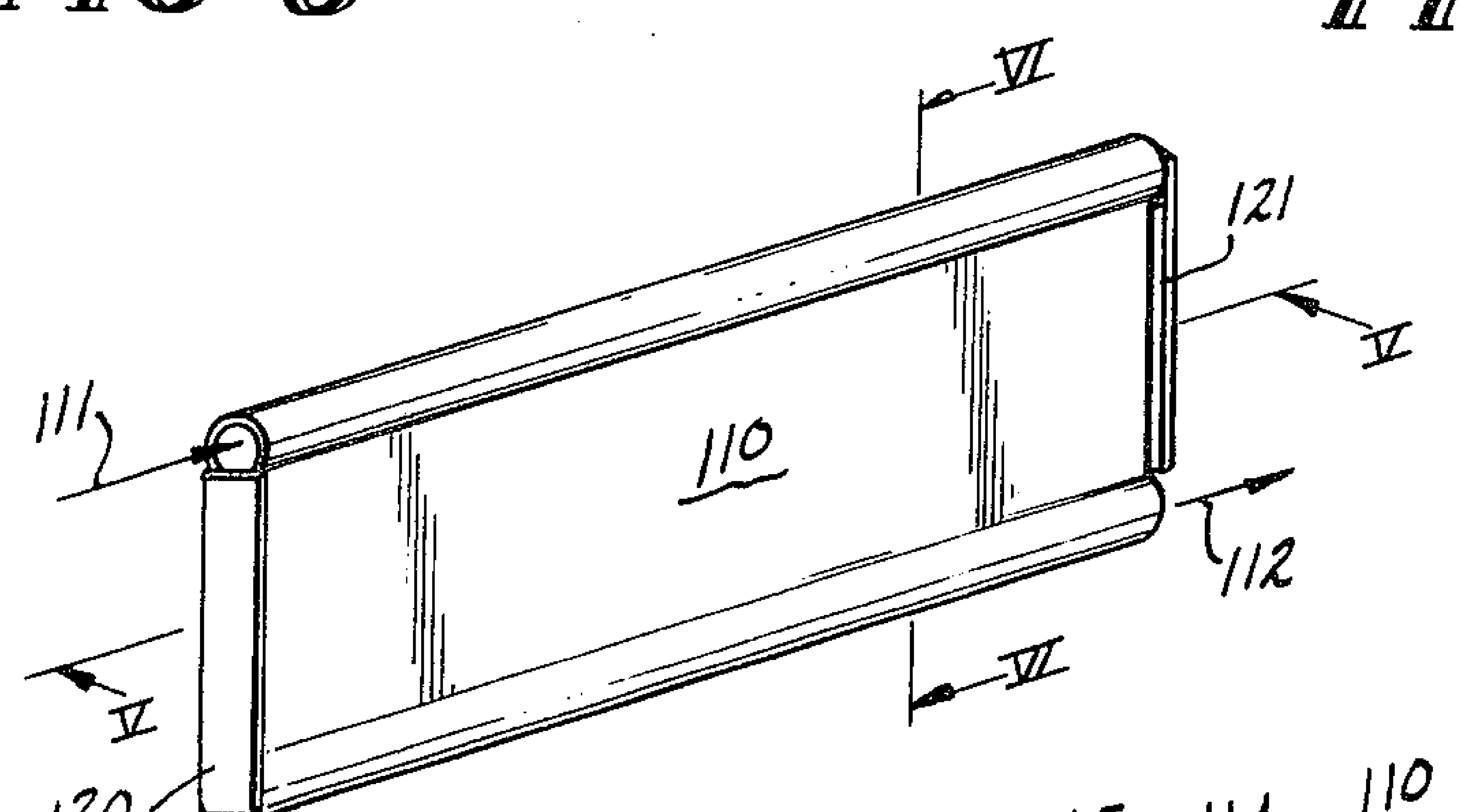

FIG-4

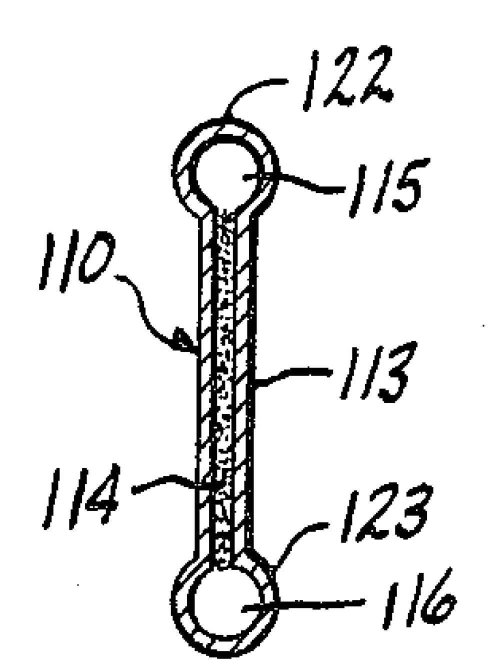

FIG-6

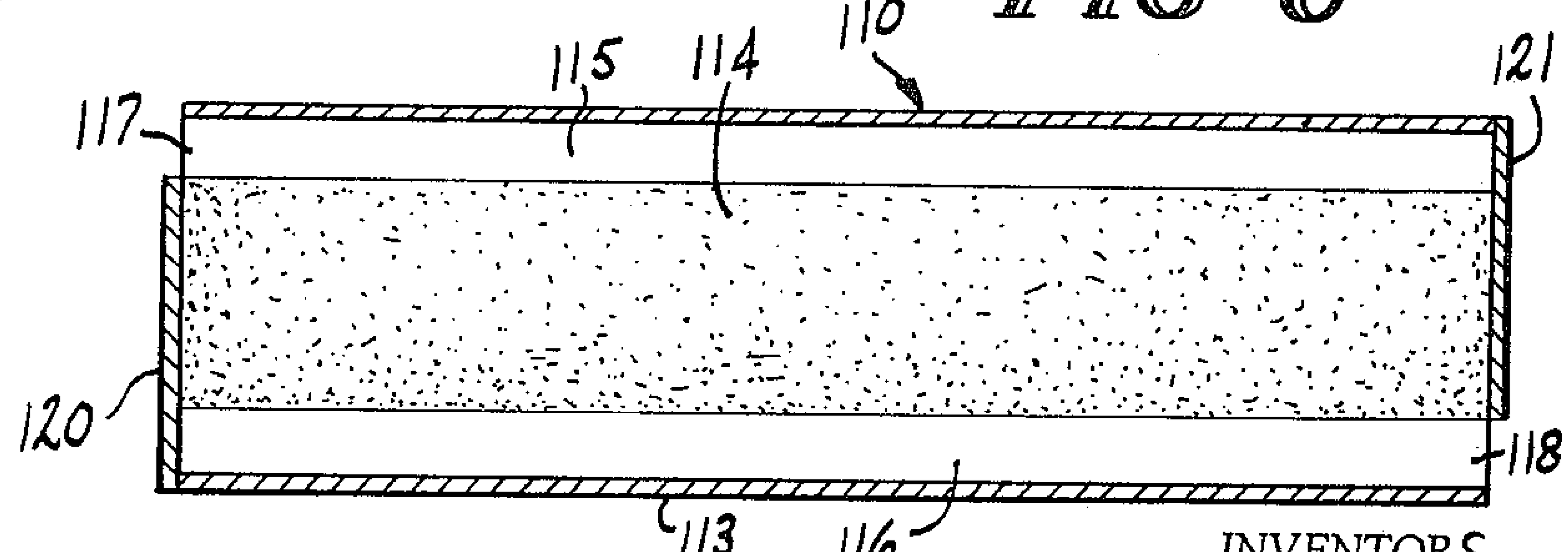

FIG-5

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HEAT EXCHANGER

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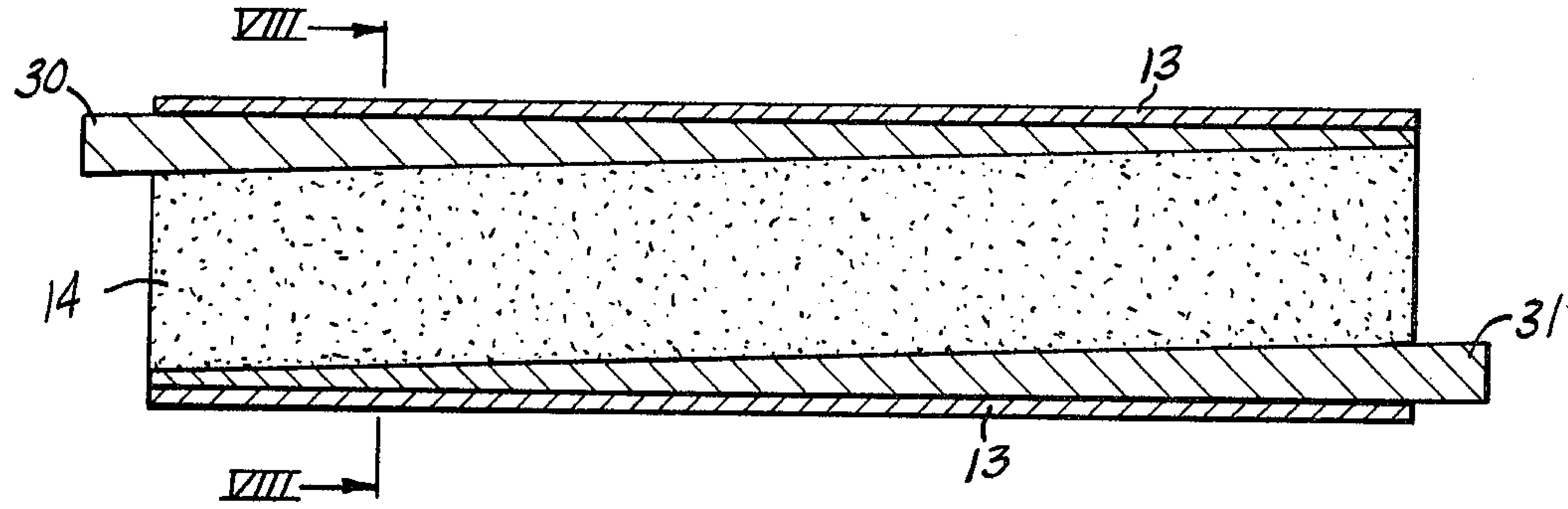

FIG-7

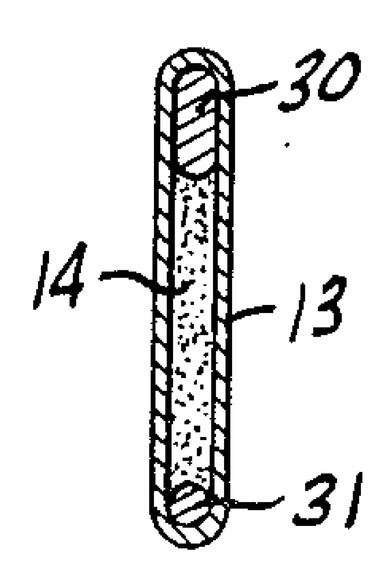

FIG-8

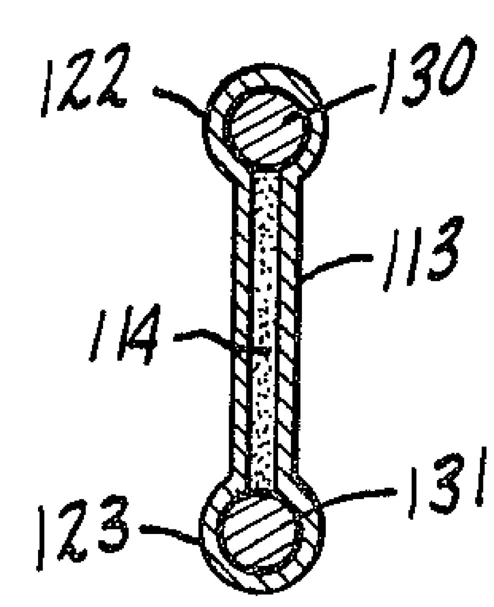

FIG-10

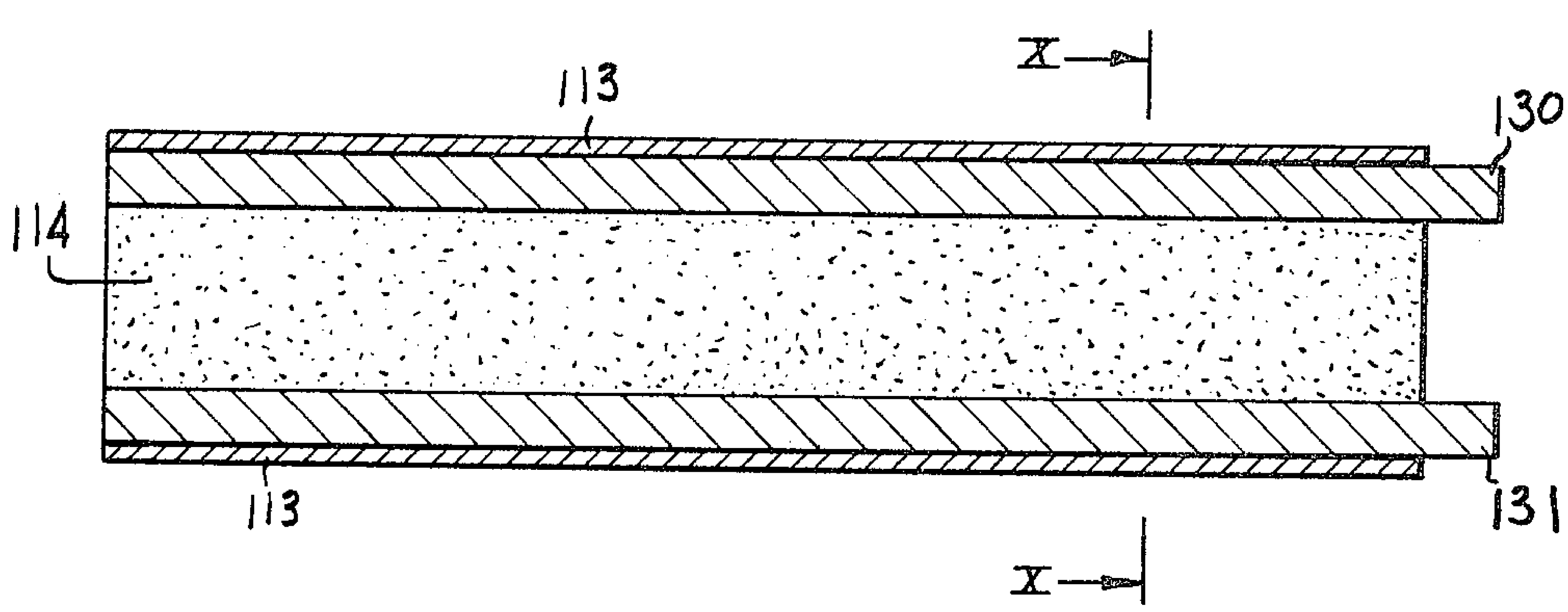

FIG-9

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HEAT EXCHANGER
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ABSTRACT OF THE DISCLOSURE

This invention relates to heat exchangers, and more particularly to a heat exchanger having a body of pervious material therein and a method for producing such a heat exchanger.

As is known in the heat exchanger art, the greatest heat exchange is achieved by providing the maximum possible area of material across which the desired heat exchange may take place. Various devices have been employed to so increase the material 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. Such a body of pervious material presents a large number of faces for heat exchange purposes, as well as other advantages to be discussed shortly.

By the instant invention there is provided a unique configuration and arrangement of such a pervious body within a heat exchanger, and a method of forming the pervious body. Such a heat exchanger has been tested and found to result in greatly increased heat exchange properties. The concept may be employed in heat exchangers of any desired shape, but is particularly adapted to tubular heat exchangers. As is known in the art, the use of heat exchangers of a tubular configuration is highly advantageous in certain environments where the exchanger is so situated that it is immersed in one of the heat exchange media. The tubular heat exchangers presently in use in such an environment commonly comprise two concentric tubes, the internal heat exchange medium flowing through the annulus between the tubes and the external heat exchange medium surrounding the outer tube also flowing through the inner tube. This arrangement has been considered necessary to achieve the desired surface areas for heat exchange between the two media.

According to the instant invention, it has been found that adequate surface area may instead be obtained with only one tube by including within the tube a body of pervious material. By a particular configuration and arrangement of the pervious body to be discussed hereinafter, channels are provided to serve as inlet and outlet means for the internal exchange medium and to assure uniform distribution of the medium through the pervious body.

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

It is a further object of this invention to provide such a heat exchanger having a body of pervious material situated therein.

It is a still further object of this invention to provide such a heat exchanger employing a single tube encasing the pervious body.

It is a still further object of this invention to provide a unique method of producing such a heat exchanger.

Other 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 first embodiment of heat exchanger contemplated in this invention;

FIGURE 2 is a longitudinal cross-section of the embodiment of FIGURE 1, taken along the lines II—II thereof;

FIGURE 3 is an axial cross-section of the embodiment of FIGURE 1 taken along the lines III—III thereof;

FIGURE 4 is a perspective view of a second embodiment of this invention.

FIGURE 5 is a longitudinal cross-section of the embodiment of FIGURE 4 taken along the lines V—V thereof;

FIGURE 6 is an axial cross-section of the embodiment of FIGURE 4 taken along the lines VI—VI thereof;

FIGURE 7 is a longitudinal cross-section view similar to FIGURE 2 showing the embodiment of FIGURE 1 during the production thereof;

FIGURE 8 is an axial cross-section of the embodiment of FIGURE 1 during the production thereof, the view being taken along the lines VIII—VIII of FIGURE 7;

FIGURE 9 is a longitudinal cross-sectional view similar to FIGURE 5 showing the embodiment of FIGURE 4 during the production thereof; and

FIGURE 10 is an axial cross-section of the embodiment of FIGURE 4 during the production thereof, the view being taken along the lines X—X of FIGURE 9.

A first embodiment of heat exchanger employing the concept of this invention is shown in FIGURE 1, and is designated generally by **10**. As indicated hereinbefore, the heat exchanger **10** is to be employed in applications where it is immersed in one of the heat exchange media. Thus, a first heat exchange medium, for example that to be employed in heating or cooling, entirely surrounds the heat exchanger **10**. 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 **11**, is circulated through the heat exchanger, and exits through a suitable fitting in the direction of the arrow **12**. Thus, heat exchange may take place between the second medium within the heat exchanger and the first medium surrounding the exchanger. It will be obvious that any desired medium might be employed in the instant heat exchanger; for example, in application in an automotive cooling system, the medium surrounding the heat exchanger **10** may be water and the medium circulated through the heat exchanger may be oil.

The construction of the heat exchanger **10** is shown in detail in FIGURES 2 and 3, wherein it may be seen that the heat exchanger **10** comprises a tube **13** having situated therein a body of pervious material **14**. The tube **13** may be formed in a variety of methods to be discussed hereinafter; as can be seen in FIGURE 3, the tube is of a configuration such that its cross-sectional major dimension is materially greater than its cross-sectional minor dimension. The pervious body **14** is so produced, in a manner also to be discussed hereinafter, that the entire internal volume of the tube **13** is filled except for a first channel **15** and a second channel **16**. The channel **15** extends from one end of the tube **13** toward the other end, decreasing in depth along its length. Channel **16** is of a configuration similar to channel **17**, but oriented in an opposite direction. One end of the tube **13** other than a portion **17** is closed off, as by a suitably shaped end plate **20**; the opposite end of the tube **13** is similarly closed off except for the portion **18**, as by a similar end plate **21**.

It will be evident that the portion **17** forms an inlet for the internal heat exchange medium to be circulated through the tube 13, and that the portion 18 forms the required outlet. In operation, the internal heat exchange medium enters the heat exchanger 10 through the inlet 17, distributes throughout the channel 15, flows through the pervious body 14 uniformly distributed along the length thereof, collects in the channel 16, then exits through outlet 18. It will be apparent that end plates 20 and 21 serve to close off the ends of channels 15 and 16 and to seal off the pervious body from the inlet 17 and outlet 18, thus forcing the heat exchange medium within channel 15 to flow through the pervious body toward the channel 16. It will be similarly evident that the tapering configuration of the channels 15 and 16 assure that the flow of the internal heat exchange medium through the pervious body 14 is uniform along the length thereof, while allowing for a maximum volume of the pervious body.

From the above description of the structure, the aforementioned heat exchange advantages will be appreciated. The pervious body 14 forces the internal heat exchange medium to flow in a multitude of flow paths through the pervious body 14 across a greatly increased surface area. That is, the surfaces of the various particles forming the pervious body 14. The pervious body 14, which is in heat exchange relationship with a major portion of the tube 13, thus provides greatly increased surface area for heat exchange between the internal heat exchange medium and the medium exteriorly of the tube 13.

A second modification of the instant invention is depicted in FIGURES 4–6. In this embodiment, the cross-sectional configuration of the tube is altered to simplify the production of the pervious body and to reduce pressure drop. As can be seen in FIGURE 4, the heat exchanger 110 operates in the same manner as the heat exchanger of FIGURE 1. Thus, the heat exchanger 110 may be immersed in a first heat exchange medium, and a second heat exchange medium introduced into the heat exchanger 110 in the direction of the arrow 111, subsequently exiting therefrom in the direction of the arrow 112. As can be best seen in FIGURE 6, the tube 113 is so formed as to have enlarged portions 122 and 123 at each end of the cross-sectional major dimension. Referring to FIGURE 5, it will be evident that an inlet portion 117 and an outlet portion 118 serve an analogous function to the portions 17 and 18 of the embodiment of FIGURE 1. The pervious body 114 of this embodiment is formed in the central portion of the tube 113, as shown in FIGURE 6, and extends along the length thereof. Channel 115 and channel 116 of this embodiment are of the same configuration throughout their lengths, most conveniently of the configuration of the enlargements 122 and 123. End plates 120 and 121 serve to appropriately seal off the ends of the tube 113 in the same manner as in the first embodiment.

As will be evident, the function of the second embodiment is similar to the first embodiment. The internal heat exchange medium enters at 117, distributes along the channel 115, passes through the body 114, collects in the channel 116, and exits through the outlet 118. However, in this embodiment, each of the channels are of a round cross-section throughout their lengths, which yields advantages to become apparent.

Considering now the novel method by which the heat exchangers previously described may be produced, reference is had to FIGURES 7–10. FIGURES 7 and 8 illustrate the production of the embodiment of FIGURE 1, and FIGURES 9 and 10 illustrate the production of the embodiment of FIGURE 4.

As a preliminary consideration, it is to be noted that the tube employed in this invention may be of any desired cross-sectional configuration, the tubes 13 and 113 illustrated being merely exemplary. Similarly, the tube may be formed in a variety of methods, as by deforming round tube stock to the desired configuration or by appropriately bending sheet stock and securing together the mating ends.

As a further preliminary consideration, it is to be noted that various combinations of metals may be utilized in forming a heat exchanger according to the instant invention; accordingly, the solid portion and the pervious body may be of the same metal or alloy or of different compositions. For example, both the pervious body and solid portion may be formed of the same stainless steels, coppers, brass, carbon steels, aluminum 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 production of the pervious body is most flexible; for example, it may be produced by a process wherein particles, frequently 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 of the resulting pervious body. The body of particles so packed is then treated in accordance with any of the well known metallurgy practices—e.g., sintering, welding, brazing or soldering employing an appropriate coating—to produce a metallic bond between the particles. Thus, there is provided a pervious body 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 body and its container.

While the above-described process is preferred in the instant invention, other processes may be employed. For example, it is possible to blend intimately a particulate material with either a combustible substance or a soluble material whose melting point exceeds the melting temperature of the particulate material. After the blend is compacted and treated to achieve a metallic bond, the combustible substance may be burned away or the soluble material removed by leaching or dissolving with a liquid. A still further method of producing the pervious body comprises melting a metal or alloy and casting it into the interstices of a loose aggregate of a particulate soluble material whose melting point exceeds that of the metal, preferably having a specific gravity of the molten metal. Upon solidification of the metal, a component is produced which contains the network of the soluble material interspersed within the solid metal which soluble material is thereupon removed by leaching or dissolving, leaving behind it interstices that interconnect and form a pervious network within the resultant metal body. A still further method of producing such pervious bodies comprises weaving or knitting metal wire into a mesh arranged in a plurality of layers. According to this process, a control of porosity is obtained by appropriate choice of wire diameters and openings arranged between adjoining wires as well as the juxtapositioning of superimposed layers of the woven or knit mesh.

Referring now to FIGURES 7 and 8, it will be appreciated that the tube 13 may be positioned on a suitable support and two appropriately shaped cores 30 and 31 placed within the tube 13. The cores 30 and 31 are of a configuration matching that of the desired channels 15 and 16 respectively. One end of the tube 13 may then be temporarily sealed off, and particulate material may then be poured into the tube 13 from the opposite end. Following any of the metallurgy procedures previously discussed, the particulate material may then be treated to achieve a metallic bond between the various particles thereof and between the particulate material and the inner walls of tube 13. The cores 30 and 31 are of a material which would be unaffected by any of the previously discussed methods of achieving a metallic bond—e.g., carbon or ceramic—or of metal coated with any of the well known "stop-off" materials—e.g., aluminum oxide—to prevent a metallic bond between the core and any other body. Accordingly, no metallic bond will be created between the resulting pervious body 14 and the cores 30 and 31 due to the character of the cores indicated previously.

Cores **30** and **31** may then be removed, as by pulling them out from opposite ends of the tube with an appropriate tool affixed to the projecting ends of the cores **30** and **31**. The end plates **20** and **21** may then be placed in position at the opposite ends of the tube **13** and suitably secured, as by brazing, soldering, cementing, or welding, or by mechanically securing as by the use of clips or by deforming a portion of the tube **13** therearound. Suitable fittings may then be added at the entry portion **17** and exit portion **18** for circulation of the internal heat exchange medium, and the heat exchanger is ready for use.

Referring now to FIGURES 9 and 10, it will be evident that production of the second embodiment is similar to that of the first. The tube **113** is positioned on a suitable support, and cores **130** and **131** inserted into the enlarged portions **122** and **123**. It will be evident that the cores **130** and **131**, being of a round cross-sectional configuration, are materially easier to fabricate than are the cores **30** and **31**. Where the enlarged portions **122** and **123** are of a convenient size, the cores **130** and **131** may consist merely of appropriately sized wires.

With the cores **130** and **131** in place, one end of the tube **113** may be temporarily sealed off and particulate material added through the other end. As in the production of the first embodiment, the particulate material may then be treated in accordance with any of the previously discussed metallurgy procedures to achieve a metallic bond between the various particles thereof and between the particulate material and the inner walls of tube **113**. The cores **130** and **131** are again of a material which would be unaffected by any of the previously discussed methods of achieving a metallic bond of metal coated with any of the well known "stop-off" materials to prevent a metallic bond between the core and any other body. The cores **130** and **131** may then be removed, as by pulling them out with an appropriate tool affixed to their projecting ends. The end plates **120** and **121** may then be placed in position at the opposite ends of the tube **113** and suitably secured in the same manner as the end plates **20** and **21**, fittings may then be added at the entry portion **117** and exit portion **118**, and the heat exchanger is ready for use.

While we have shown and described different desirable embodiments of this invention, it is to be understood as for the purpose of illustration only and that various changes and modifications, as well as the substitution of equivalent elements and expedients for those herein shown and described, may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A heat exchanger adapted to being immersed in a first heat exchange medium, comprising
   (A) a conduit means for conveying a second heat exchange medium, said conduit means having
      (1) an inlet portion for said second heat exchange medium, and
      (2) an outlet portion for said second heat exchange medium
   (B) a body of pervious sintered metal within said conduit in heat exchange relationship therewith joined by a metallic bond to said conduit means, said body of pervious sintered metal being situated between said inlet portion and said outlet portion, whereby said second heat exchange medium passes through said body of pervious sintered metal in a multitude of flow paths,
   (C) channel means adjacent said body of pervious sintered metal including

      (1) a first channel in communication with said inlet portion for controlled distribution of said second heat exchange medium entering the heat exchanger, and
      (2) a second channel in communication with said outlet portion for controlled collection of said second heat exchange medium leaving the heat exchanger.

2. A tubular heat exchanger adapted to being immersed in a first heat exchange medium, comprising
   (A) tubular conduit means for conveying a second heat exchange medium, said conduit means having
      (1) an outlet opening at a first portion thereof for entry of said second heat exchange medium, and
      (2) an outlet opening at a second portion thereof for exit of said second heat exchange medium,
   (B) a body of pervious sintered metal within said tubular means in heat exchange relationship therewith joined by a metallic bond to said tubular means, said body of sintered metal being in contact with a major portion of the inner periphery of said tubular means for substantially the full extent thereof and being situated between said inlet opening and said outlet opening, whereby said second heat exchange medium passes through said body of pervious sintered metal in a multitude of flow paths,
   (C) channel means within said tubular conduit means adjacent said body of pervious sintered metal including
      (1) a first channel along substantially the full extent of said tubular conduit means in communication with said inlet opening for controlled distribution of said second heat exchange medium entering the heat exchanger, and
      (2) a second channel along substantially the full extent of said tubular conduit means in communication with said outlet opening for controlled collection of said second heat exchange medium leaving the heat exchanger.

3. A heat exchanger in accordance with claim **2** wherein the major cross-sectional dimension of said tubular means is substantially greater than the minor cross-sectional dimension thereof.

4. A heat exchanger in accordance with claim **3** wherein said first channel decreases in depth from said first portion of said tubular means toward said second portion thereof, and said second channel decreases in depth from said second portion of said tubular means toward said first portion thereof.

5. A heat exchanger in accordance with claim **2** wherein said tubular means has an enlarged portion at each end of the major cross-sectional dimension thereof.

6. A heat exchanger in accordance with claim **5** wherein said first channel and said second channel are each of substantially equal depths along substantially the full extent thereof.

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