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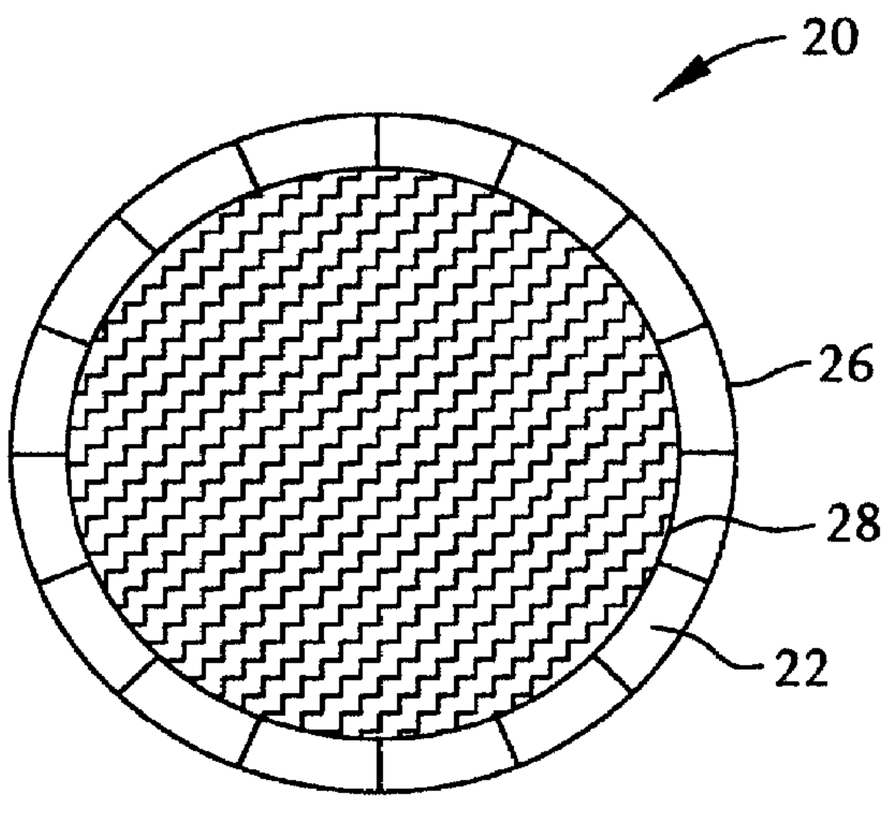
(54) **DISPOSITIFS POUR REDUIRE LA DERIVATION DE VAPEUR DANS DES COLONNES GARNIES ET METHODE D'ASSEMBLAGE**

(54) **DEVICES TO REDUCE VAPOR BYPASS IN PACKED COLUMNS AND METHOD OF ASSEMBLY**



(57) An apparatus is disclosed for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream. The apparatus includes a substantially cylindrical section of a column having an inner wall, and a plug of packing disposed inside the section of the column. The plug of packing has an exterior surface spaced apart from the inner wall of the section of the column. The apparatus also includes restricting means for minimizing flow of the vapor stream in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

ABSTRACT OF THE DISCLOSURE

An apparatus is disclosed for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream. The apparatus includes a substantially cylindrical section of a column having an inner wall, and a plug of packing disposed inside the section of the column. The plug of packing has an exterior surface spaced apart from the inner wall of the section of the column. The apparatus also includes restricting means for minimizing flow of the vapor stream in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

PATENT

Attorney Docket Number: 211PUS05822

TITLE OF THE INVENTION:

DEVICES TO REDUCE VAPOR BYPASS IN PACKED COLUMNS AND METHOD OF ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

BACKGROUND OF THE INVENTION

The present invention relates to minimizing vapor bypass in a packed column for exchanging heat and/or mass between a liquid and a vapor. The invention has particular application in cryogenic air separation processes utilizing distillation, although it may be used in other heat and/or mass transfer processes that use packing (*e.g.*, random or structured packing). The present invention also relates to methods for assembling packed columns incorporating restricting means for minimizing vapor bypass.

The term, "column", as used herein, means a distillation or fractionation column or zone, *i.e.*, a column or zone wherein liquid and vapor phases are counter-currently contacted

to effect separation of a fluid mixture, such as by contacting of the vapor and liquid phases on packing elements mounted within the column.

The term "packing" means solid or hollow bodies of predetermined size, shape, and configuration used as column internals to provide surface area for the liquid to allow mass transfer at the liquid-vapor interface during countercurrent flow of two phases. Two broad classes of packings are "random" and "structured".

"Random packing" means packing wherein individual members do not have any particular orientation relative to each other or to the column axis. Random packings are small, hollow structures with large surface area per unit volume that are loaded at random into a column.

"Structured packing" means packing wherein individual members have specific orientation relative to each other and to the column axis. Structured packings usually are made of expanded metal or woven wire screen stacked in layers or as spiral windings; however, other materials of construction, such as plain sheet metal, may be used.

The term "plug of packing" (or "plug"), as used herein, means one or more layers of packing, where a layer is composed of one or more individual segments of packing.

Cryogenic separation of air is carried out by passing liquid and vapor in countercurrent contact through a distillation column. A vapor phase of the mixture ascends with an ever increasing concentration of the more volatile components (*e.g.*, nitrogen) while a liquid phase of the mixture descends with an ever increasing concentration of the less volatile components (*e.g.*, oxygen). Various packings or trays may be used to bring the liquid and gaseous phases of the mixture into contact to accomplish mass transfer between the phases.

The use of structured packing in distillation columns is standard practice and has many advantages where low pressure drop is important. The liquid and the vapor flow

counter-currently in a distillation column, which usually has an annular space between the packing and the column wall.

The performance of a packed distillation column may be very sensitive to vapor bypass along the column wall via this annular space, depending on the operating conditions of the column. The effect of vapor bypass is particularly significant in column sections with a very high purity top product, such as a high pressure column, a top hat section of a low pressure column, or a pure argon column in an air separation plant. For example, in a typical high pressure column, 1% vapor bypass can increase the oxygen concentration in the nitrogen product from 1ppm to 2100 ppm (where ppm means parts per million; ppb means parts per billion). Although total vapor bypass does not occur in practice, partial bypass with remixing does occur. Mixing of the bypassed vapor with the distilled vapor reduces the impact of vapor bypass on performance, but does not eliminate the detrimental impact.

Column diameter has a significant effect on the potential for bypass along a column wall. Small-diameter columns are more susceptible to vapor bypass because the percent annular area near the column wall increases for a fixed gap size as column diameter decreases. Figure 1 illustrates this point with a plot of percent annular area versus column diameter at a typical packing to wall distance of 4.5 millimeters (mm). As shown, relative to a 200 millimeter (mm) column, a 400 millimeter (mm) column has about one half the percent annular area, and a 1000 millimeter (mm) column has about one fifth the percent annular area.

Through analysis and experimentation, the present inventors have found that minimizing or eliminating vapor bypass can have a significant impact on mass transfer performance in distillation columns. This is especially important for columns which require high purity top products (*e.g.*, impurities measured in ppm or ppb), such as a high pressure column or a top hat column section in a low pressure column which separates nitrogen from

oxygen and argon. Another example is a distillation column which separates argon from oxygen to very low oxygen impurities (ppm).

The prior art methods are not very effective in minimizing vapor bypass in small packed columns. This is because the geometry of a packing plug is determined by considering not only performance factors, but also cost, ease of fabrication, and ease of installation.

One supplier's standard offering for small-diameter plug packing is with gauze wipers. The supplier also offers a 3 millimeter metal band option around the plug for ease of installation. The primary intended use of the gauze wipers is to wipe liquid off the walls of the column. The gauze wipers are subject to vapor bypass, however, and the 3mm band increases the annular area between the edge of the packing and the column wall, both of which can increase vapor bypass along the column wall.

In large-diameter field-installed columns, where plug packing is not practical, the same supplier recommends that a space be left between the packing and the column wall so that liquid does not reach and then flow down the wall. While this may reduce liquid bypass, it creates a channel for vapor bypass, which can be very detrimental for ultra-high purity applications.

Other suppliers use various devices on their packing plugs to reduce or eliminate liquid flow on the column wall. However, as the present inventors have discovered, a major performance benefit can be obtained by blocking the annular area in small-diameter columns so as to minimize vapor bypass in the columns. The benefit is not obtained in the prior art, which does not recognize the need to eliminate vapor bypass.

The purpose of the prior art devices in the annular space (between the structured packing and the column wall) is to reduce or eliminate liquid flow on the column wall, not to eliminate vapor bypass. The need to minimize vapor bypass is not recognized in the prior

art. Even where solid wipers are used, the intent is to remove liquid from the walls, not to minimize vapor bypass.

For example, U.S. Pat. No. 5,464,573 discloses a wall wiper to receive and direct liquid from the internal wall of a column inwardly for collection and distribution by a liquid collector-distributor device. No mention is made of vapor bypass or a desire to minimize vapor bypass.

It is desired to have a means for significantly minimizing or eliminating vapor bypass in a distillation column (and other exchange columns) with packing in order to improve mass transfer performance of the column.

It is further desired to have a means for significantly minimizing or eliminating vapor bypass in a distillation column that shows high performance characteristics for cryogenic applications, such as those used in air separation, and for other heat and/or mass transfer applications.

It also is further desired to have a method of assembling an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream which overcomes many of the difficulties and disadvantages of the prior art to provide better and more advantageous results.

BRIEF SUMMARY OF THE INVENTION

The present invention is an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream. The invention also includes methods for assembling various embodiments of the apparatus.

In a first embodiment, the apparatus includes: (1) a substantially cylindrical section of a column having an inner wall; (2) a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column; and (3) restricting means for minimizing flow of the vapor stream

in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

In a second embodiment, the restricting means is at least one solid wiper positioned peripherally about the exterior surface of the plug of packing. The solid wiper has an inner peripheral portion mounted on the exterior surface of the plug of packing and an outer peripheral portion abutting the inner wall of the section of the column. The solid wiper preferably is made of metal.

In a third embodiment, the restricting means is again at least one solid wiper positioned peripherally about the exterior surface of the plug of packing. However, in this embodiment, the solid wiper has an inner peripheral portion abutting the exterior surface of the plug of packing and an outer peripheral portion mounted on the inner wall of the section of the column. In this embodiment, the solid wiper also preferably is made of metal.

In a fourth embodiment, the restricting means is at least one gasket positioned peripherally about the exterior surface of the plug of packing. The gasket has an inner peripheral portion mounted on the exterior surface of the plug of packing and an outer peripheral portion abutting the inner wall of the section of the column. The gasket preferably is made of an aerated foam-like material, such as Gore-tex (which is a trademark of Gore Associates).

In a fifth embodiment, the restricting means is again at least one gasket positioned peripheral about the exterior surface of the plug of packing. However, in this embodiment the gasket has an inner peripheral portion abutting the exterior surface of the plug of packing and an outer peripheral portion mounted on the inner wall of the section of the column. As in the previous embodiment, the preferred material for the gasket is Gore-tex.

A sixth embodiment of the invention is an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream which includes: (1) a substantially cylindrical section of a column having an inner wall; and (2) a substantially

cylindrical plug of packing disposed inside the section of the column, wherein the outer diameter of the substantially cylindrical plug of packing is substantially equal to the diameter of the inner wall of the substantially cylindrical section of the column.

A seventh embodiment of the invention is an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream which includes: (1) a substantially cylindrical section of a column having an inner wall; (2) a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column; and (3) means for providing a vapor-tight seal in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

An eighth embodiment is an apparatus for exchanging heat and/or mass between a liquid and a vapor flowing counter-currently which includes: (1) a substantially cylindrical section of a column having an inner wall, the liquid entering at one end of the section of the column and the vapor entering at an opposite end of the section of the column; (2) a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column, thereby being an annulus between the inner wall of the section of the column and the exterior surface of the plug of the packing; and (3) means for directing the vapor from the annulus inwardly away from the inner wall of the section of the column toward the plug of packing.

A ninth embodiment is an improvement in an exchange column for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, the exchange column having a substantially cylindrical section having an inner wall and having a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column. The improvement includes restricting means for minimizing flow of the vapor stream in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

Another aspect of the present invention is a process for cryogenic air separation including contacting vapor and liquid counter-currently in at least one distillation column containing at least one mass and/or heat transfer zone, the process having at least one apparatus as in the first, sixth, seventh or eighth embodiments described above.

The present invention also includes methods for assembling the various embodiments of the apparatus described above. In one embodiment, the method for assembling an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream includes the following steps. The first step is to provide a substantially cylindrical section of a column having an inner wall. The next step is to dispose a plug of packing inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the column. The final step is to dispose restricting means for minimizing flow of the vapor stream in the space between the inner wall and the section of the column and the exterior surface of the plug of packing.

Another embodiment of the method for assembling an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream includes the following steps. The first step is to provide a substantially cylindrical section of a column having an inner wall. The second step is to dispose a substantially cylindrical plug of packing inside the section of the column, wherein the outer diameter of the substantially cylindrical plug of packing is substantially equal to the diameter of the inner wall of the substantially cylindrical section of the column.

Yet another embodiment of the method for assembling an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream includes the following steps. The first step is to provide a substantially cylindrical section of the column having an inner wall, the liquid entering at one end of the section of the column and the vapor entering at an opposite end of the section of the column. The next step is to dispose a plug of packing inside the section of the column, the plug of packing having an exterior

surface spaced apart from the inner wall of the section of the column, thereby being an annulus between the inner wall of the section of the column and the exterior surface of the plug of packing. The final step is to dispose means for directing the vapor from the annulus inwardly away from the inner wall of the section of the column toward the plug of packing.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the Invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a graph illustrating the % annular area in a packed column as a function of column diameter (mm), assuming a 4.5 millimeter (mm) gap or annulus between the packing and the column wall;

Figure 2 is a perspective view of a schematic representation of a solid wiper used in one embodiment of the invention;

Figure 3 is a schematic representation of a top view of a plug of packing inside a column with a solid wiper (such as that in Figure 2) in the annular space between the packing and the inner wall of the column;

Figure 4 is a schematic representation of a side view showing a solid wiper in the annular space between the packing and the column wall of a packed column, such as that in Figure 3;

Figure 5 is a schematic representation of a side view showing a gasket between the packing and the column wall of a packed column; and

Figure 6 is a perspective view of a plug of structured packing encircled with two solid wipers inside a section of a column shown in cross section.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is based on the surprising and unexpected improvements in the performance of packed exchange columns due to minimizing or eliminating vapor bypass in the annular space between the inner wall of a column and the packing inside the column.

The surprising and unexpected performance results are achieved by blocking the annular space or by minimizing (or eliminating) the annular space. Minimizing the annular space is especially important for relatively small-diameter columns which use plug packing (*e.g.*, columns less than 2 meters in diameter and typically, less than 1 meter in diameter). Minimizing vapor bypass improves column mass transfer performance, particularly for columns in air separation plants producing high-purity vapor products.

One means for blocking the annular space is a solid wiper 22, such as that shown in Figure 2. The solid wiper is installed in a packed column as shown in Figures 3 and 4, where the solid wiper blocks the annular space 32 between the exterior surface of the packing 28 and the inside of the column wall 26. The solid wiper may be attached to the packing or to the column wall, or both.

The solid wiper 22 has an inner portion 36 and an outer portion 34, as shown in Figure 2. The inner portion may be mounted on the exterior surface of the packing 28, with the outer portion abutting the inner wall of the column 26. Alternatively, the outer portion may be mounted on the inner wall of the column with the inner portion abutting the exterior surface of the packing. Also, in yet another alternative, the inner portion of the solid wiper may be mounted on the exterior surface of the packing and the outer portion of the solid wiper may be mounted on the inner wall of the column.

The solid wiper 22 preferably is made of metal. As indicated in Figure 2, the solid wiper may have a plurality of slits 24 to make it easier to bend the solid wiper around the packing 28, as shown in Figure 3. Although the slits will allow some vapor bypass, the slits are a simple design which provides for an economic way to install the solid wiper around the

packing. It is possible, however, to design a solid wiper without slits that would fit snugly about the packing substantially across the annular space 32. However, such a design would be more expensive, and installation would be more difficult.

Although Figure 4 shows a solid wiper 22 at only one level or elevation, additional solid wipers (22′) may be installed at elevations above or below each other in the annular space 32, as shown in Figure 6.

Figure 5 illustrates another embodiment of the invention which uses a gasket 30 (rather than a solid wiper 22) to block the annular space 32 between the packing 28 and the column wall 26. As with the solid wiper, there may be more than one gasket installed peripherally on each plug of packing, each gasket being at a different level or elevation.

The gasket 30 may be made of any material that can withstand the cryogenic temperatures in distillation service and thermal cycling. One such material is Gore-tex, a well-known gasket material, which is an aerated foam-like material. (Gore-tex is a trademark of Gore Associates.)

The gasket 30 has an inner portion 40 mounted on the exterior surface of the packing 28 and an outer portion 38 abutting the inner wall of the column 26. Alternatively, the outer portion of the gasket may be mounted on the inner wall of the column with the inner portion abutting the exterior surface of the packing. Also, in yet another alternative, the inner portion of the gasket may be mounted on the exterior surface of the packing and the outer portion of the gasket may be mounted on the inner wall of the column.

Another alternative is to substantially minimize or eliminate the space 32 between the column wall 26 and the packing 28 by making the packing outer diameter substantially equal to the inner diameter of the column wall. This eliminates the need to use solid wipers 22 or gaskets 30 to prevent vapor bypass.

The benefits of the present invention have been demonstrated in a 200 millimeter (mm) diameter distillation column. The use of solid metal wipers in the column consistently

resulted in about 5% to 15% reduction in HETP (height of an equivalent theoretical tray of separation) versus a similar 200 mm packed column without solid metal wipers. The reduction in HETP was particularly significant under conditions where a pure vapor product was produced. The demonstrations also showed that decreasing the distance between the packing and the column wall from 5 millimeters to 3 millimeters reduced the HETP of a 500 m^2/m^3 density packing by about 10%.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, comprising:

a substantially cylindrical section of a column having an inner wall;

a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column; and

restricting means for minimizing flow of the vapor stream in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

2. An apparatus as in claim 1, wherein the restricting means is at least one solid wiper positioned peripherally about the exterior surface of the plug of packing, the solid wiper having an inner peripheral portion mounted on the exterior surface of the plug of packing and an outer peripheral portion abutting the inner wall of the section of the column.

3. An apparatus as in claim 1, wherein the restricting means is at least one solid wiper positioned peripherally about the exterior surface of the plug of packing, the solid wiper having an inner peripheral portion abutting the exterior surface of the plug of packing and an outer peripheral portion mounted on the inner wall of the section of the column.

4. An apparatus as in claim 1, wherein the restricting means is at least one gasket positioned peripherally about the exterior surface of the plug of packing, the gasket having an inner peripheral portion mounted on the exterior surface of the plug of packing and an outer peripheral portion abutting the inner wall of the section of the column.

5. An apparatus as in claim 1, wherein the restricting means is at least one gasket positioned peripherally about the exterior surface of the plug of packing, the gasket having an inner peripheral portion abutting the exterior surface of the plug of packing and an outer peripheral portion mounted on the inner wall of the section of the column.

6. An apparatus as in claim 2, wherein the solid wiper is made of metal.

7. An apparatus as in claim 3, wherein the solid wiper is made of metal.

8. An apparatus as in claim 4, wherein the gasket is made of an aerated foam-like material.

9 An apparatus as in claim 5, wherein the gasket is made of an aerated foam-like material.

10. An apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, comprising:

a substantially cylindrical section of a column having an inner wall; and

a substantially cylindrical plug of packing disposed inside the section of the column, wherein the outer diameter of the substantially cylindrical plug of packing is substantially equal to the diameter of the inner wall of the substantially cylindrical section of the column.

11. A process for cryogenic air separation comprising contacting vapor and liquid counter-currently in at least one distillation column containing at least one mass and/or heat transfer zone, the process having at least one apparatus as in claim 1.

12. A process for cryogenic air separation comprising contacting vapor and liquid counter-currently in at least one distillation column containing at least one mass and/or heat transfer zone, the process having at least one apparatus as in claim 10.

13. A method for assembling an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, comprising the steps of:

providing a substantially cylindrical section of a column having an inner wall;

disposing a plug of packing inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column; and

disposing restricting means for minimizing flow of the vapor stream in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

14. A method for assembling an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, comprising the steps of:

providing a substantially cylindrical section of a column having an inner wall; and

disposing a substantially cylindrical plug of packing inside the section of the column, wherein the outer diameter of the substantially cylindrical plug of packing is substantially equal to the diameter of the inner wall of the substantially cylindrical section of the column.

15. An apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, comprising:

a substantially cylindrical section of a column having an inner wall;

a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column; and

means for providing a vapor-tight seal in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

16. An apparatus for exchanging heat and/or mass between a liquid and a vapor flowing counter-currently, comprising:

a substantially cylindrical section of a column having an inner wall, the liquid entering at one end of the section of the column and the vapor entering at an opposite end of the section of the column;

a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column, thereby being an annulus between the inner wall of the section of the column and the exterior surface of the plug of packing; and

means for directing the vapor from the annulus inwardly away from the inner wall of the section of the column toward the plug of packing.

17. In an exchange column for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, the exchange column having a substantially cylindrical section having an inner wall, and having a plug of packing disposed inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column, the improvement comprising:

restricting means for minimizing flow of the vapor stream in the space between the inner wall of the section of the column and the exterior surface of the plug of packing.

18. A process for cryogenic air separation comprising contacting vapor and liquid counter-currently in at least one distillation column containing at least one mass and/or heat transfer zone, the process having at least one apparatus as in claim 15.

19. A process for cryogenic air separation comprising contacting vapor and liquid counter-currently in at least one distillation column containing at least one mass and/or heat transfer zone, the process having at least one apparatus as in claim 16.

20. A method for assembling an apparatus for exchanging heat and/or mass between a flowing liquid stream and a flowing vapor stream, comprising the steps of:

providing a substantially cylindrical section of a column having an inner wall, the liquid entering at one end the section of the column and the vapor entering at an opposite end of the section of the column;

disposing a plug of packing inside the section of the column, the plug of packing having an exterior surface spaced apart from the inner wall of the section of the column, thereby being an annulus between the inner wall of the section of the column and the exterior surface of the plug of packing; and

disposing means for directing the vapor from the annulus inwardly away from the inner wall of the section of the column toward the plug of packing.

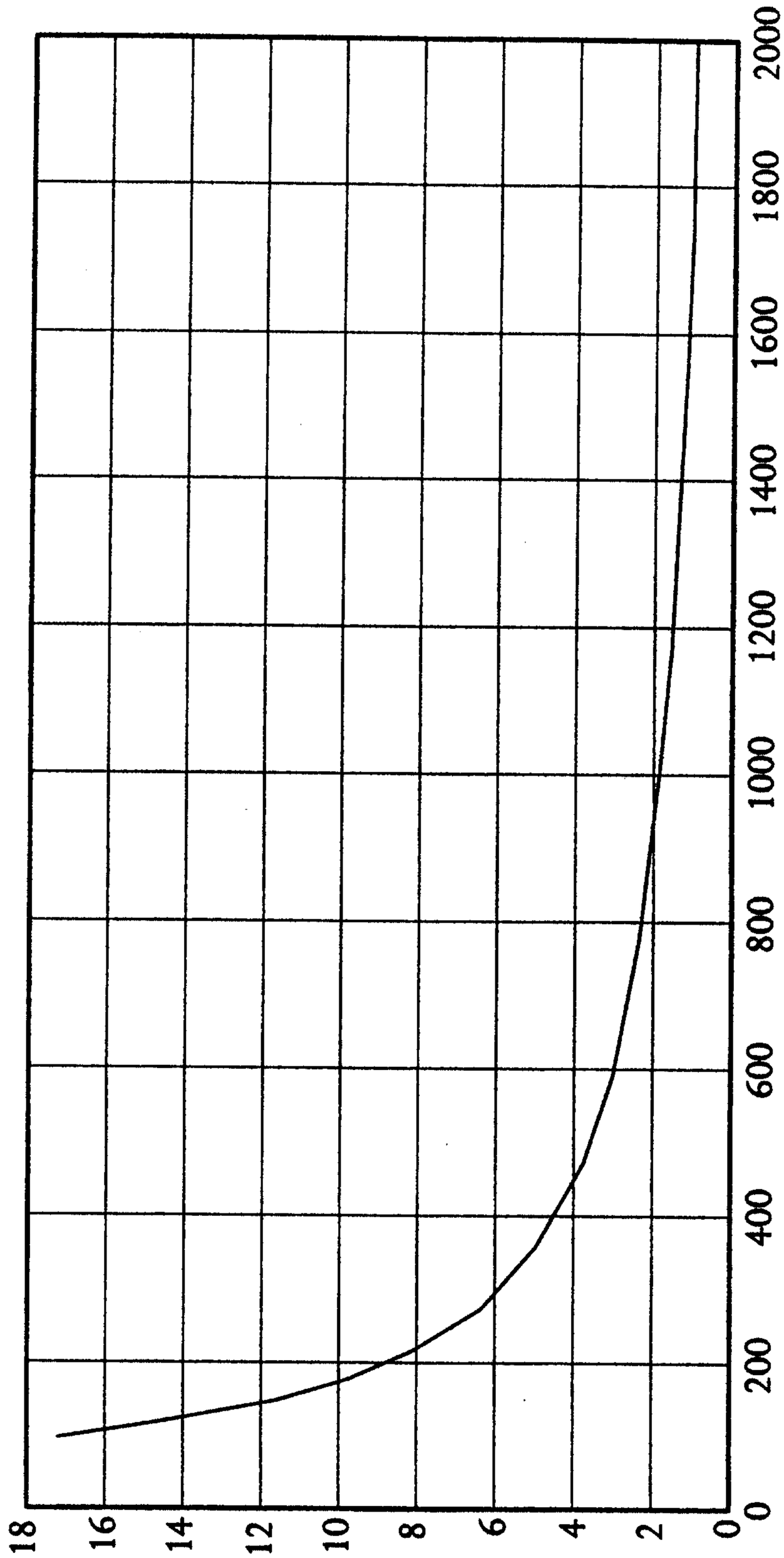


FIG. 1

McFadden, Fincham

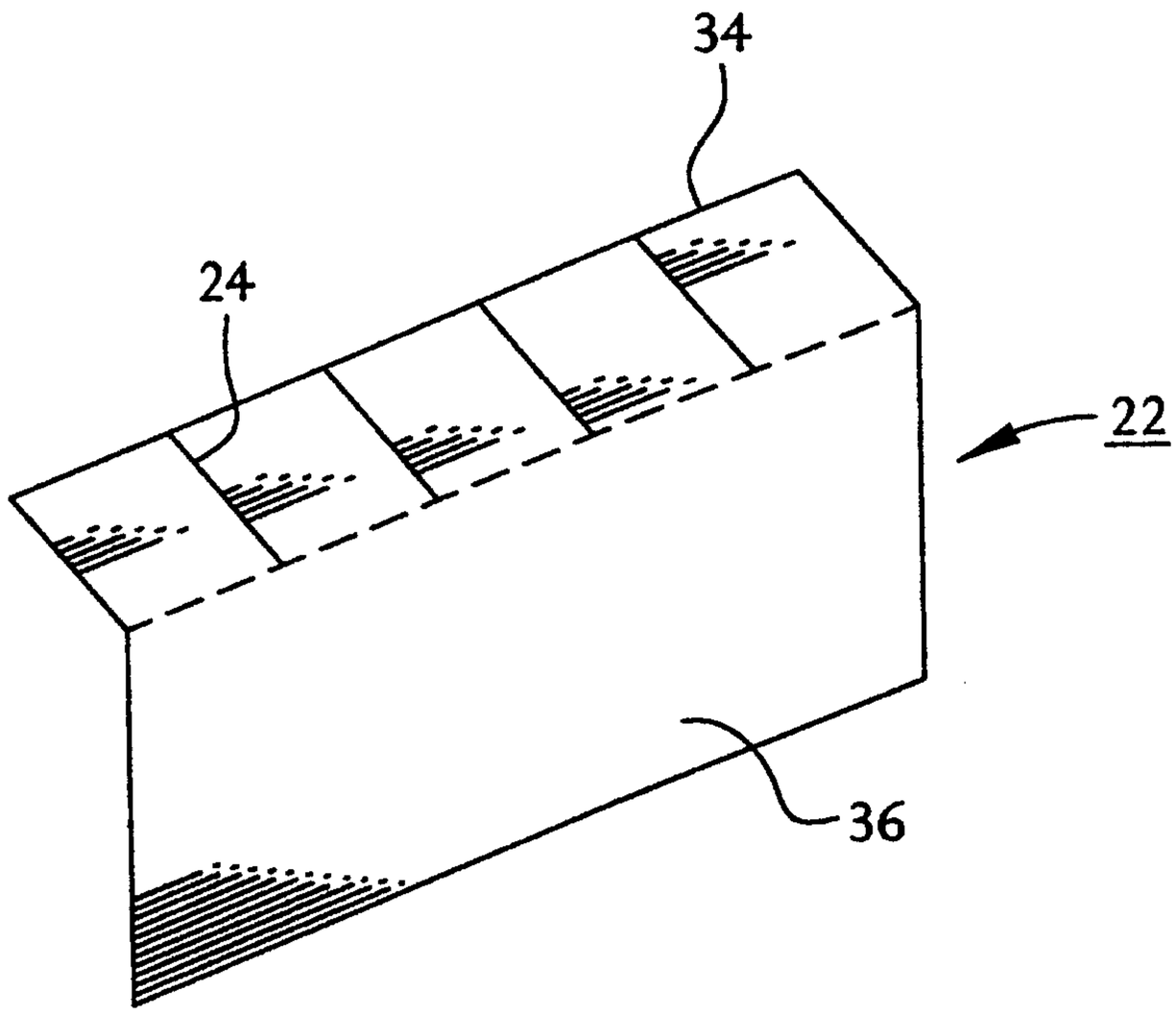


FIG. 2

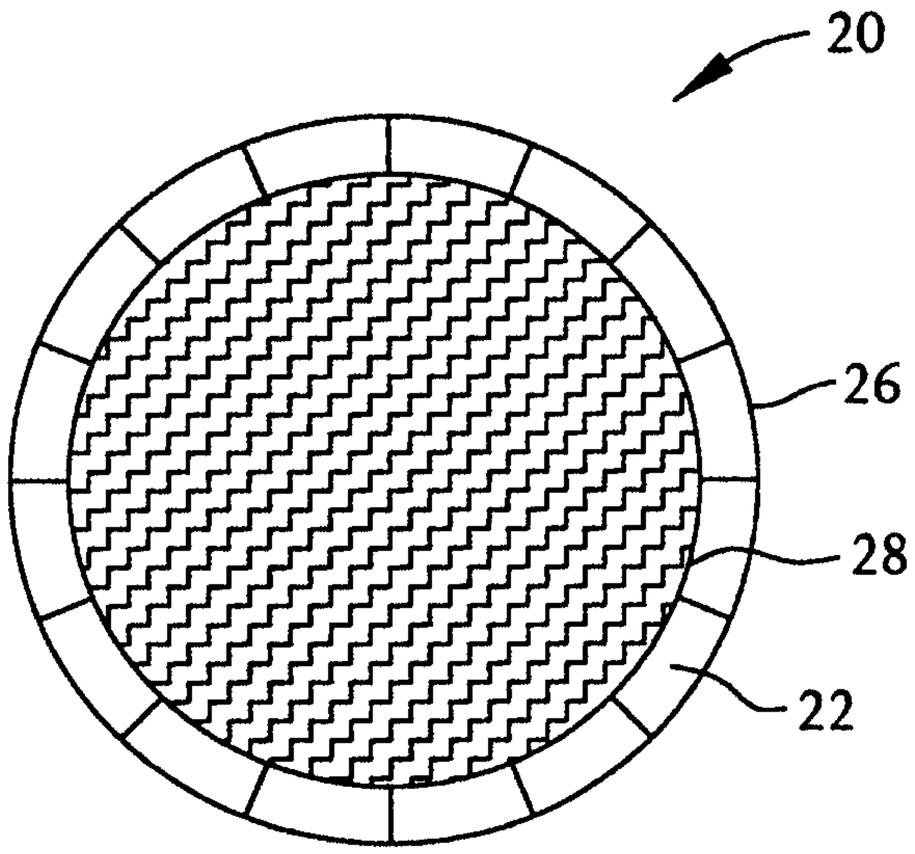


FIG. 3

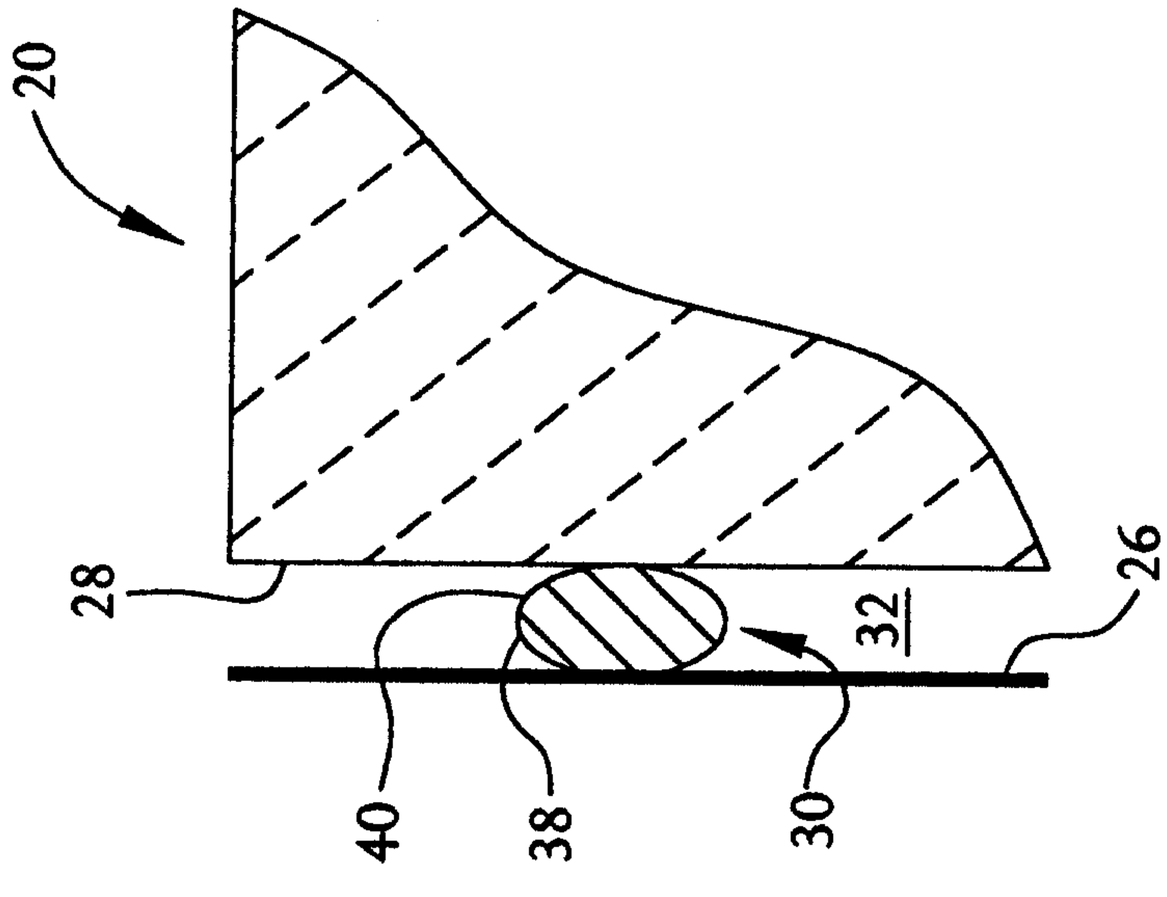


FIG. 5

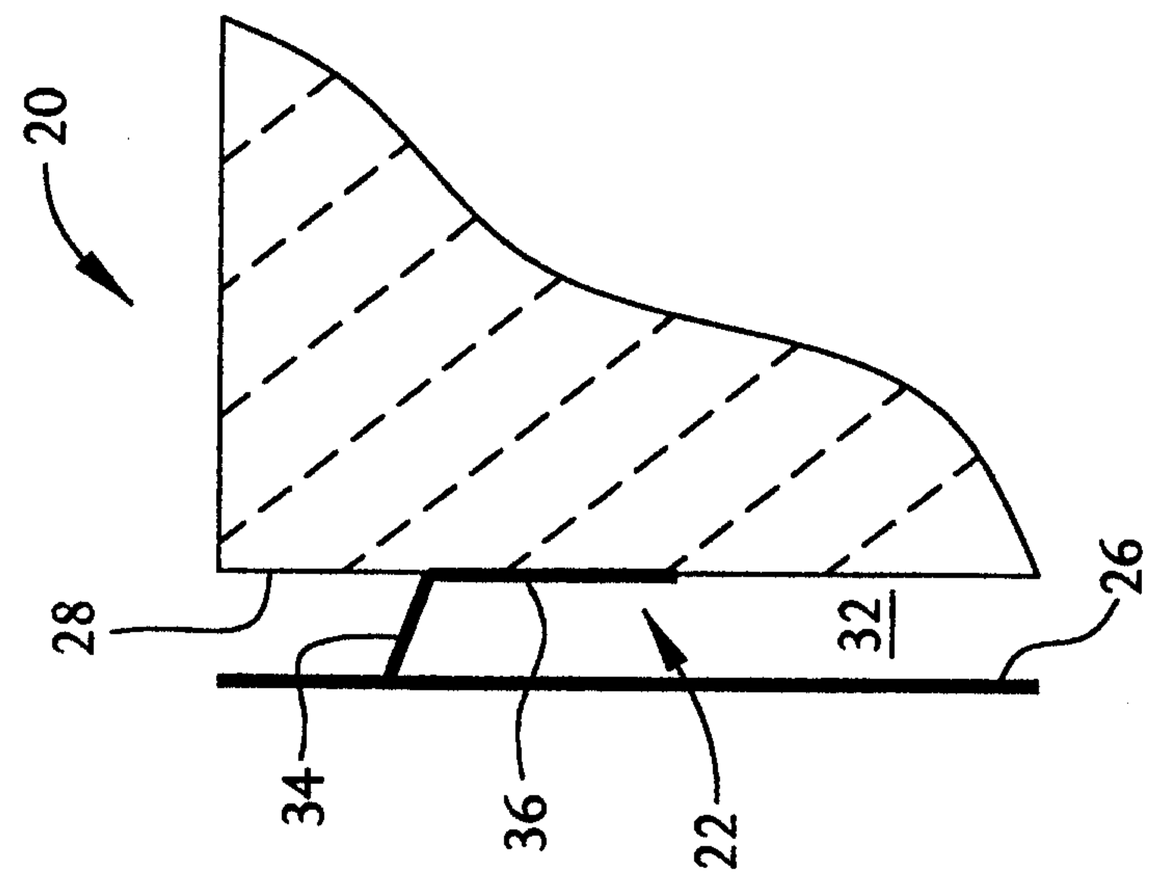


FIG. 4

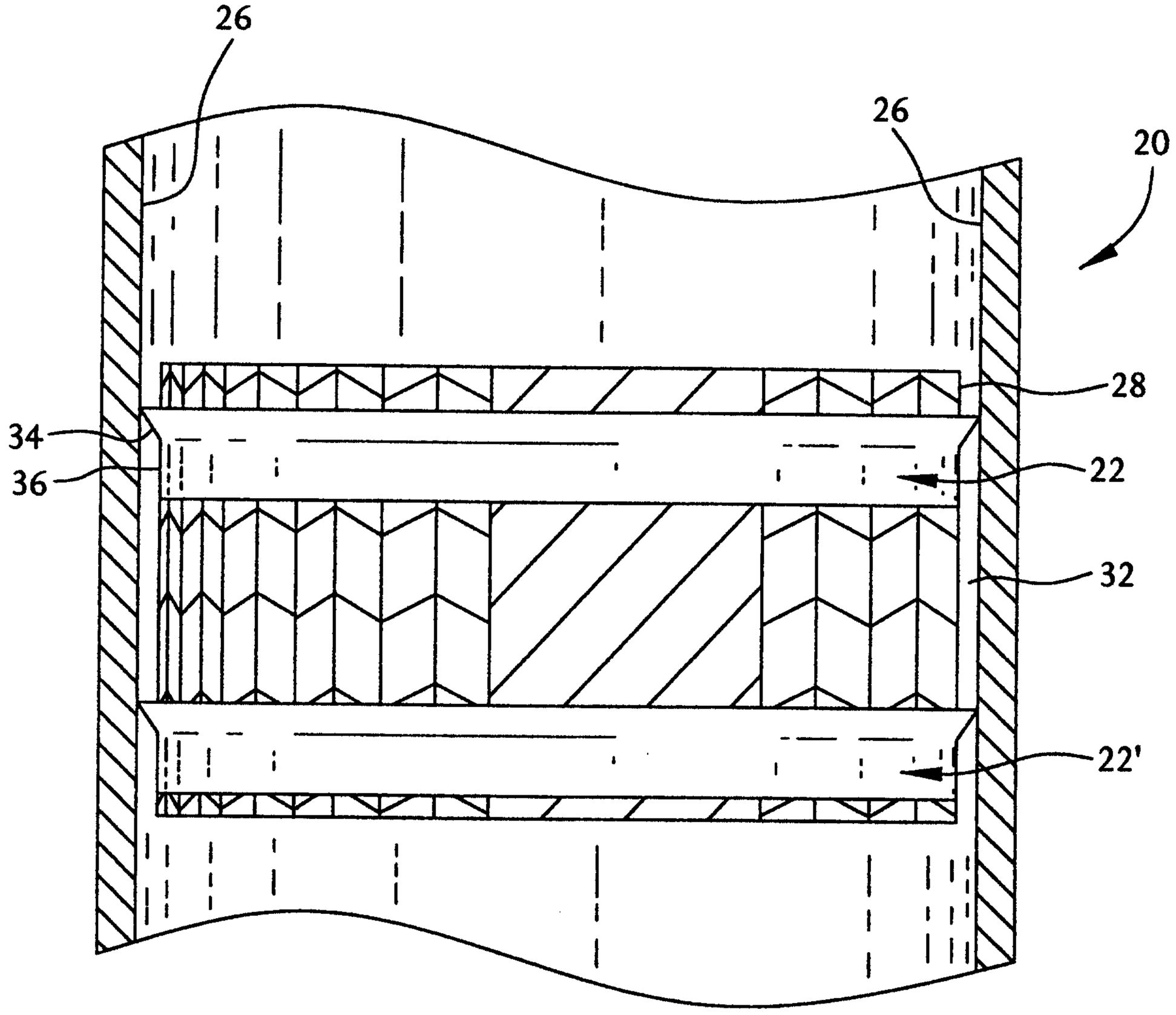


FIG. 6