Sept. 5, 1967 F. A. BURNE ET AL 3,339,260

METHOD OF PRODUCNG HEAT EXCHANGERS

Filed Nov. 25, 1964 3 Sheets-Sheet 1

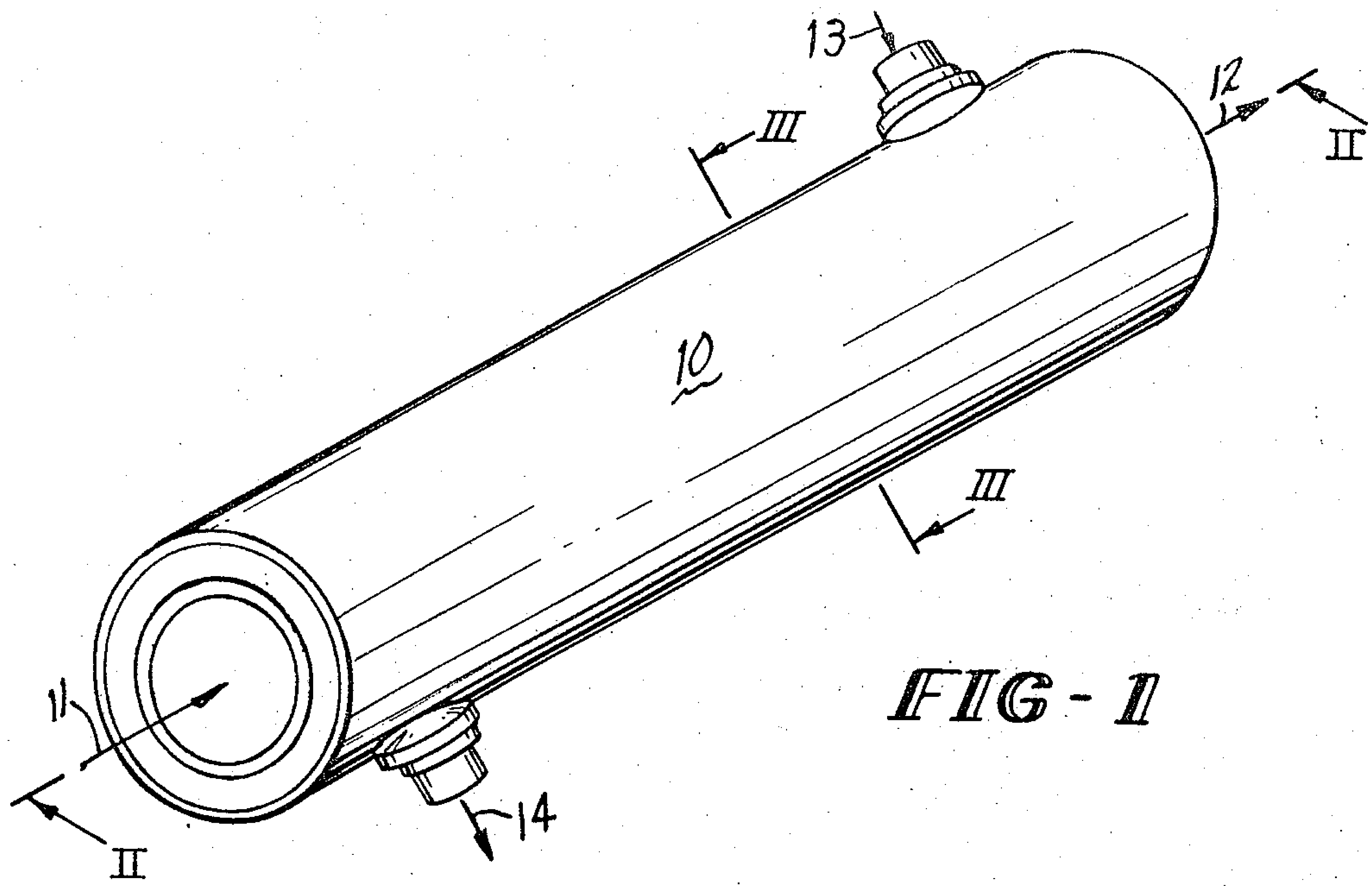


FIG-1

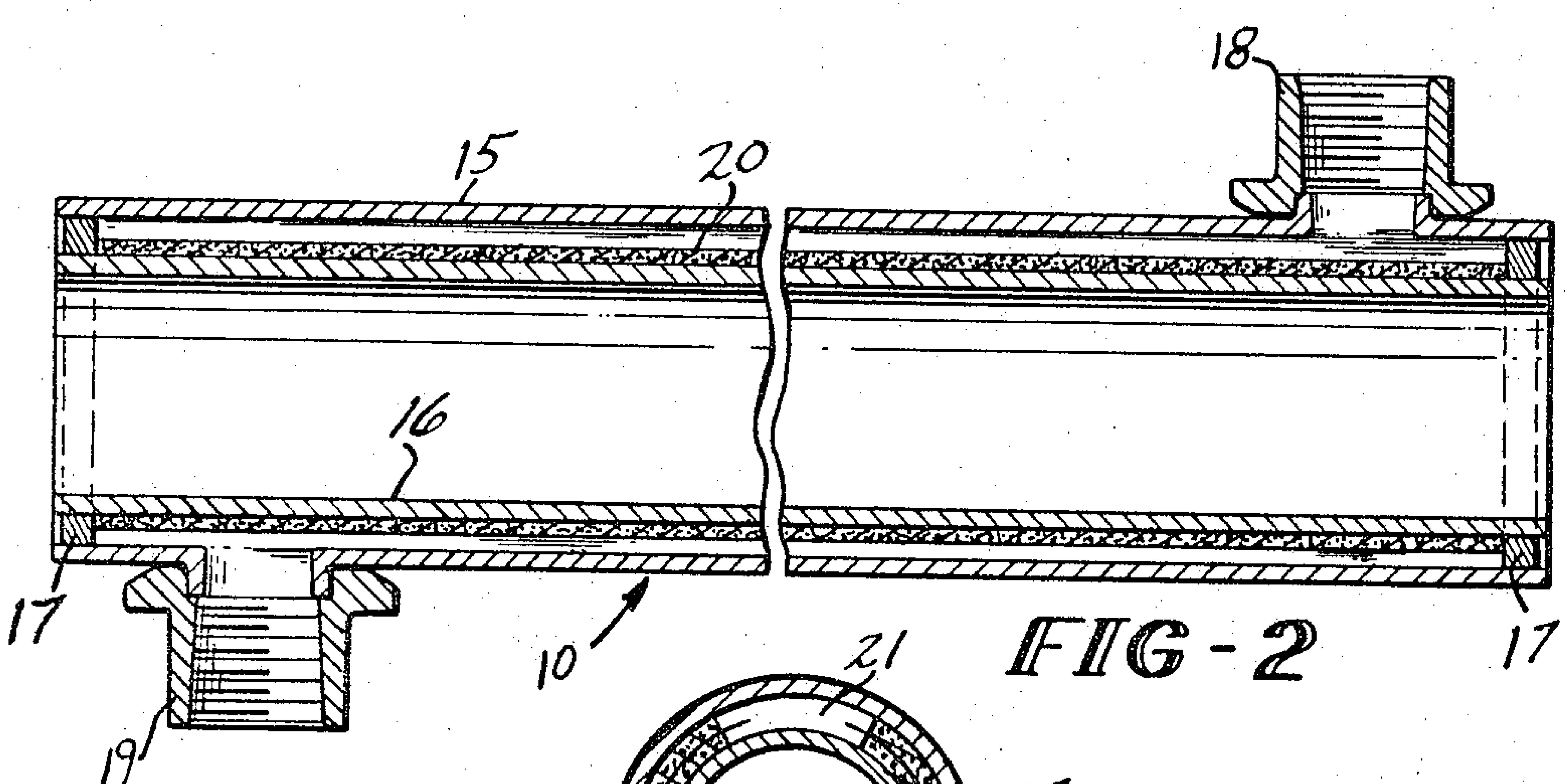


FIG-2

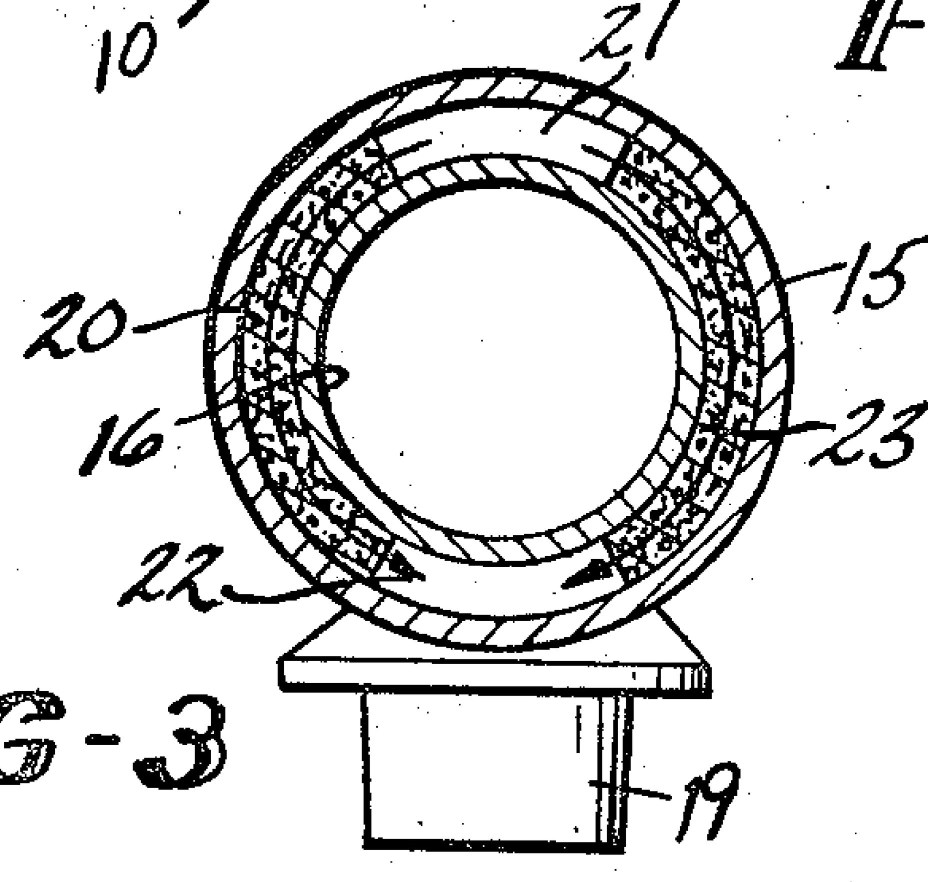


FIG-3

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METHOD OF PRODUCNG HEAT EXCHANGERS

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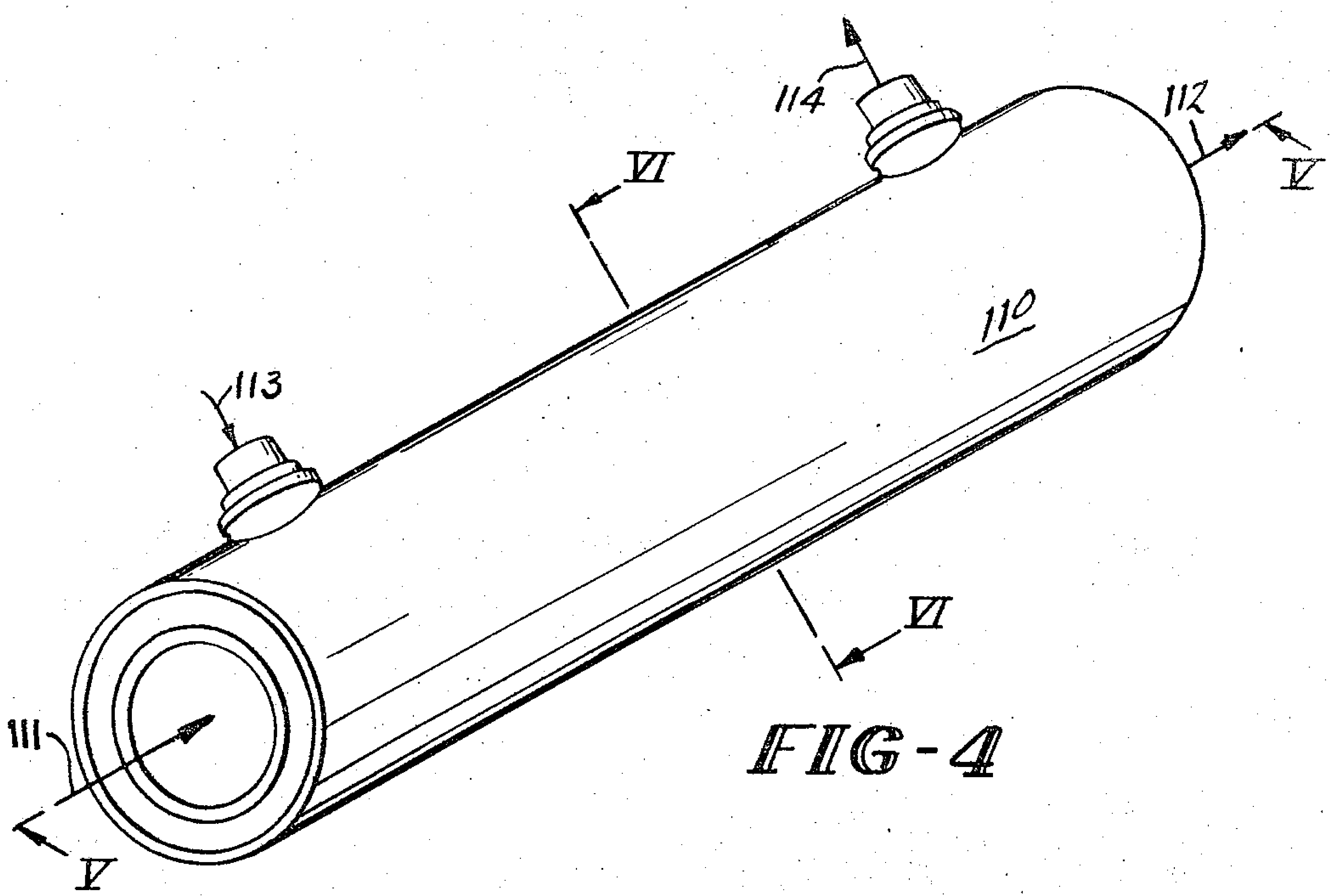


FIG-4

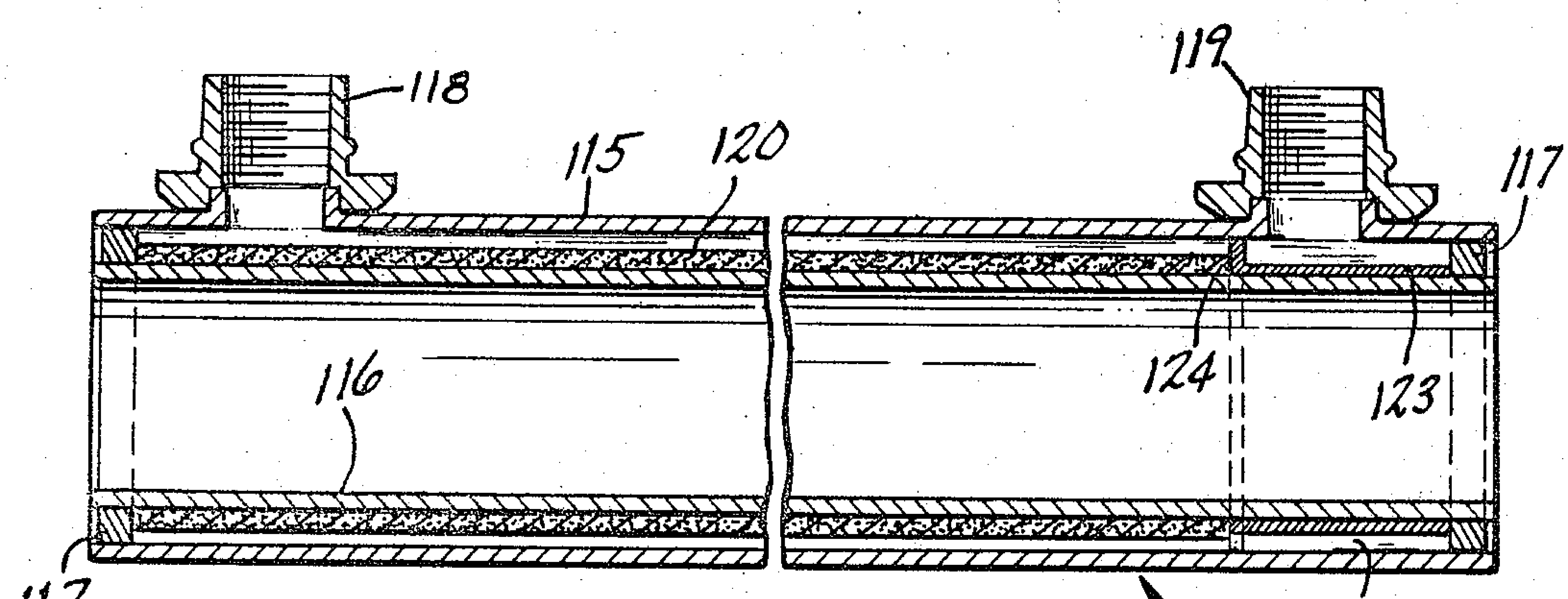


FIG-5

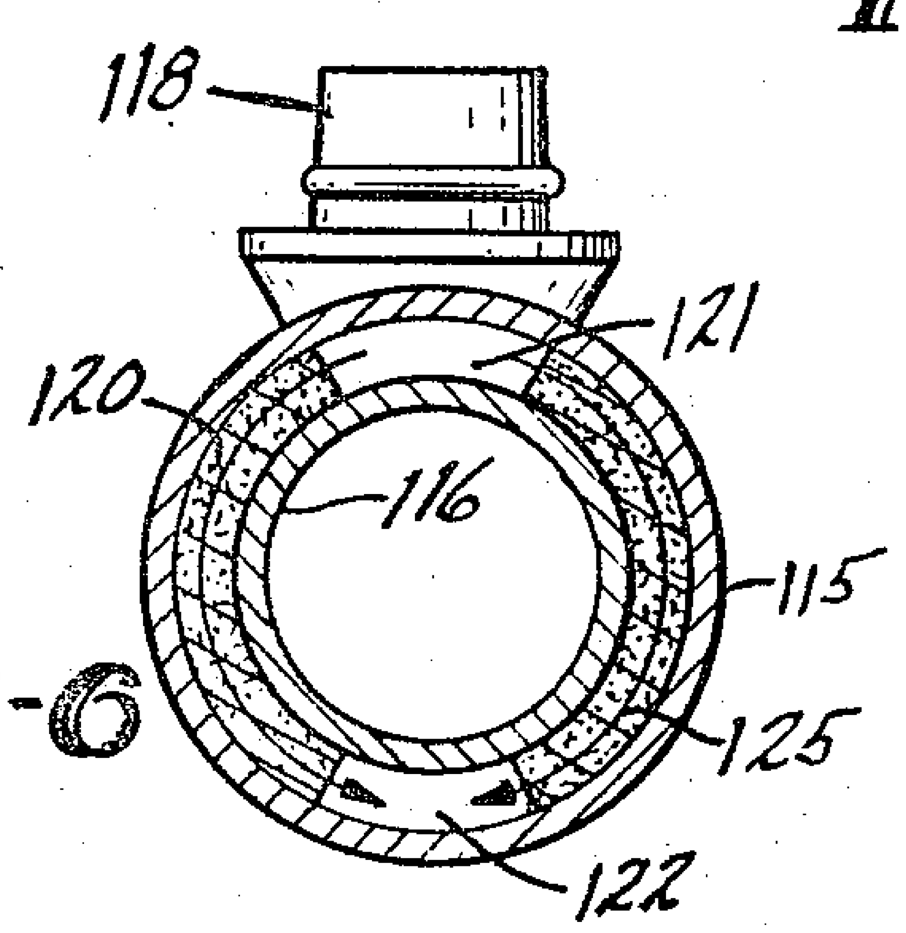


FIG-6

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METHOD OF PRODUCNG HEAT EXCHANGERS

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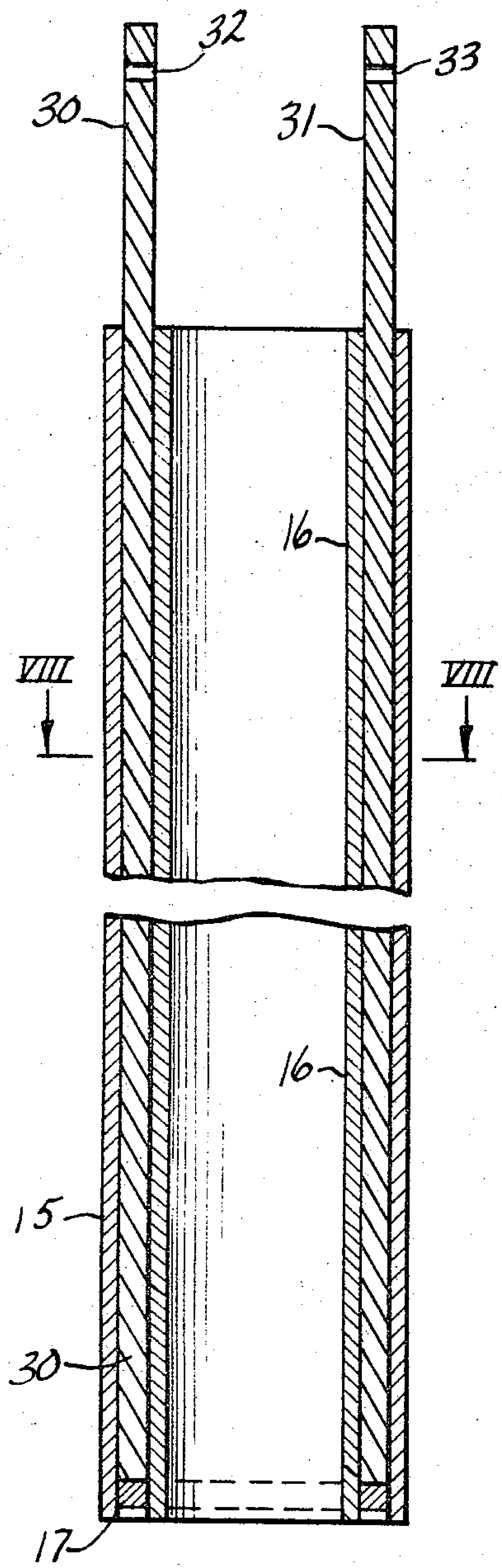


FIG-7

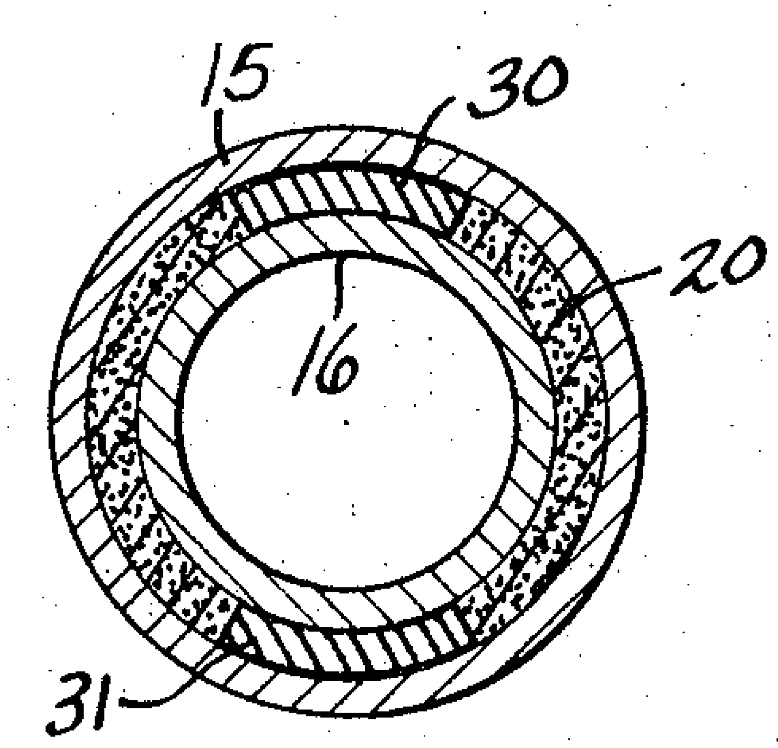


FIG-8

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# METHOD OF PRODUCING HEAT EXCHANGERS

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## ABSTRACT OF THE DISCLOSURE

This invention is a method of producing channels in a tubular heat exchanger comprising positioning a first tubular member within a second tubular member, inserting one or more cores between the tubular members, introducing a particulate material into the space between the first and second tubular members not occupied by core material, metallurgically bonding the particulate material to the first and second tubular members and removing the core material to define a channel between the two tubular members in the pervious body.


This application is a continuation-in-part of our copending application Serial Number 403,857, filed October 14, 1964.

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

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 method of producing a heat exchanger having a unique configuration and arrangement of such a 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 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, often with corrugations in the annulus between the tubes to turbulate the circulated medium; the flow path in the annulus is substantially axial along the tubes.

In the concept of the instant invention there is provided a method of producing a heat exchanger in which not only the heat exchange area is increased but the medium flow is directed in a peripheral path through the annulus formed by the concentric tubes. The advantages resulting are achieved by the provision of a body of pervious material in the space between the tubes. By a particular construction of the pervious body to be discussed hereinafter, channels are formed to serve as inlet and outlet means for a heat exchange medium and to permit uniform distribution of the medium through the pervious material in a peripheral path through the annulus.

While the usual expedient is to arrange the tubes so as to be concentric, the concept of this invention is

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equally applicable to any arrangement of a tube or tubes within a tube.

It is accordingly an object of this invention to provide a method for producing 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 a method for producing such a heat exchanger having a body of pervious material situated therein.

It is a still further object to provide a method for producing such a heat exchanger of concentric tubular members having a body of pervious material joined by a metallic bond within the annulus between the tubular members.

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

FIGURE 1 is a perspective view of a first embodiment of heat exchanger produced in accordance with the method of this invention,

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

FIGURE 3 is an axial cross-section of the heat exchanger of FIGURE 1, taken along the lines III—III thereof,

FIGURE 4 is a perspective view of a second heat exchanger produced in accordance with the method of this invention,

FIGURE 5 is a longitudinal cross-section of the heat exchanger of FIGURE 4, taken along the lines V—V thereof,

FIGURE 6 is an axial cross-section of the heat exchanger of FIGURE 4, taken along the lines VI—VI thereof,

FIGURE 7 is a longitudinal cross-sectional view similar to FIGURES 2 and 5, showing either of the embodiments of FIGURE 1 or 4 during the production thereof; and

FIGURE 8 is an axial cross-section of either of the embodiments of FIGURE 1 or 4 during the production thereof, the view being taken along the lines VIII—VIII of FIGURE 7.

An understanding of the function of heat exchangers produced according to this invention being helpful in appreciating the precise method employed, several embodiments of a heat exchanger will first be described, followed by a description of the method of producing each. Thus, a first embodiment of heat exchanger 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, surrounds the heat exchanger **10** and is also introduced into the heat exchanger **10** at one end, as shown by the arrow **11**, and exits from the opposite end as shown by the arrow **12**. Obviously, required fittings, not shown, may be employed. 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**. Thus, heat exchange may take place between the second medium and (a) the first medium surrounding the exchanger, and (b) the first medium flowing through the heat exchanger. It will be obvious that any desired mediums might be employed in the instant heat exchanger; for example, in application in an automotive cooling system, the medium introduced at **11** may be water and the medium introduced at **13** 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 two concentric tubes **15** and **16** having therebetween a body of pervious material **20**. Suitable inlet and outlet fittings **18** and **19** are provided at opposite ends of the heat exchanger. The annulus between tubes **15** and **16** is closed off at its opposite ends, for example by annular seals **17**. The pervious body **20** is formed so that there exists two channels **21** and **22** spaced 180° apart, for example as shown in FIGURE 3, to form the body **20**. It will be evident that the pervious body **20** will be securely bonded to the tubes **15**, **16** and that channel **21** communicates with the inlet **18**, and the channel **22** with the outlet **19**. Thus, the medium introduced at the inlet **18** flows through the channel **21** and distributes uniformly along the length of tube **16**, thence around the tube **16** as shown by the arrows **23** of FIGURE 3 through the circuitous paths within the pervious material **20** to the lower channel **22**, where it may pass through the outlet **19**. It will be evident that the provision of the pervious body **20** not only presents increased heat exchange surfaces for contact by the circulated medium but, due to the circuitous peripheral flow paths presented, also provides uniform distribution through the entire pervious structure with a minimum pressure drop.

A second modification of heat exchanger is depicted in FIGURES 4–6. In this embodiment, there is provided an appropriate manifold so that the exchanger may be employed in applications where it is desirable that the inlet and outlet be on the same side of the exchanger. As was the case with the exchanger of FIGURES 1–3, the heat exchanger **110** is immersed in a first heat exchange medium, which enters the exchanger in the direction of the arrow **111** of FIGURE 4, and exits at the opposite end as shown by the arrow **112**. However, in this embodiment, the second medium may enter and exit from the same side of the exchanger, as shown at **113** and **114**.

Referring now to FIGURES 5 and 6, it will be evident that the tubes **115** and **116**, the annular seals **117**, and the pervious body **120** having channels **121** and **122** are analogous to the structure of the heat exchanger of FIGURES 1–3 referenced by the respective characters, **15**, **16**, **17**, **20**, **21**, and **22**. However, the inlet **118** and outlet **119** are situated on the same side of the heat exchanger **110**. A manifold is provided near the outlet **119** comprising a ring **123** surrounding the inner tube **116** and having a peripheral flange **124**. The flange **124** covers the entire annulus between the tubes **116** and **115** except for an area in alignment with and matching the configuration of the channel **122**. Thus, it will be seen that the second medium, e.g., that to be heated or cooled, enters through the fitting at **118** and distributes uniformly along the length of the tube **116** within the channel **121**, thence around the tube **116** as shown by the arrows **125** of FIGURE 6, through the circuitous paths provided in the pervious body **120**, collecting in the channel **122**, from which it is forced wtihin the annulus **126** between the ring **123** and tube **115** from the lower portion thereof to the upper portion thereof, where it exits through the fitting provided at **119**. The flange **124** prevents such medium from entering the ring **123** except at the desired point, that is, at the lower portion thereof through the channel **122**.

It is to be understood that the concept of this invention need not be limited to the particular configuration indicated above. For example, tubes need not be exclusively employed; any desired shape of exchanger may be provided, with the pervious body shaped accordingly to fit. Furthermore, any number of tubes may be employed, the exchanger may be used for either heating or cooling, and the tubes may be of any desired cross-section.

Considering now the novel method by which the heat exchangers previously described may be produced, reference may be had to FIGURES 7 and 8. Since production of the heat exchanger of FIGURE 4 is basically similar to that of FIGURE 1, the discussion which follows will be directed only to the latter, it being understood that production of the heat exchanger of FIGURE 4 is similar unless indicated to the contrary.

As will be understood, 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, brass, 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 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 bebetween 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 of forming the pervious body 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 seen that a heat exchanger may be produced in accordance with this invention by a unique method. Tube **16** is positioned on a suitable support, and cores **30** and **31** situated around tube **16**, as best shown in FIGURE 8. Tube **15** may then be slipped down over cores **30** and **31**, it being understood that appropriate openings for the fittings **18** and **19** may first be formed in any conventional fashion, or that tube **15** may be purchased with the extruded openings already present. The annulus between tubes **15** and **16** may be closed off at its lower end as by appropriate projections of the support or by end seal **17**.

As shown in FIGURE 7, cores **30** and **31** project above the upper ends of tubes **15** and **16**. And, as best seen in FIGURE 8, cores **30** and **31** are spaced apart to form the channels previously discussed. For reasons to become evident shortly, 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 metal core and any other body.

Particulate material may now be poured into the annulus between tubes **15** and **16** in the volume not occupied by cores **30** and **31**. For the heat exchanger of FIGURE 1, the particulate material will be poured to a level short of the upper end of the tubes a distance suitable to allow for subsequent insertion of the second annular seal **17**. For the heat exchanger of FIGURE 4, the particulate material will be poured to a level short of the upper end of the tubes sufficiently to allow for insertion of manifold **123**, see FIGURE 5. The particulate material introduced may not flow through the openings in tube **15**, for such openings would be covered by cores **30** and **31**. Following any of the metallurgy procedures previously discussed, the particulate material may be then treated to achieve a metallic bond between the various particles and between the particulate material and tubes **15** and **16**. No metallic bond will be created between the resulting pervious body **20** and 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 with an appropriate tool inserted in holes **32** and **33**, respectively, of cores **30** and **31**. Annular seal **17** may now be inserted and suitably secured in the upper portion of the annulus, or—in the case of the heat exchanger of FIGURE 4—manifold **123** and seal **117** (see FIGURE 4) may be inserted and suitably secured, as by brazing, soldering, cementing, welding, or mechanically securing by deforming the seal or tube or tubes. Addition of the required fittings completes the fabrication, and the heat exchanger is ready for use.

While we have shown and described different desirable embodiments which result from the method of this invention, it is to be understood as for the purpose of illustration only and that various changes and modifications may be made in the disclosed method without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

**1**. A method of producing a tubular heat exchanger



having a body of pervious material therein, said body of pervious material having channels therein for controlled circulation of a heat exchange medium, the method comprising

(A) positioning a first tubular member within a second tubular member, said second tubular member having at least one radial opening therein,

(B) inserting at least one preformed removable core in the space between said first and second tubular members, said core being of a configuration of the desired channel and in communication with said radial opening in said second tubular member,

(C) introducing particulate metallic material into the remaining space between said first and second tubular members,

(D) creating a metallic bond between the particles of said particulate metallic material and between said particulate metallic material and said first and second tubular members, to form a pervious body in the space between said first and second tubular members, and

(E) removing said core to form a channel in said pervious body in communication with said radial opening in said second tubular member.

**2**. The method of claim **1** wherein two cores are employed, said cores being spaced from each other.

**3**. The method of claim **1** wherein said core is of a material unaffected by said metallic bond.

**4**. The method of claim **1** wherein said core comprises a metal coated with a material unaffected by said metallic bond.


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