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[54] METHOD OF FORMING A HEAT PIPE

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[58] Field of Search. 29/157.3 R; 165/105

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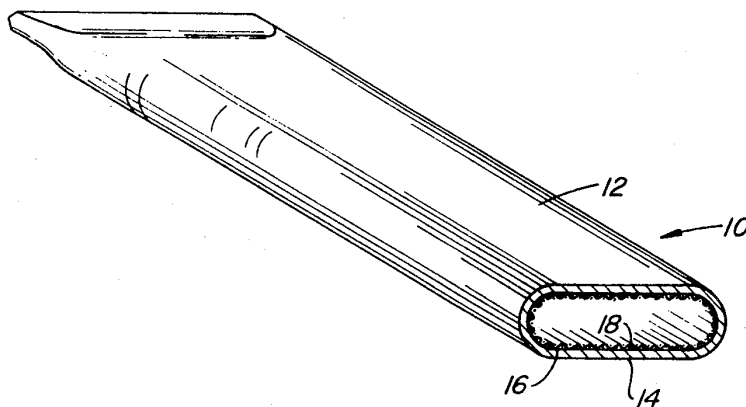
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[57] ABSTRACT

The specification and drawings disclose flat heat pipe structures and methods for forming same. One embodiment comprises an outer tube into which a second tube of wick material is inserted. The outer tube and the wick tube are selected so that the wick has a higher tensile strength. Thereafter, the outer tube can be deformed to a flattened configuration and the higher tensile strength of the wick causes it to closely engage the inner surface of the outer tube. The second embodiment comprises a sandwich-like construction of outer wall forming plate members, wick sheets, and intermediate spacers bonded to both the wick sheets and the outer wall forming plates.

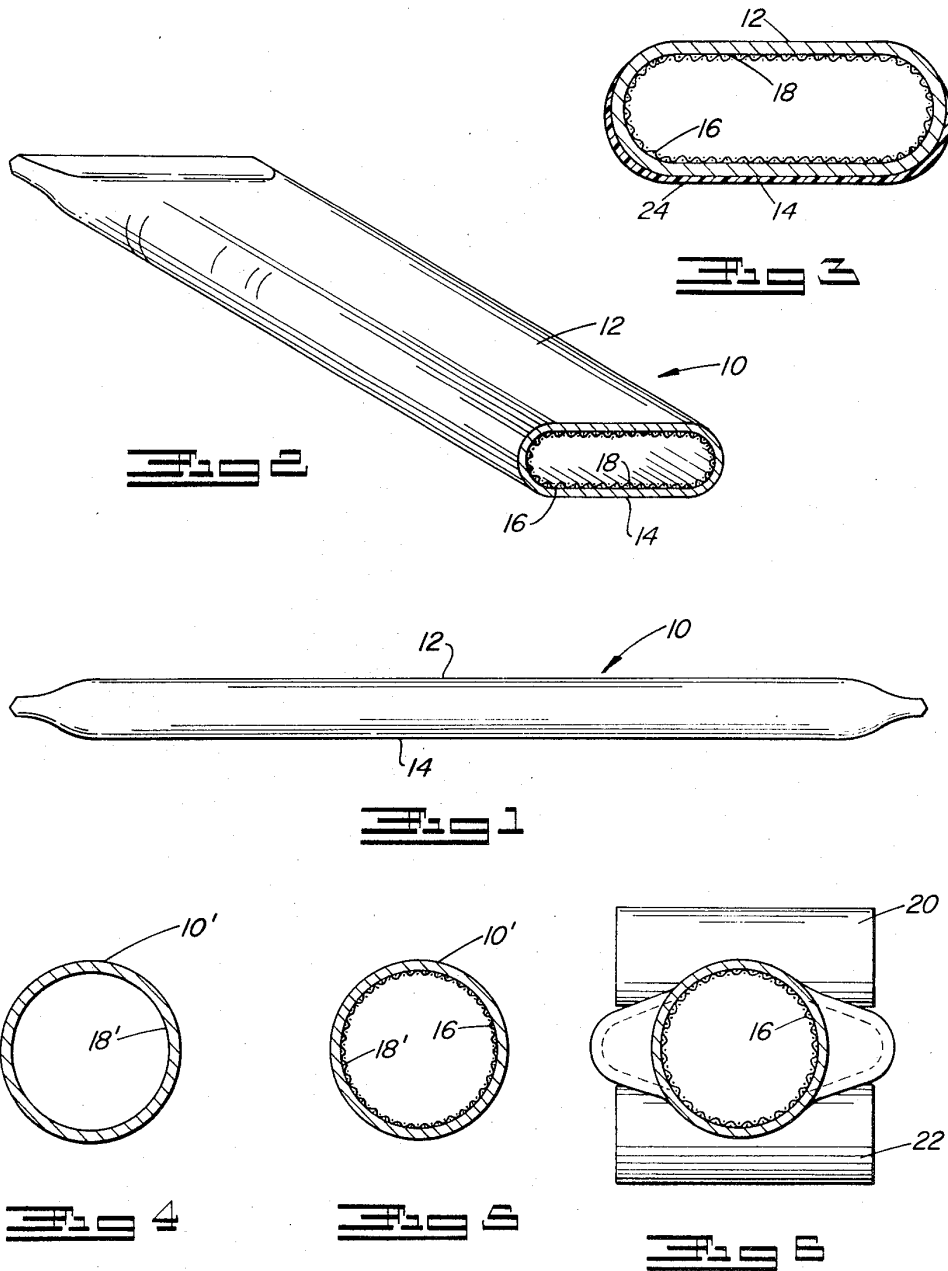
10 Claims, 9 Drawing Figures



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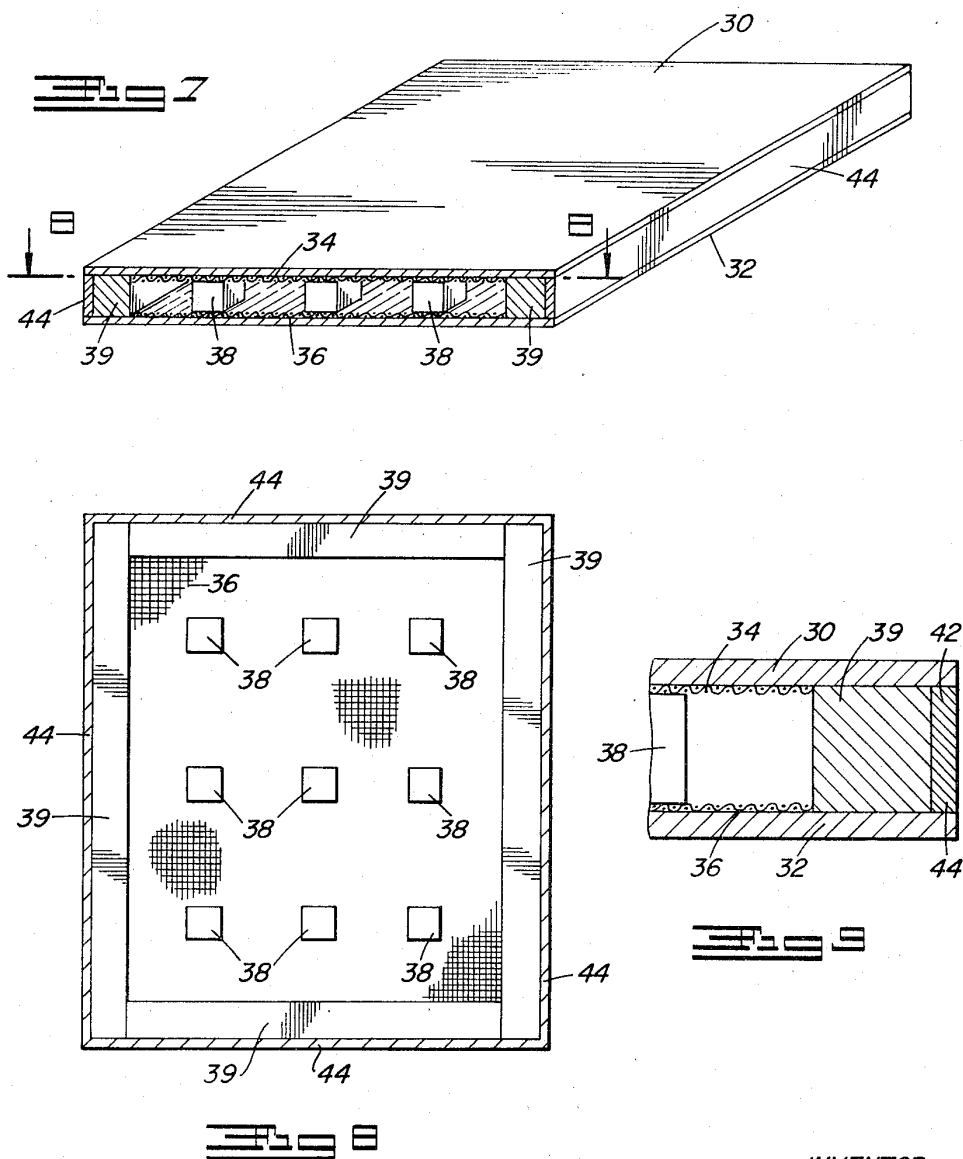


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METHOD OF FORMING A HEAT PIPE

The present invention is directed toward the art of heat exchange and, more particularly, to improved flat heat pipe constructions and methods of forming the same.

The invention will be described with reference to preferred embodiments; however, it will become apparent that the invention could take embodiments other than those specifically disclosed.

Heat pipes have become an increasingly important method of transferring heat. They are often used for conducting heat away from electronic components, maintaining spaced parts at a common temperature, and wherever extremely efficient heat transfer is required.

The typical heat pipe comprises a cylindrical tube having a wick positioned about its internal surface. Normally, a vaporizable fluid is placed in the tube in an amount slightly in excess of that required to completely wet the wick. Thereafter, the tube is partially evacuated and sealed. Sometimes, non-condensable gases are introduced into the tube to vary the heat pipes' characteristics.

The operation of a heat pipe is relatively simple. The liquid in the wick at a hot point on the tube is vaporized and the vapor moves to a cool point in the tube and condenses. The wick acts to move the condensed liquid by capillary action back to the point or points where evaporation is taking place. Because the latent heat of vaporization of the liquid is carried by vapor from the point of evaporation to the point of condensation, heat is transferred down the pipe with little or no temperature drop along the length of the pipe.

As mentioned above, the typical heat pipe has been of cylindrical shape. In many applications, it would be much more preferable to have a heat pipe with a flat configuration. For example, with a flat heat pipe, the contact area between a component to be cooled and the heat pipe can often be greatly increased over that possible with a cylindrical pipe. Similarly, a flat heat pipe structure offers designers the possibility of using the heat pipe itself as a structural component such as a housing, mounting board or the like.

The problems involved in forming flat heat pipes are many. First, to be most efficient and economical, a heat pipe should preferably be formed from thin material. With a cylindrical shape, the pressures involved can be handled with a thin wall; however, in a flat pipe the wall must normally be substantially thicker. Thus, cost and efficiency are impaired. Secondly, with a cylindrical heat pipe construction, pressure sealing is accomplished simply by closing the ends of the tube, whereas, in a flat construction difficulties are encountered in assuring a pressure seal because of the relatively extensive length of edge. Thirdly, in a flat heat pipe it has been difficult to provide and maintain intimate contact between the wick and the wall surfaces.

The present invention provides heat pipe constructions and methods of forming the same which allow flat heat pipes of substantially any size to be formed rapidly and economically. The invention further permits wide variation in the dimensions of the heat pipes so that they can be constructed for substantially any need.

In accordance with one aspect of the invention, there is provided a method of forming a flat heat pipe comprising the steps of:

selecting a tube having a desired length and formed from a deformable metal;

providing a cylinder of screen having an outer diameter which closely approximates the inner diameter of the tube and formed from a material having a higher tensile strength than the tube;

inserting the cylinder of screen in the tube; and, thereafter applying pressure to generally diametrically opposite sides of the assembly in an amount sufficient to change its cross-section from circular to a tube with at least one generally flat exterior wall.

Preferably, but not necessarily, the tube is formed so that the diametrically opposite sides to which the pressure is applied are deformed so as to both be generally flat and parallel. During the deformation, the higher tensile strength of the screen cylinder causes it to tightly engage the inner walls of the tube. The screen thus remains in engagement with the walls.

To complete the assembly for use as a heat pipe, the ends are sealed and the interior evacuated and/or filled with a desired gas to cause the assembly to have selected heat transfer characteristics.

As can be appreciated, the above discussed method is particularly suited for producing heat pipes of substantially any length with flat exterior surfaces and small cross-sections. The advantages and used for this type of heat pipe are many. For example, they are particularly suited for cooling small electronic parts such as transistors and the like. They can be made small enough to fit between the electrical leads and in direct contact with the body of the component. Further, they can be used to keep a large number of components at the same temperature by being deformed longitudinally as desired.

An additional feature is that a large number of different types of materials can be used to form heat pipes by the disclosed method to provide characteristics desired. It is only necessary that the inner screen (i.e., the wick member) have a higher tensile strength than the tube. This assures proper mating or engagement between the tube's inner wall and the screen.

In accordance with another aspect of the invention, there is provided a heat pipe construction comprising a body having relatively closely spaced, generally parallel flat walls with terminal edges joined by small rod or bar members bonded to each to seal the interior. Wick members are positioned on the interior of the assembly adjacent each wall and substantially coextensive therewith. A plurality of spacer members are positioned between the wick members to maintain them in engagement with the respective wall. The spacer members are bonded to both the wick members and the walls. Preferably, the walls, wick members, and the spacer members are all formed from metal. The bonding is accomplished by applying the bonding material, for example solder, to the ends of the spacers prior to assembly. During or after assembly, the bonding material is caused to pass through the wick members to the walls. In the case of solder, the assembled components are merely heated to a temperature sufficient to melt the solder so as to cause it to flow through the wick to the wall. Thus, all elements are bonded together in one operation.

It should be understood that the method and structures described can be used to make heat pipes of substantially any size. Further, the materials used can vary

depending upon the application or characteristics desired.

Accordingly, the primary object of the invention is the provision of heat pipe constructions and methods of forming the same for producing heat pipes having flat surface areas of substantial extent.

Another object is the provision of a heat pipe construction and method of forming the same which is particularly suited for making extremely small heat pipes of the type needed for cooling electronic components and the like.

A further object of the invention is the provision of a heat pipe construction which allows rapid fabrication of flat heat pipes having substantial structural strength.

Yet another object of the invention is the provision of a heat pipe construction that allows heat pipes to be easily constructed from many types of materials.

The above and other objects and advantages will become apparent from the following description when read in conjunction with the accompanying drawings wherein:

FIG. 1 is a longitudinal side view of a heat pipe formed in accordance with a preferred embodiment of the invention;

FIG. 2 is a pictorial view of the heat pipe shown in FIG. 1 with a portion cut away to show the interior of the heat pipe;

FIG. 3 is a cross-sectional view through a heat pipe formed in accordance with the invention and showing how insulating material can be applied to portions of the outer surface;

FIGS. 4 through 6 are views showing the preferred sequence of steps used for forming the heat pipe of FIG. 1;

FIG. 7 is a pictorial view of a second form of heat pipe formed in accordance with the invention with a portion cut away to show the interior of the structure;

FIG. 8 is a cross-sectional view taken on line 8-8 of FIG. 7; and,

FIG. 9 is an enlarged cross-sectional view showing a corner or edge portion of the heat pipe of FIG. 7 to more clearly illustrate the manner in which the corner is sealed.

Referring more particularly to the drawings wherein the showings are for the purpose of illustrating preferred embodiments of the invention only and not for the purpose of limiting same, FIGS. 1 and 2 show a heat pipe construction which is particularly suited for forming extremely small, flat heat pipes having at least one outer surface which is flat throughout a considerable extent of the pipe. As will be noted, the heat pipe shown in FIG. 1 comprises an elongated tubular member 10 having opposed walls 12 and 14 which are generally flat and parallel throughout the length of the tube. As will be discussed more fully hereafter, the particular material from which the tube 10 is formed can vary substantially; however, it preferably has a specific strength relationship relative to the material from which the internal wick member is formed.

In the embodiment under consideration, the internal wick comprises a tubular wire screen member 16 which extends the length of the tube and has its outer surface closely and tightly in engagement with the interior surface 18 of the tube 10. For reasons which will hereafter be set forth at length, the internal screen cylinder or

tube 16 preferably has a tensile strength which is substantially greater than the tensile strength of the tube 10.

As can be appreciated, the screen cylinder 16 functions as the wick to conduct condensed fluid through capillary action to the hot section of the pipe as is customary in heat pipe units. Consequently, it should be understood that the cylinder could be formed from many separate layers and/or from different types of screen or fabric.

Although many types of materials could be used for forming the heat pipe illustrated in FIG. 1, according to the preferred embodiment, the outer tube 10 is formed from hard copper tubing and the inner screen or wick member 16 is formed from a fine silicon bronze wire screening or mesh. The manner in which the heat pipe illustrated in FIGS. 1 through 3 is formed, constitutes an important aspect of the invention. FIGS. 4 through 6 show the preferred sequence followed in making the heat pipe. Referring first to FIG. 4, the first step constitutes selecting a section of tubing 10' having a length as great as needed for the particular heat pipe to be formed. Preferably, but not necessarily, the interior surface 18' of the section 10' is provided with a multiplicity of longitudinal score lines to increase capillary action in the final heat pipe. The particular manner in which the score lines are provided could vary widely; however, it has been found that merely by taking a tube of emery paper or sand paper and forcing it through the tube, the interior is scored sufficiently to provide substantial improvement in capillary action.

After the tube has been scored, a cylinder of wicking material, for example, the silicon bronze screen 16, is formed of a length substantially equal to the tube 10'. Preferably, the cylinder 16 has an outer diameter equal to or slightly greater than the interior diameter of the tube 10'. The cylinder is then inserted entirely within the tube 10' so as to engage the interior wall 18'.

After the screen has been inserted in the tube, as shown in FIG. 5, a pressure is applied to the tube to deform it in the manner intended. For most uses, the tube has pressure applied to diametrically opposite exterior surfaces in an amount sufficient to deform the tube to the cross-section shown in FIG. 2. For example, FIG. 6 illustrates a pair of pinch rolls 20 and 22 being utilized to deform the tube to the cross-section illustrated in FIG. 2. During the deforming operation, the internal screen cylinder 16 is also deformed but because of the screen cylinder's greater tensile strength, it has greater "spring back" and attempts to resume its original cylindrical shape. This causes the screen to closely engage the inner surface of the wall for improved capillary action.

After or even before the tube's cross-section is deformed, the ends of the tube are sealed. The sealing can be accomplished by a simple crimping and soldering process. Of course, other types of inserts, plugs or the like could be used for sealing the tube. After the sealing step or jointly therewith, the interior of the tube can be evacuated to the level desired or filled with a desired gas to produce a heat pipe having the characteristics needed.

This structure and method of forming a heat pipe is extremely useful for forming very tiny heat pipes of the type needed in many electronic cooling applications. It

should be appreciated that the exterior of the heat pipe can be coated with an electrically insulating paint or the like 24 (See FIG. 3) so that various portions of the outer surface can be placed in contact with leads of transistors or similar components. For example, the shape as shown in FIG. 3 can be made so as to engage the under surface of a transistor with the leads running down the curved ends adjacent the insulated portion of the surface. The lower surface can directly contact the various parts of a printed circuit board or the like.

FIG. 7 illustrates a second embodiment of the invention which is suited for forming flat heat pipes of substantial longitudinal and lateral extent. In particular, the FIG. 7 embodiment includes a pair of relatively thin, spaced, wall forming plate members 30 and 32 formed from any desired fluid impervious sheet material. In the embodiment under consideration, the sheets 30, 32 are preferably a copper or copper alloy for reasons which will hereafter become apparent.

The wick members for the tube preferably comprise wire screen sheets having a size substantially equal to the plate members 30, 32. Each of the plates 30, 32 has associated therewith a separate wick member 34 and 36 respectively. It should be noted that the wick members preferably terminate inwardly a short distance from the terminal edge portions of their respective plate member. Positioned between the plate and wick combinations 30, 34 and 32, 36 respectively, are a multiplicity of spacer members 38. The spacer members 38 have a height to provide a desired spacing between the components. Further, their cross-section can be any desired shape. Although they are illustrated as small rectangles, they can obviously be circular discs or the like. The number of spacer members utilized can vary widely; however, they should be sufficient to provide the final assembly with desired strength characteristics.

In the embodiment under consideration, each of the spacer members 38 is bonded to the outer wall forming members 30, 32 by a bonding material which passes through the screen or wick members 34, 36 into engagement with the interior surfaces of the outer walls. According to the preferred embodiment, each of the members 30, 32 and 34, 36 are formed from a metal which can be soldered. Also, the spacer members 38 are likewise formed from metal or other material which can be soldered. To assemble the unit, solder is applied to the opposite ends of each of the spacer members 38. The spacer members are then positioned in the desired pattern over the lower assembly 32, 36. The upper assembly 30, 34 is then positioned on the top surfaces of the spacers. The assembled sandwich-like structure is clamped or held in the assembled position and the entire unit heated to a point sufficient to melt the solder and have it flow by capillary action through the wicks or screens into engagement with the inner surface of the walls. The unit is thus quickly bonded in the desired final shape.

As can be appreciated, the outer edge portions of the sandwich-like structure must be sealed so as to allow the unit to function as a heat pipe. Many different types of edge sealing arrangements could be used; however, in the preferred embodiment, the outer edges of the assembly are sealed by small rectangular bars of solderable metal 39 positioned as best illustrated in FIG. 8. Preferably, the bars 39 are positioned inwardly from

the outer edges of the respective plates 30, 32 so as to leave a small recess or gap 42. Preferably, the bars 39 are joined in proper position in the same manner as described with reference to the spacers 38. That is, the outer surfaces are coated with solder and the bars are positioned in the assembly prior to the heating operation.

After the heating operation has been completed and the bars have been soldered, the edges are further sealed by filling the gaps 42 with solder or similar sealant 44.

A small evacuating hole can be left open along the peripheral edge at any desired point. Alternately, a separate evacuating hole can be drilled through the assembly and subsequently filled by soldering or the application of a suitable adhesive.

Although the structure has been described in conjunction with the use of solder and metal components, it should be appreciated that various types of materials and bonding substances could be used. Additionally, although the unit has been described as having a completely flat shape, it should be appreciated that it could be formed in various polygonal cross-sections with the spacing between the plates varying throughout the extent of the unit.

The invention has been described in great detail sufficient to enable one of ordinary skill in the heat pipe art to make and use the same. Obviously, modifications and alterations of the preferred embodiments will occur to others upon a reading and understanding of the specification and it is my intention to include all such modifications and alterations as part of my invention insofar as they come within the scope of the appended claims.

What is claimed is:

1. A method of forming a heat pipe comprising the steps of:

- selecting a tube having a desired length and formed from a deformable material;
- forming a cylinder of wick material with an outer diameter which closely approximates the inner diameter of the tube and formed from a deformable material having higher tensile strength than the tube;
- positioning the cylinder in the tube; and,
- thereafter, applying pressure to generally diametrically opposite sides of the assembly in an amount sufficient to deform the tubing's circular cross-section to a cross-section throughout a substantial portion of the length which has at least one generally flat exterior wall.

2. The method of claim 1 wherein the pressure is applied in a manner so that the diametrically opposite sides are deformed so as to both be generally flat and parallel substantially throughout the length of the tube.

3. The method as defined in claim 1 wherein the ends of the tube are sealed.

4. The method as defined in claim 1 wherein said cylinder is provided with a length slightly less than the length of said tube and wherein the cylinder is positioned entirely within said tube.

5. The method as defined in claim 1 wherein said cylinder is formed from fine wire screen.

6. The method as defined in claim 1 wherein the ends of said tube are sealed after the tube has been deformed the desired cross-section.

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7. The method as defined in claim 1 wherein portions of the exterior surfaces of said tubing are coated with electrical insulating material.

8. The method as defined in claim 1 wherein the tube is formed from hard copper and the wick material is phosphor bronze screening.

9. The method of claim 1 wherein the interior of said

tube is provided with longitudinally extending score lines.

10. The method as defined in claim 9 wherein said score lines are formed by abrading the interior of said tube.

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