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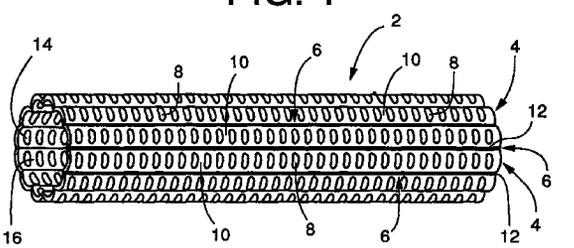
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(54) HEATING TUBE FOR ABSORBER AND METHOD OF MANUFACTURING SAME

(57) The present invention provides a heat exchanger tube for an absorber, which has a degree of improvement of heat exchangeability matching the degree of increase of the heating surface area thereof, and whose mass per unit length is as small as that of a smooth surface tube so as not to increase the material cost.

The heat exchanger tube 2 has a structure such that a plurality of raised portions 4 each having an arcuately curved shape in a circumferential direction of the tube, are disposed on an outer circumferential tube so as to extend in an axial direction of the tube, and are arranged in the circumferential direction of the tube such that recessed portions 6 are formed between adjacent ones of the plurality of raised portions 4, and an inner circumferential surface of the tube is corrugated corresponding to the raised and recessed portions 4, 6. Absorbent is dripped spread on the outer circumferential surface of the tube, while a cooling fluid flows through an inside of the heat exchanger tube so as to cool the absorbent on the outer circumferential surface of the tube. A plurality of circumferential groove portions 8 are formed on each of the raised portions 4 at an interval in the axial direction of the tube, each of which circumferential groove portions 8 extending in the circumferential direction of the tube and has a curbed shape at a bottom portion thereof in cross section in the axial and circumferential directions of the tube, so that local portions of the raised portions 4 which are interposed between adjacent ones of the circumferential groove portions 8 constitute mutually independent fins 10, respectively. Opposite end portions of each of the circumferential groove portions 8 in the circumferential direction of the tube have a width which gradually decreases toward the ends, such that the width is zero at the ends.

FIG. 1



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Description

FIELD OF THE ART

The present invention relates in general to a heat exchanger tube for an absorber which is horizontally installed in an absorber of an absorption refrigerator, an absorption heat pump and the like, more particularly, to such a heat exchanger tube for the absorber, which exhibits excellent heat exchanging efficiency, and whose mass per unit length is as small as that of a smooth surface tube, and a method of producing such a heat exchanger tube.

BACKGROUND OF THE INVENTION

For a heat exchanger tube used in an absorber of an absorption refrigerator, an absorption heat pump and the like as described above, there is generally employed a smooth surface tube having smooth inner and outer surfaces and a circular shape in cross section. However, such a smooth surface tube cannot meet requirements for improving the performance of and downsizing the absorber, due to its relatively low heat exchangeability. The smooth surface tube has another problem that the width of a layer of an absorbent flowing down in the circumferential direction of the tube decreases as the absorbent flows downwardly, due to the surface tension of the absorbent. Thus, the smooth surface tube does not permit the absorbent to contact its outer circumferential surface over an area sufficient for assuring an effective heat exchanging action, and the outer circumferential surface of the tube tends to have a dry area portion, leading to a low vapor absorption efficiency of the absorbent, and consequently low heat exchangeability of the heat exchanger tube.

To solve the above described problems, there have been proposed heat exchanger tubes constructed as disclosed in JP-U-2-89270 and JP-A-2-176378, for example. Namely, the proposed heat exchanger tubes are constructed such that a plurality of raised portions extending in the axial direction of the tube are formed on the outer circumferential surface of the tube, while recessed portions are formed between adjacent ones of the raised portions. These raised and recessed portions are arranged in the circumferential direction of the tube so as to provide curved surfaces which are continuous in the circumferential direction. The recessed portions have a radius of curvature which is larger than that of the raised portions.

When such a heat exchanger tube is horizontally installed in the absorber, the absorbent which is dripped or spread on the outer surface of the tube flows smoothly in the recessed portion, since the radius of curvature of the recessed portions is larger than that of the raised portions. Accordingly, the absorbent smoothly flows into and out of the recessed portions so that the absorbent flows uniformly over the entire circumference of the tube. Marangoni convections of the absorbent (which arise from a variation of its surface tension caused by uneven distribution of a surface active agent contained in the absorbent, on the surface of the absorbent layer) occur at the raised and recessed portions, respectively, and these Marangoni convections interfere with each other, whereby the absorbent on the outer circumferential surface of the tube has a large degree of turbulence in the longitudinal i.e., in the axial direction of the tube. Thus, heat exchanging on the outer surface of the tube is effectively promoted, resulting in improved heat exchanging efficiency of the heat exchanger tube.

The heat exchanger tube constructed as described above exhibits improved heat exchangeability. However, the heat exchanger tube suffers from an inherent problem that further improvement of the heat exchangeability of the tube is basically limited, due to its heating surface area which is substantially the same as that of the smooth surface tube.

Whereas, there is disclosed in JP-B-7-111287 a heat exchanger tube for an absorber, which has a plurality of grooves formed on the outer circumferential surface of the tube so as to extend in the longitudinal direction of the tube, and a multiplicity of fins formed between adjacent ones of the grooves at a relatively short interval. In the heat exchanger tube having such a structure, the plurality of grooves having a relatively large depth cause rigorous agitation of the absorbent and flows of the absorbent in the axial direction, so that the absorbent is spread over the outer surface of the tube. The multiplicity of fins formed between the adjacent grooves assure an increased heating surface area of the tube and an improved wettability of the surface of the tube with the absorbent, whereby the tube is given a considerably increased effective heating surface area.

In view of the embodiment disclosed in JP-B-7-111287, it is considered that the heat exchanger tube of the structure described above is prepared by forming the grooves extending in the axial direction of the tube in a known low-fin tube. There is a problem that the heat exchangeability of the heat exchanger tube of this structure is only 1.4 times that of the smooth surface tube, although the heating surface area of the tube is at least several times that of the smooth surface tube. Moreover, the heat exchanger tube constructed as described above is made from the low-fin tube used as a base tube, so that a mass per unit length of the tube is at least about twice that of the the low-fin tube, leading to an inherent problem that the degree of increase of the cost of material of the heat exchanger tube is higher than that of improvement of the heat exchangeability of the tube.

DISCLOSURE OF THE INVENTION

The present invention was developed in view of the above described situation and it is therefore an object of

the present invention to provide a heat exchanger tube for an absorber, which has a degree of improvement of heat exchangeability matching the degree of increase of a heating surface area of the tube and whose mass per unit length is as small as that of the smooth surface tube, and which does not increase the material cost.

The above object may be accomplished by a heat exchanger tube for an absorber, having a structure wherein a plurality of raised portions each having an arcuately curved shape in a circumferential direction of the tube, are disposed on an outer circumferential surface so as to extend in an axial direction of the tube, and are arranged in the circumferential direction of the tube such that recessed portions are formed each between adjacent ones of the plurality of raised portions, and an inner circumferential surface of the tube is corrugated corresponding to the raised and recessed portions, and wherein an absorbent is dripped or spread on the outer circumferential surface of the tube, while a cooling fluid flows through an inside of the heat exchanger tube so as to cool the absorbent on the outer circumferential surface of the tube, characterized in that: a plurality of circumferential groove portions are formed in each of the raised portions at an regular interval in the axial direction of the tube, each of the circumferential groove portions extending in the circumferential direction of the tube and having a curved shape at a bottom portion thereof in cross section in the axial and circumferential directions of the tube, local portions of the raised portions which are interposed between adjacent ones of the circumferential groove portions constituting mutually independent fins, respectively, opposite end portions of each of the circumferential groove portions in the circumferential direction of the tube having a width which gradually decreases toward the ends, such that the width is zero at the ends.

In the heat exchanger tube constructed according to the present invention, the absorbent, such as an aqueous solution of LiBr, which is attached to the outer surface of the tube, effectively flows and spreads in the axial direction of the tube along the recessed portions, while flowing down in the circumferential direction of the tube across the raised portions. Each of the raised portions is formed in the arcuately curved shape. This arrangement permits smooth flows of the absorbent on the surface of the heat exchanging tube in the circumferential direction of the tube across the raised portions, and effectively keeps the surface of the raised portions wetted with the absorbent, resulting in prevention of deterioration of the heat exchangeability of the tube due to the presence of a dry surface area on the outer circumferential surface of the tube, which is not wetted with the absorbent. Moreover, when the absorbent flows down across each of the raised portions, turbulence and convection of the absorbent may be induced so that a mass of the absorbent having a relatively high concentration is effectively moved to the outer surface of the absorbent layer, resulting in improved vapor absorption efficiency.

Further, the above described heat exchanger tube permits occurrence of the Marangoni convections of the absorbent in the raised and recessed portions formed in the outer surface of the tube, respectively, which Marangoni convections have different intensities proportional to the thickness values of layers of the absorbent formed on the respective raised and recessed portions. The thickness values of the layers of the absorbent on the raised and recessed portions are remarkably different from each other, leading to a remarkable difference between the intensity of the Marangoni convection occurring on the raised portion and that occurring on the recessed portions. These Marangoni convections of the absorbent which have different intensities interfere with each other, to thereby intensively agitate the absorbent.

Moreover, in the heat exchanger tube for the absorber according to the present invention, a plurality of circumferential groove portions each extending in the circumferential direction of the tube are formed in the raised portions at a predetermined interval in the axial direction of the tube, and local portions of the raised portions which are interposed between the adjacent circumferential groove portions constitute mutually independent fins, respectively. Each of the circumferential groove portions is formed such that the bottom portion of the circumferential groove portion has a curved shape in cross section in the axial and circumferential directions of the tube, and opposite ends of the circumferential groove portion in the circumferential direction have a width which gradually decreases such that the width is zero at the ends. When the absorbent flows down on the outer surface of the heat exchanger tube, the unique
configuration of the circumferential groove portions as described above restricts flows of the absorbent in the circumferential direction of the tube, while promoting flows of the absorbent in the axial direction of the tube. Accordingly, the absorbent is smoothly spread in the axial direction of the tube in comparison with the conventional tube having fins, so that the absorbent is effectively agitated by the Marangoni convections thereof and the collision thereof with the circumferential groove portions. Thus, heat exchanging operation of the heat exchanger tube can be further promoted.

According to one preferred form of the present invention, the heat exchanger tube is arranged such that the circumferential groove portions are formed radially outwardly with respect to bottoms of the recessed portions, so as to prevent the circumferential groove portions from communicating with the bottoms of the recessed portions, and the opposite end portions of each of the circumferential groove portions terminate at corresponding side faces of the raised portions. In this arrangement, the flows of the absorbent in the axial direction along the recessed portions are more promoted than those in the circumferential direction along

the circumferential groove portions between the adjacent fins, assuring the smooth flows of the absorbent in the axial direction of the tube.

According to another preferred form of a heat exchanger tube for an absorber of the present invention, the raised and recessed portions are formed by a drawing process, while the circumferential groove portions are formed by a rolling process, whereby the heat exchanger tube having a desired shape is advantageously obtained.

According to yet another preferred form of a heat exchanger tube for an absorber of the present invention, there are formed in the bottoms of the recessed portions axial grooves extending in the axial direction of the tube, which are arranged in the circumferential direction of the tube such that surfaces of the axial grooves are non-smoothly contiguous with the bottoms in cross section in the circumferential direction. With the axial grooves formed in the bottoms the recessed portions so as to extend in the axial direction of the tube, the thickness of the layer of absorbent is discontinuously varied in the circumferential direction of the tube, whereby the interference of the Marangoni convections occurring in the raised and recessed portions is further promoted.

Moreover, since the axial grooves are formed in the recessed portions, a difference between the thickness of the layers of the absorbent on the raised-portions and that on the recessed portions is further increased. This arrangement is effective not only to induce the Marangoni convections of the absorbent when a suitable amount of absorbent is dripped on the tube, as in a normal operation, but also to give the layer of absorbent with a sufficient thickness on the tube when a small amount of the absorbent is dripped on the tube, as in an operation immediately after starting, so that turbulence of the absorbent is effectively induced due to the Marangoni convections. Thus, the heat exchangeability of the tube can be further improved. The axial grooves have a depth which is too small to disturb flows of the absorbent into and from the axial grooves so that the absorbent can rapidly flow on the outer surface of the tube in the circumferential direction of the tube.

According to yet another preferred form of the heat exchanger tube for the absorber of the present invention, local portions of the inner circumferential surface of the tube which correspond to the circumferential groove portions, are protruded toward the inside of the tube by the formation of the circumferential groove portions in the raised portions, while local portions of the inner circumferential surface of the tube which correspond to the fins disposed between the adjacent circumferential groove portions constitute concave portions. Accordingly, the circumferential surface of the tube has the concave portions and the convex portions which are arranged in the axial direction of the tube, in the local portions corresponding to the raised portions. This arrangement causes turbulence of the cooling fluid flowing through the inside of the tube, resulting in effective improvement of the overall heat transfer coefficient of the tube.

According to the present invention, the heat exchanger tube for the absorber according to the present invention as described above may be advantageously produced by a method of producing a heat exchanger tube for an absorber wherein an absorbent is dripped or spread on an outer circumferential surface of the heat exchanger tube, while a cooling fluid flows through an inside of the heat exchanger tube so as to cool the absorbent on the outer circumferential surface of the heat exchanger tube, the method being characterized by comprising: (a) a first step of drawing a cylindrical blank tube into a corrugated tube which is constructed such that a plurality of raised portions each having an arcuately curved shape in a circumferential direction of the tube, are disposed on the outer circumferential surface so as to extend in an axial direction of the tube, and are arranged in the circumferential direction of the tube such that recessed portions are formed between adjacent ones of the plurality of raised portions, and an inner circumferential surfaces of the tube is corrugated corresponding to the raised and recessed portions; and (b) a second step of subjecting the corrugated tube to a rolling process so as to form a plurality of circumferential groove portions each extending in the circumferential direction of the tube and having a bottom portion having a curved shape in cross section in the axial and circumferential direction of the tube, in each of the raised portions at a regular interval in the axial direction of the tube, local portions of the raised portion which are interposed between adjacent ones of the circumferential groove portions constituting mutually independent fins, respectively, opposite end portions of each of the circumferential groove portions in the circumferential direction of the tube having a width which gradually decreases toward the ends, such that the width is zero at the ends.

According to the method of producing the heat exchanger tube for the absorber of the present invention, the cylindrical blank tube is subjected to the drawing process so as to form the axial grooves in the tube (so as to form the corrugated tube) in the first step, and then is subjected to the rolling process so as to form fins on the tube in the second step. Thus, the heat exchanger tube having a desired shape can be obtained without suffering from appearance of burrs between the adjacent fins formed in each raised portion. Each of fins produced as described above has a height which gradually decreases toward the opposite ends in the circumferential direction of the tube, while each of the circumferential groove portions formed by the rolling process has a width which gradually decreases toward the opposite ends in the circumferential directions of the tube such that the width is zero at the ends.

In the heat exchanger tube for the absorber constructed as described above, each of the raised portions extending in the axial direction of the tube is formed on

the outer surface of the tube so as to have the arcuately curved shape in the circumferential direction of the tube, and a plurality of the raised portions are arranged in the circumferential direction of the tube. In this arrangement, the absorbent dripped on the outer circumferential surface of the tube can easily flow in the circumferential and axial directions of the tube. The numbers of the raised portions arranged in the circumferential direction of the tube is not particularly limited, but may be suitably selected in view of the diameter of the heat exchanger tube or the like. If an excessively small number of the raised portions are arranged on the tube, the tube cannot exhibit sufficient heat exchangeability. If an excessively large number of the raised portions are arranged in the tube, ease of manufacture of the tube is deteriorated. Generally, the raised potions are arranged with a pitch of about 3-9mm (circumferential length of the tube based on the outer diameter of the blank tube divided by the number of the raised portions). To form the desired number of raised portions on the outer surface of the tube, each of the raised portion preferably has a radius of curvature of about 0.5-5.0mm.

The recessed portions formed between the adjacent raised portions may be formed according to the shape of the raised portions. In any case, the recessed portions are constituted, by respective portions of the tube interposed between and contiguous with the corresponding adjacent raised portions. The wall thickness of the tube in the recessed portions is substantially equal to that in the raised portions (so that the concave and convex portions are formed in the inner surface of the tube, which are correspond to the raised and recessed portions, respectively). Further, the recessed portions generally have a thickness of about 0.3-1.2mm, since the recessed portions having an excessively large depth may deteriorate the ease of manufacture of the tube, and reduce the cross sectional area of the fluid passage of the heat exchanger tube, resulting in an increase of the pressure loss within the tube. The depth of each of the recessed portions is interpreted to mean a length of a normal line extending from a bottom surface of the recessed portion (a bottom surface of the axial groove if provided) to a straight line which is tangent to the apexes of the adjacent raised portions between which the recessed portion is interposed.

The heat exchanger tube for the absorber according to the present invention is also characterized in that the plurality of circumferential groove portions each extending in the circumferential direction of the tube are formed in each of the raised portions at a predetermined interval, in the axial direction of the tube, so that the local portions of the raised portion which are interposed between the adjacent circumferential groove portions constitute independent fins, respectively. That is, the fins have a shape in traverse cross section of the tube, which is similar to that of the raised portions, namely, an arcuately curved shape, since the fins are constituted by the corresponding portions of the raised portion in which no circumferential groove portions are formed. On the other hand, the shape of the fin in longitudinal cross section of the tube is determined by that of the adjacent circumferential groove portions.

According to the present invention, the circumferential groove portions which determine the shape of the fins in the longitudinal cross section of the tube are formed such that a bottom portion of each of the circumferential groove portions has a curved shape in cross section in the axial and circumferential direction of the tube, and opposite end portions of each of the circumferential groove portions in the circumferential direction of the tube have a width which gradually decreases toward the ends at which the width is zero. The circumferential groove portions are preferably formed to have a curved shape such as a U-shape and an arcuate shape, while meeting the dimensional requirement such as the height of fins, the interval between the adjacent fins and the interval between the opposite ends of the adjacent fins.

If the fins formed on the raised portions have an excessively small height, an area of contact of heating surface area of the tube with the absorbent is not expected to be sufficiently large. On the other hand, if the fins have an excessively large height, the fins may divide the layer of the absorbent formed on the outer surface of the tube. Generally, the fins have a height of about 0.3-1.5mm. It is especially desired that the circumferential groove portions are formed such that the depth of the circumferential groove portions do not reach the bottoms of the recessed portions, in order to promote expansion of the absorbent especially in the axial direction of the tube. The height of each of the fins is interpreted to mean a length of a normal line extending from a bottom surface of the circumferential groove portion interposed between the adjacent fins, to a straight line tangent to the apexes of the adjacent fins.

The adjacent fins have an interval of about 0.9-4.0mm. It is not preferable to form the fins with an excessively small interval, since the absorbent hardly flows into the circumferential groove portions disposed between the adjacent fins and tends to stay in the circumferential groove portions if once entered, even if the absorbent has a relatively low concentration. It is also not preferable to form the fins with an excessively large interval, since the heating surface area of the tube is not increased as needed. The interval between the adjacent fins is interpreted to mean a distance in the axial direction of the tube between a selected portion of one of the adjacent fins and the corresponding portion of the other of the adjacent fins.

Further, the interval between the top ends of the adjacent fins is preferably about 0.45-3.0mm, so as to facilitate entry into the circumferential groove portions of different absorbents whose concentrations vary in a wide range, and so as to prevent unnecessarily long stay of the absorbent in the circumferential groove por-

tions. This interval between the top ends of the adjacent fins means a length of a straight line between the top ends of the opposite side faces of the adjacent fins.

The heat exchanger tube for the absorber of the present invention is preferably characterized in that the local portions of the inner surface of the tube which correspond to the raised portions have a shape which is determined by the shape of the circumferential groove portions in cross section, so that the shape is reverse with respect to the outer surface of the tube in the raised portion, as seen in a cross section in the axial direction of the tube (in the longitudinal cross section of the tube). Namely, the circumferential groove portions formed in the outer surface of the tube provide convex or protruding portions on the inner surface of the tube, while the fins interposed between the adjacent circumferential groove portions in the outer surface of the tube constitute concave portions in the inner surface of the tube. This characteristic construction of the heat exchanger tube can be easily attained by performing the drawing process in the first step and the rolling process in the second step. For instance, the reverse order of the steps is not available. Each fin formed on the outer surface of the tube takes the form of a bent plate, so that the tube has substantially no increase in the wall thickness at the fin portions, assuring the heat exchanger tube having a mass per unit length which is substantially equal to that of the base tube such as the grooved tube (corrugated tube) and the smooth surface tube. The concave and convex portions formed on the inner surface of the tube permit turbulence of the cooling fluid flowing through the inside of the tube, resulting in an improved overall heat transfer coefficient of the tube.

The heat exchanger tube of the present invention preferably has axial grooves formed in the bottoms of the recessed portions, so as to promote the turbulence of the absorbent. These axial grooves are formed in the bottoms of the recessed portions such that the surface of each of the axial grooves is non-smoothly contiguous with the corresponding raised and recessed portions in the circumferential direction of the tube. Namely, as seen in cross sectional plane perpendicular to the axis of the tube, the outer curved surface of the axial groove is connected to the outer curved surfaces of the corresponding raised and recessed portions in the circumferential direction of the tube, such that the curved surface of the axial groove portion intersect the curved surfaces of the raised and the recessed portions, at points at which there are no common lines tangent to those curbed lines. In this intersections, there is no common tangent.

The shape of the axial groove in the traverse cross section is not particularly limited, and various kinds of shapes such as a U-shape, a V-shape, a rectangular shape and a trapezoidal shape may be employed. Preferably, the axial groove has a depth of about 0.01-0.15mm, so as to prevent an unnecessary stay of the absorbent therein.

The heat exchanger tube as described above may be formed of various kinds of materials as well known in the art. For obtaining a heat exchanger tube having excellent heat exchangeability, it is preferable to employ a material exhibiting excellent thermal conductivity, such as copper and alloyed copper. Generally, the formed heat exchanger tube has a diameter of about 6.35-25.4mm.

The heat exchanger tube for the absorber according to the present invention as described above, is basically produced as follows: Initially, an appropriate corrugated tube used in the present invention is obtained by a known method as disclosed in JP-B-2-89270, JP-A-2-176378 and JP-A-7-24522. Then, the obtained corrugated tube is subjected to the rolling process so as to form the circumferential groove portions only in the raised portions and provide fins constituted by the local portions of the raised portions which are interposed between adjacent ones of the circumferential groove portions, to thereby obtain the desired heat exchanger tube for the absorber.

According to the present invention, the corrugated tube is obtained by subjecting the cylindrical blank tube to a cold drawing process. The desired corrugated tube may otherwise be obtained by hot extrusion of a copper pipe of a suitable composition.

In the heat exchanger tube of the present invention, the surfaces of the axial grooves formed in the respective recessed portions are non-smoothly contiguous with the corresponding raised and recessed portions. The heat exchanger tube having such a structure can be easily produced with high stability in shape, by using a technique usually practiced for processing a tube having different diameters in the method of producing the tube as described above.

In the heat exchanger tube of the present invention, the raised and recessed portions formed on the outer surface of the tube need not extend straightly in the axial direction of the tube, but may extend helically in the axial direction of the tube. In this case, the helix angle of the raised and recessed portions is preferably not greater than 15°, since an excessively large helix angle causes reduction of the amount of the absorbent which flows in the circumferential direction across the raised portions, leading to deterioration of heat exchangeability of the tube.

The heat exchanger tube having helical raised and recessed portions can be easily produced as follows: Initially, a blank tube is subjected to the drawing process using dies having helical raised and recessed portions, or by drawing the blank tube while rotating the blank tube and the dies relative to each other, so as to obtain a processed tube having helically formed raised and recessed portions. Then, the obtained tube is subjected to the rolling process to form appropriate circumferential groove portions.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view showing one embodiment of a heat exchanger tube for an absorber according to the present invention.

Fig. 2 is a traverse cross sectional view of the heat exchanger tube shown in Fig. 1.

Fig. 3 is an enlarged view in longitudinal cross section of a raised portion of the heat exchanger tube shown in Fig. 1.

Fig. 4 is a cross sectional view in cross section perpendicular to an axis of the heat exchanger tube, showing a rolling process for producing the heat exchanger tube shown in Fig. 1.

Fig. 5 is a view for explaining the rolling process performed on one of the raised portions, using rolling disks.

Fig. 6 is a fragmentary enlarged view showing the details of a shape of the raised portion in traverse cross section before and after the rolling process, and the details of a shape of fins after the rolling process.

Figs 7 (a)-(c) are views showing configurations of circumferential groove portions and fins formed by the rolling process at the raised portion, wherein Fig 7(a), Fig. 7(b) and Fig. 7(c) are perspective, top plan, and side views of the raised portion, respectively.

Fig. 8 is a view showing one example of arrangement of a plurality of heat exchanger tubes each shown in Fig. 1, which are disposed in an absorber.

Fig. 9 is a traverse cross sectional view of the heat exchanger tube disposed in the upper portion of the absorber shown in Fig. 8.

Fig. 10 is an enlarged view in longitudinal cross section of the raised portion of the heat exchanger tube for the absorber shown in Fig. 9.

Fig. 11 is an enlarged view in longitudinal cross section similar to that of Fig. 3, of the raised portions of the heat exchanger tube, showing another example of configuration of fins of the heat exchanger tube for the absorber of the present invention.

Fig. 12 is an enlarged view in longitudinal cross section similar to that of Fig. 3, of one of the raised portions of the heat exchanger tube, showing yet another example of configuration of fins of the heat exchanger tube for the absorber of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

To further clarify the present invention, there will be described the embodiments of the invention. It is to be understood that the present invention is not limited by the details of these embodiments. It is also to be understood that various changes, modifications and improvements may be made with respect to the following embodiments and the arrangements described above in detail, based on the knowledge of those skilled in the art, without departing from the spirit of the invention.

Referring first to Figs. 1-3 there is shown a heat exchanger a heat exchanger tube 2 for an absorber, according to one embodiment of the present invention. The heat exchanger tube 2 is prepared from a phosphor-deoxidized copper tube (outside diameter: 16mm∅, wall thickness: 0.6mm) made of a material C1220 (JIS H3300), which is provided as a cylindrical blank tube. The blank tube is subjected to a cold drawing operation with a die, so as to form a corrugated tube having raised portions and recessed portions which extend in the axial direction of the tube. Then, the corrugated tube is subjected to a rolling process using rolling disks as used in a rolling process usually employed for producing a finned tube, such that circumferential groove portions each extending in the circumferential direction of the tube are formed in the raised portions at a predetermined interval in the axial direction of the tube. Thus, the heat exchanger tube 2 is obtained.

More specifically described, as shown in Fig. 2, on an outer circumferential surface of the heat exchanger tube 2 having a diameter d of 16mm∅, the raised portions 4 each having an arcuately curved shape and the recessed portions 6 formed between adjacent ones of the raised portions 4 are arranged alternately in the circumferential direction of the tube. These raised and recessed portions 4, 6 extend straight in the axial direction of the tube. The depth D1 of each of the recessed portions 6 is 0.5mm. Moreover, in each of the raised portions 4, there are formed circumferential groove portions 8 each extending in the circumferential direction of the tube are arranged at a predetermined interval in the axial direction of the tube. Local portions of the raised portions 4 interposed between the adjacent ones of the circumferential groove portions 8 constitute mutually independent fins 10, respectively. Further, in the bottoms of the recessed portions 6, there are formed respective axial grooves 12 having a depth D2 of 0.03mm such that the surfaces of the axial grooves 12 are non-smoothly contiguous with the raised portions 4 and the recessed portions 6. Moreover, the axial grooves 12 are formed not in the raised portions 4 but in the recessed portions 6. This arrangement further increases a difference between the thickness of a layer of an absorbent on the the raised portions 4 and that on the recessed portions 6, and accordingly increases a difference between intensities of the Marangoni convection occurring in the raised portions 4 and that in the recessed portions.

Referring next to Fig. 3, there is provided an enlarged fragmentary view of the heat exchanger tube 2 in longitudinal cross section. Described in detail, the circumferential groove portions 8 are formed in the raised portion 4 so as to extend at right angles to the raised portions, while the local portions of the raised portion 4 which are disposed between the adjacent ones of the circumferential groove portions 8, constitute fins 10. Each of the fins 10 has a generally curved shape in longitudinal cross section, while having a height F of 0.8mm. The fins 10 are arranged at an interval P of

2.0mm while having a distance W of 0.9mm between the end faces of the adjacent fins 10. The fins 10 having the generally curved shape is less likely to prevent flows of the absorbent in the axial direction of the tube, and facilitate formation of the layers of the absorbent and flows of the absorbent in the circumferential direction of the tube.

The heat exchanger tube 2 has an inner circumferential surface which includes local portions corresponding to raised portions 4. In each of the local portions, there are formed protrusions 14 and concave portions 16 which are arranged alternately in the axial direction of the tube. Namely, these protrusions 14 are formed by protrusion of local portions of the inner circumferential surface of the tube which correspond to the circumferential groove portions 8, into the inside of the tube, while the concave portions 16 are formed by local portions of the inner circumferential surface of the tube which correspond to the fins 10 disposed between the adjacent circumferential groove portions 8. These protrusions 14 and concave portions 16 constitute a corrugated structure of the inner circumferential surface of the tube, which structure promotes turbulent flows of a cooling fluid through the interior of the tube, resulting in improved heat exchangeability of the heat exchange tube 2. Moreover, an increase in the wall thickness of the heat exchanger tube 2 at the fin portions is effectively restrained, so that the unit weight of the heat exchanger tube 2 of the present invention can be made as small as a smooth surface tube.

The heat exchanger tube 2 of this construction can be easily produced from the appropriate cylindrical blank tube, as described above, by successively subjecting the blank tube to a drawing process and a rolling process, which are known in the art. More specifically described, the blank tube is initially subjected to an ordinary cold drawing process to produce a corrugated tube 20 having the plurality of raised portions 4 which are formed on the outer circumferential surface so as to extend in the axial direction of the tube and each of which has an arcuately curbed shape as seen in the circumferential direction of the tube. The raised portions 4 are arranged in the circumferential direction of the tube such that the recessed portions 6 are formed between the adjacent ones of the raised portions 4, which raised and recessed portions 4, 6 have substantially the same wall thickness. The thus obtained corrugated tube 20 is subjected to the rolling process using rolling disks 22 as shown in Fig. 4. In an arrangement of Fig. 4, three sets of rolling disks 22 are disposed around the corrugated tube 20 that is to be subjected to the rolling process, such that these sets of the rolling disks 22 are equally spaced from each other at an angular interval of 120°. Each of these sets of the rolling disks consists of a plurality of rolling disks 22 which are disposed coaxially with each other and rotated together as a unit. With the sets of rolling disks being rotated, each rolling disk 22 is pressed onto the raised portions 4 of the corrugated tube 20, so that the raised portions 4 of the corrugated tube 20 are subjected to the rolling process.

Referring next to Fig. 5, there is shown a manner of forming the circumferential groove portions 8 in one of the raised portions 4 by the rolling process, that is, a manner of forming the fins 10. It is noted that on the left side of Fig. 5, there are illustrated several stages of the rolling process as seen in cross section in a plane normal to the axis of the tube, while on the right side of Fig. 5, there are illustrated several stages of the rolling process in elevation as seen on the right side of the tubes illustrated in the left views. Further, the rolling process proceeds beginning with the stage of Fig. 5 (a) and ending with the stage of Fig. 5 (d). As well known in the art, the circumferential groove portions 8 (fins 10) are not formed by one rolling disk 22, but are progressively formed by the individual rolling disks 22 which belong to the respective sets of rolling disks 22, such that the rolling disks 22 of the different sets presses each raised portion 4, so that the fins 10 are are also formed between the adjacent rolling disks 22 such that the height of each fin 10 gradually increases in the radially outward direction of the tube as the rolling process progresses, as indicated in the right views.

As shown in Fig. 6, the circumferential groove portions 8 and the fins 10 having the predetermined height are formed on each of the raised portions 4, alternately in the axial direction of the tube, by the rolling process as described above, whereby the desired heat exchanger tube 2 is produced. As is apparent from Figs. 5 and 6 and the enlarged view of Fig. 7, each of the circumferential groove portions 8 formed by the rolling process has a curved shape, more specifically, an arcuately curved shape at its bottom portion, in cross section in both of the axial and circumferential directions of the tube. Moreover, the opposite end portions of the circumferential groove portion 8 as seen in the circumferential direction of the tube have a width which gradually decreases to zero, as is apparent from Fig. 7(b) which is a top plan view of the circumferential groove portions 8. Namely, each circumferential groove portion 8 interposed between the adjacent fins 10 has the opposite end portions as seen in the circumferential direction of the tube. These portions have a width which decreases gradually as the end portions extend toward their ends, in other wards, toward the corresponding recessed portions 6, such that the width is zero at the ends of the circumferential groove portion. This arrangement restricts flows of the absorbent in the circumferential direction, while permitting easier flows of the absorbent in the axial direction, than in the conventional finned heat exchanger tube. Thus, the heat exchange effect of the heat exchanger tube 2 is further improved due to the turbulence of the absorbent caused by the Marangoni convection of the absorbent, and the collision of the layers of the absorbent with the circumferential groove portions 8.

It is preferable that the circumferential groove por-

tions 8 constructed as described above are formed radially outwardly with respect to the bottoms of the recessed portions 6, so as to prevent the circumferential groove portions 8 from communicating with the corresponding recessed portions 6, and that the opposite ends of the circumferential groove portions 8 in the circumferential direction terminate at the corresponding side faces of the raised portions 4. In this arrangement, the flows of the absorbent along the recessed portions 6 in the axial direction of the tube are further effectively promoted.

It is noted that a plurality of heat exchanger tubes 2 each constructed as described above are generally disposed in an absorber 30 of an absorption refrigerator, such that the heat exchanger tubes 2 are arranged in the vertical direction, while each heat exchanger tube has a horizontal attitude. Cooling water as a coolant fluid is caused to flow through the inside of the heat exchanger tubes 2, so that the absorbent on the outer surfaces of the heat exchanger tubes 2 is effectively cooled. More specifically described, the absorbent 36, such as an aqueous solution of lithium bromide including a surface active agent, is dripped or dispersed on the heat exchanger tube 2 from spreader nozzles 34 of a spreader 32 which are disposed above the heat exchanger tube 2. The absorbent 36 dispersed on the heat exchanger tubes 2 has a relatively high concentration so that the absorbent flows down smoothly on the outer circumferential surfaces of the heat exchanger tubes 2, while absorbing a vapor which exists inside the absorber 30. The heat generated upon absorption of the vapor is transferred from the absorbent 36 to the cooling water flowing through the inside of the heat exchanger tube 2, so that the absorbent 36 is effectively cooled.

More specifically described, as illustrated in Figs. 9 and 10, the absorbent 36 which is dripped from the spreader nozzles 34 of the spreader 32 disposed above the heat exchanger tube 2 (not shown), initially flows down on the outer circumferential surface of the heat exchanger tube 2 in the circumferential direction of the tube 2 via the raised portions 4 and the recessed portions 6 alternately In the raised and recessed portions 4, 6, Marangoni convections of the absorbent 36 occur, depending upon the thickness values of the layers of the absorbent 36 on the raised and recessed portions 4 and 6. The thickness of the layer of the absorbent on each of the raised portions 4 is considerably smaller than that on each of the recessed portions 6. Accordingly, the Marangoni convection of the absorbent 36 occurring in the raised portion 4 has a relatively low intensity, while the Marangoni convection of the absorbent 36 occurring in the recessed portion 6 has a relatively high intensity, in the axial direction of the heat exchanger tube 2. These Marangoni convections occur on the respective raised and recessed portions 4 and 6 interfere with each other, whereby turbulence of the absorbent 36 in the axial direction of the tube is remarkably promoted.

In the heat exchanger tube 2 according to the present invention, the absorbent 36 can enter into the circumferential groove portions 8 interposed between the adjacent fins 10 as also shown in Fig. 10, resulting in an effective increase of the area of contact of the heat exchanger tube 2 with the absorbent 36. Thus, the heat exchanger tubes 2 for the absorber constructed according to the present invention exhibits an improved heat exchangeability.

In the heat exchanger tube 2 constructed according to the present invention, the axial grooves 12 are formed in the bottoms of the recessed portions 6 so that the layer of the absorbent 36 on each of the recessed portions 6 has, a relatively large thickness. Accordingly, the Marangoni convection of the absorbent 36 occurs to a great extent when a suitable amount of absorbent 36 is dripped onto the heat exchanger tube 2, as in a normal operation of the absorption system. Moreover, even when the amount of absorbent dripped onto the heat exchanger tube 2 is relatively small, as in an operation immediately after starting of the absorption system, the absorbent 36 collects in the axial grooves 12 so as to provide the layer of the absorbent 36 having a desired thickness on the recessed portions 6, so that the intensity of the Marangoni convections occurring on the recessed portions 6 is effectively increased, thereby assuring improved heat exchangeability of the heat exchanger tube 2. The axial grooves 12 are configured to have a relatively small depth of 0.03mm, which depth is too small to disturb flows of the absorbent 36 across the recessed portions 6, so that the absorbent 36 dripped on the outer surface of the heat exchanger tube 2 is smoothly moved in the circumferential direction of the tube. Accordingly, the heat exchanger tube 2 constructed as described above can exhibits improved heat exchanging efficiency, as compared with the conventionally used heat exchanger tube, by simply forming the axial grooves 12 in the recessed portions 6 so as to increase the amount of the absorbent 36 on the outer circumferential surface.

It is to be understood that a heat exchanger tube for an absorber according to the present invention is not limited to the details of the illustrated construction as described above. For instance, the fins 10 may be configured to have a shape in the longitudinal cross section as illustrated in Fig. 11 or 12. In the heat exchanger tube having the fins 10 formed in the raised portions 4 at a predetermined interval, as shown in Fig. 11, each of the fins 10 has a flat top surface as seen in the longitudinal cross section. In the heat exchanger tube having the fins 10 formed in the raised portions 4 at a predetermined intervals, as shown in Fig. 12, each of the fins 10 has a top having an extremely small width as seen in the longitudinal cross section. These heat exchanger tubes, having such constructions have an excellent action of turbulence of the absorbent, like the heat exchanger tube 2 described above.

The absorber equipped with the heat exchanger

tubes 2 as described above was operated under the following conditions: inside pressure of the absorber = 6.6mmHg; concentration of the absorbent = 63.5mass%; and amount of flow of the absorbent = 1.0l/min • m. There was measured heat exchangeability of the heat exchanger tube 2. The measurement reveals that the heat exchanger tube 2 according to the present invention exhibited an overall heat transfer coefficient which is about 1.2 times that of the corrugated tube 20, which is a base of the heat exchanger tube 2, and about 1.5 times that of the smooth surface tube. The actual heating surface area of the heat exchanger tube 2 was about 1.2 times that of the corrugated tube or the smooth tube. It was confirmed that the degree of increase of the heat exchangeability of the heat exchanger tube 2 was the degree of increase of the heating surface area.

As is apparent from the foregoing explanation, in the heat exchanger tube according to the present invention, the circumferential groove portions disposed between the adjacent fins are formed to have a curbed shape, so that the absorbent effectively flows into the circumferential groove portions irrespective of the concentration of the absorbent, resulting in prevention of unnecessary stay of the absorbent in the circumferential groove portions, whereby the formed layer of the absorbent is given a suitable thickness. Accordingly, the surface area of contact of the heat exchanger tube with the absorbent is advantageously increased, whereby the heat exchangeability of the heat exchanger tube is effectively improved. Moreover, the circumferential groove portions are configured such that the opposite end portions of each of the circumferential groove portions in the circumferential direction have a gradually decreasing width, so that the width is zero at the opposite ends. Thus, the circumferential groove portions hardly prevent the flows of the absorbent in the axial direction of the tube and the Marangoni convections of the absorbent, leading to intensive turbulence of the absorbent, whereby the heat exchangeability of the heat exchanger tube is improved. Further, on each raised portion of the tube, there is formed a layer of the absorbent with openings, which layer is continuous with the layers of the absorbant formed on the recessed portions, permitting flows of the absorbent in the axial direction and the Marangoni convection of the absorbent. Accordingly, the Marangoni convections of the absorbent occurring in the respective raised and recessed portions interfere with each other so as to cause relatively strong turbulence of the absorbent, whereby the heat exchangeability of the heat exchanger tube is further improved.

INDUSTRIAL APPLICABILITY

As is apparent from the above explanation, the present invention relates to a heat exchanger tube for an absorber, which is horizontally disposed in the absorber for an absorption refrigerator, an absorption heat pump and the like, and a method of producing the heat exchanger tube. Particularly, the present invention provides the heat exchanger tube which assures an excellent heat exchanging efficiency and whose mass per unit length is as small as that of the the smooth surface tube, and the method according to which the heat exchanger tube can be advantageously produced.

Claims

1. A heat exchanger tube for an absorber, having a structure wherein a plurality of raised portions each having an arcuately curved shape in a circumferential direction of said tube, are disposed on an outer circumferential surface so as to extend in an axial direction of said tube, and are arranged in said circumferential direction of said tube such that recessed portions are formed each between adjacent ones of said plurality of raised portions, and an inner circumferential surface of said tube is corrugated corresponding to said raised and recessed portions, and wherein an absorbent is dripped or spread on said outer circumferential surface of said tube, while a cooling fluid flows through an inside of said heat exchanger tube so as to cool said absorbent on said outer circumferential surface of said tube, characterized in that:

   a plurality of circumferential groove portions are formed in each of said raised portions at an interval in said axial direction of said tube, each of said circumferential groove portions extending in said circumferential direction of said tube and having a curved shape at a bottom portion thereof in cross section in the axial and circumferential directions of said tube, local portions of said raised portions which are interposed between adjacent ones of said circumferential groove portions constituting mutually independent fins, respectively, opposite end portions of each of said circumferential groove portions in said circumferential direction of said tube having a width which gradually decreases toward the ends, such that the width is zero at the ends.

2. A heat exchanger tube for an absorber according to claim 1, wherein said circumferential groove portions are formed radially outwardly with respect to bottoms of said recessed portions, so as to prevent said circumferential groove portions from communicating with said bottoms of said recessed portions, and said opposite end portions of each of said circumferential groove portions terminate at corresponding side faces of said raised portions.

3. A heat exchanger tube for an absorber according to

claims 1 or 2, wherein said raised and recessed portions are formed by a drawing process, and said circumferential groove portions are formed by a rolling process.

4. A heat exchanger tube for an absorber according to any one of claims 1-3, wherein axial grooves extending in said axial direction of said tube are disposed in said bottoms of said recessed portions, and arranged in said circumferential direction of said tube such that surfaces of said axial grooves are non-smoothly contiguous with said bottoms as seen in cross section in the circumferential direction.

5. A heat exchanger tube for an absorber according to any one of claims 1-4, wherein local portions of said inner circumferential surface which correspond to said circumferential groove portions are protruded toward an inside of said tube, while local portions of said inner circumferential surface which correspond to said fins disposed between adjacent ones of said circumferential groove portions constitute concave portions.

6. A method of producing a heat exchanger tube for an absorber wherein an absorbent is dripped or spread on an outer circumferential surface of said heat exchanger tube, while a cooling fluid flows through an inside of said heat exchanger tube so as to cool said absorbent on said outer circumferential surface of said heat exchanger tube, said method being characterized by comprising:

a first step of drawing a cylindrical blank tube into a corrugated tube, which is constructed such that a plurality of raised portions each having an arcuately curved shape in a circumferential direction of said tube, are disposed on said outer circumferential surface so as to extend in an axial direction of said tube, and are arranged in said circumferential direction of said tube such that recessed portions are formed between adjacent ones of said plurality of raised portions, and an inner circumferential surface of said tube is corrugated corresponding to said raised and recessed portions; and

a second step of subjecting said corrugated tube to a rolling process so as to form a plurality of circumferential groove portions each extending in said circumferential direction of said tube and having a bottom portion having a curbed shape in cross section in the axial and circumferential directions of said tube, in each of said raised portions at an regular interval in the axial direction of said tube, local portions of said raised portion which are interposed between adjacent ones of said circumferential groove portions constituting mutually independent fins, respectively, opposite end portions of each of said circumferential groove portions in said circumferential direction of said tube having a width which gradually decreases toward the ends, such that the width is zero at the ends.

FIG. 1

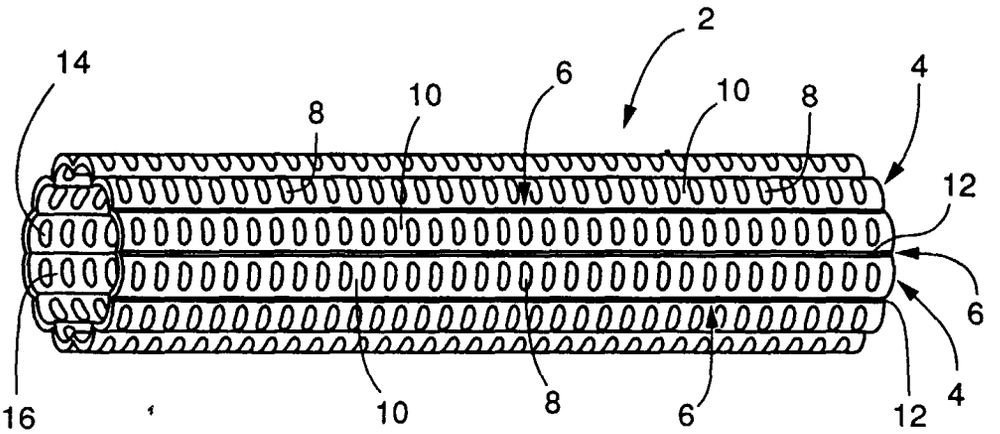

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12

FIG. 2

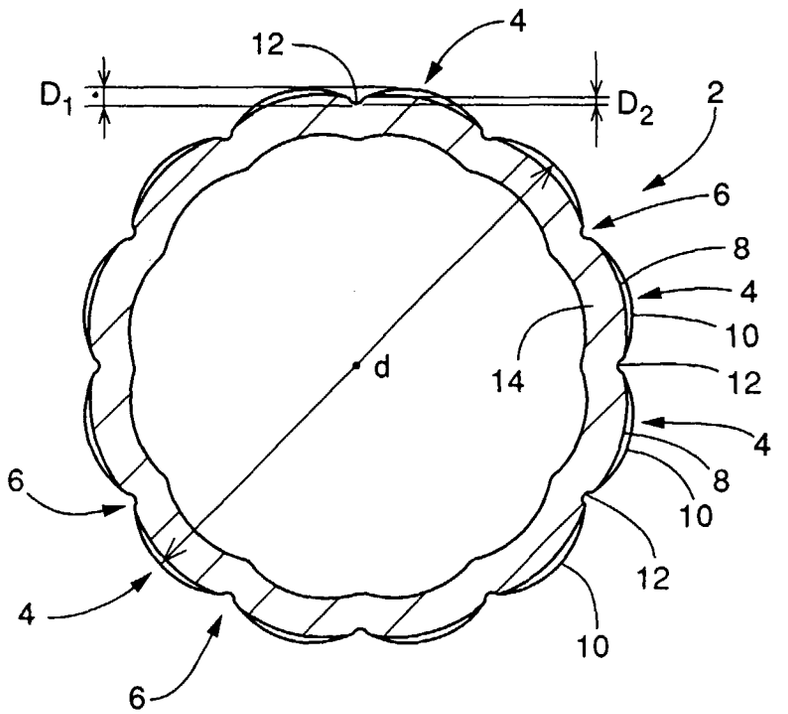

12
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D_1
D_2
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d
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10
6

FIG. 3

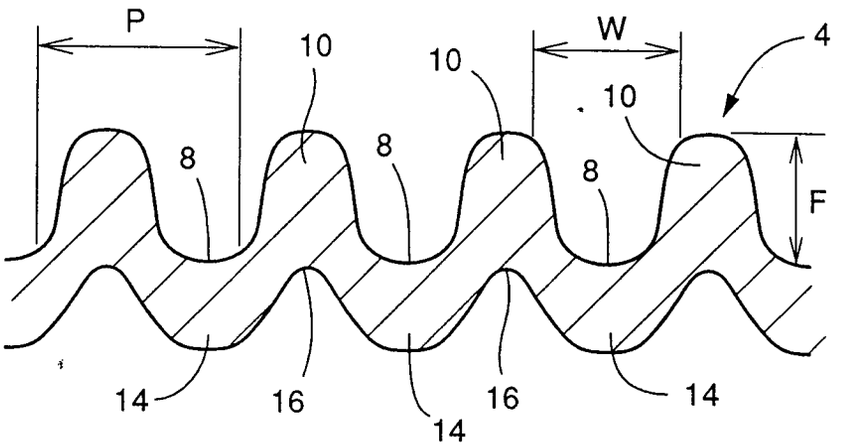


FIG. 4

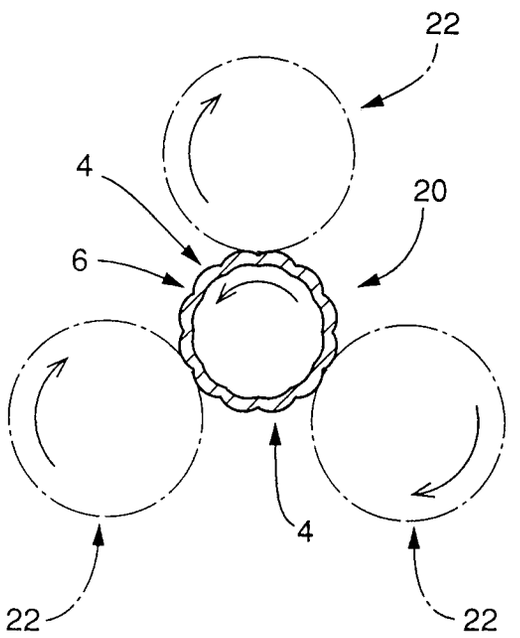


FIG. 5

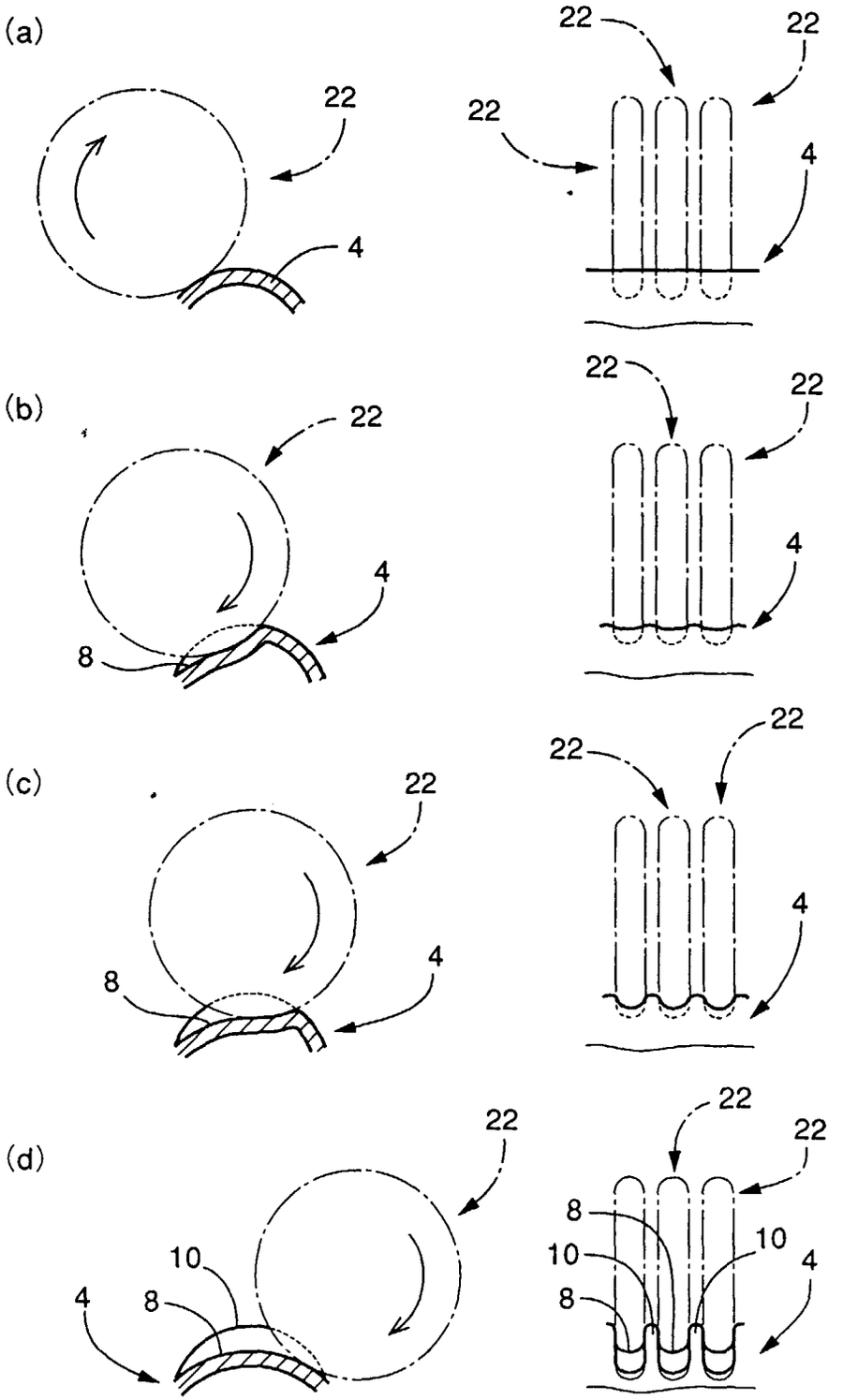


FIG. 6

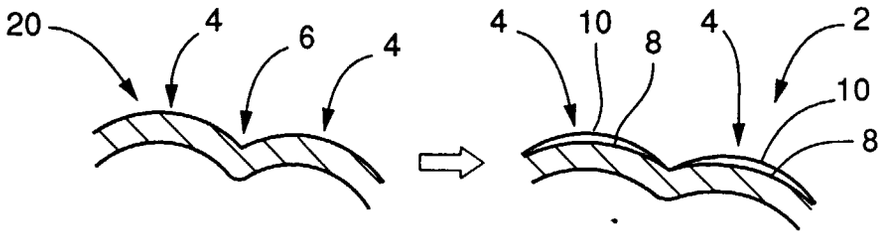


FIG. 7

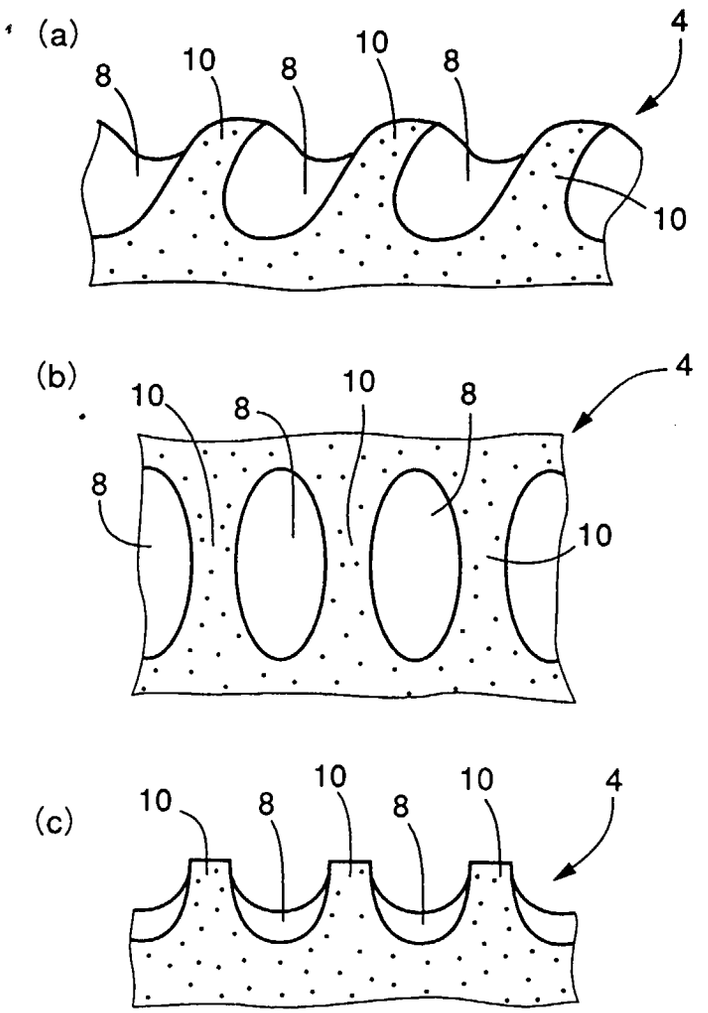


FIG. 8

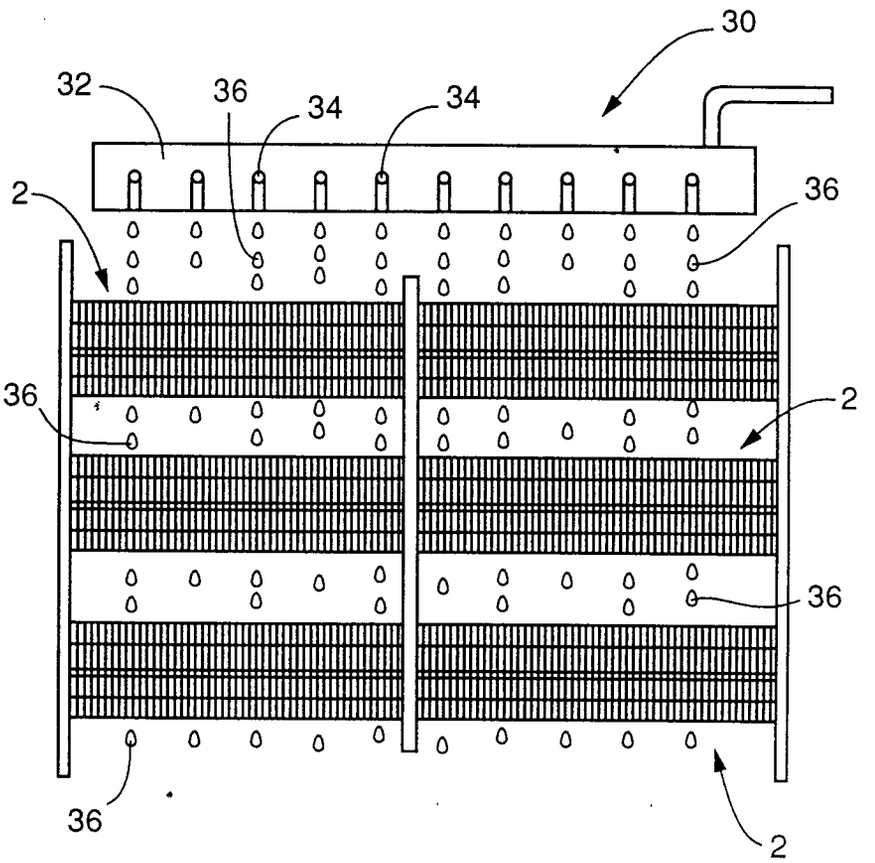


FIG. 9

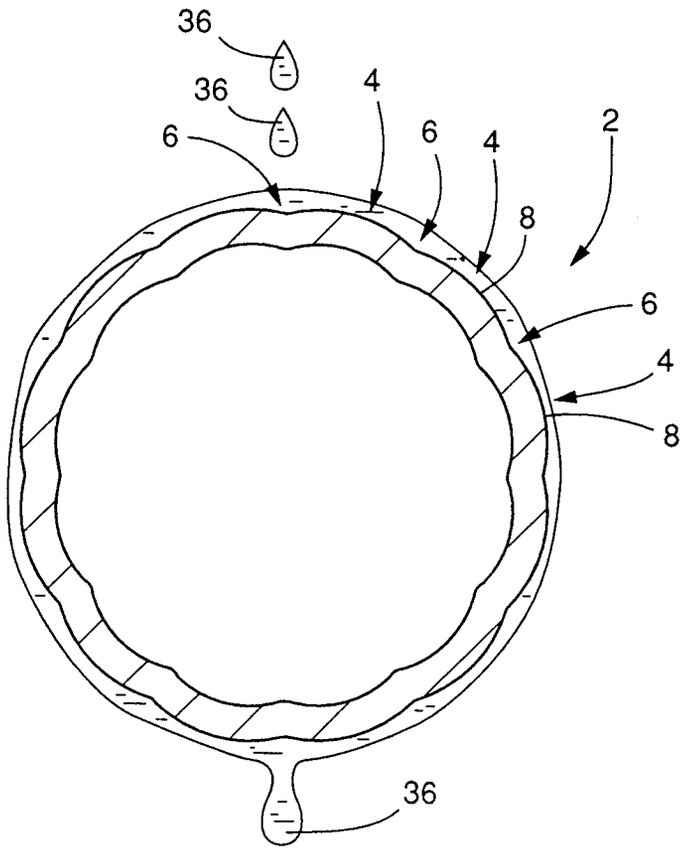


FIG. 10

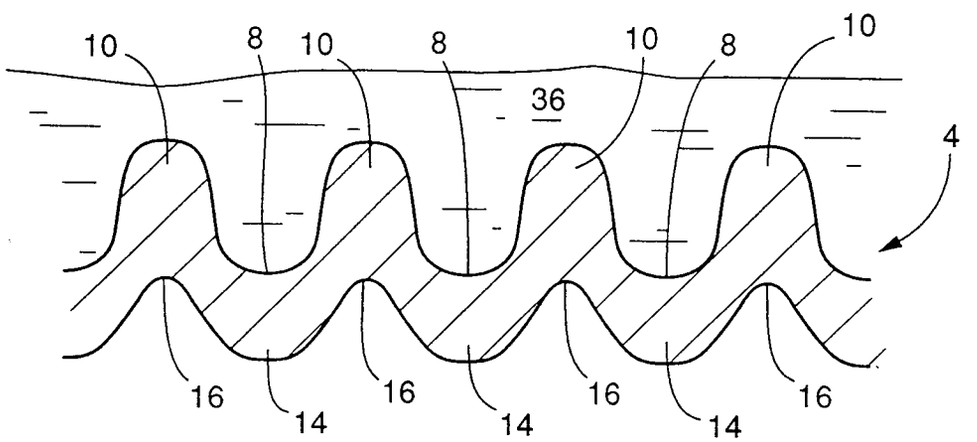


FIG. 11

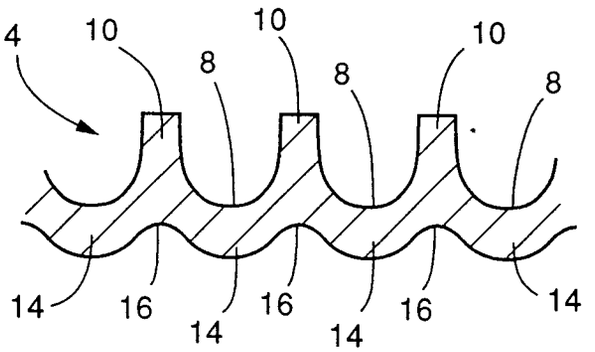
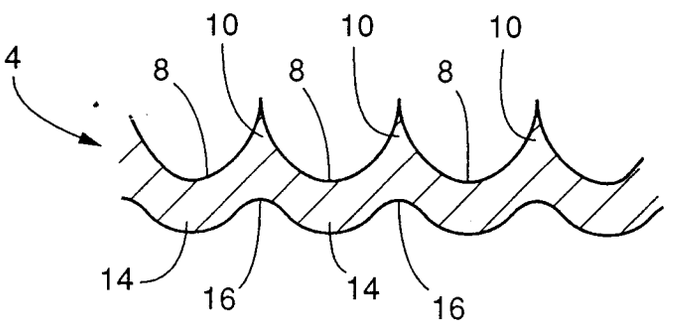


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/04554

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] F25B37/00, F28F1/06, F28F1/12, B21D53/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] F25B37/00, F28F1/06, F28F1/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1998
Kokai Jitsuyo Shinan Koho 1971-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 7-45994, B2 (Tokyo Gas Co., Ltd. and others), May 17, 1995 (17. 05. 95), Fig. 1 (Family: none)	1, 2, 6
Y	JP, 6-159862, A (Sanyo Electric Co., Ltd. and others), June 7, 1994 (07. 06. 94), Figs. 1 to 3 ; page 3, Par. No. [0013] (Family: none)	1, 3, 4, 6
Y	JP, 8-159605, A (Kobe Steel Corp.), June 21, 1996 (21. 06. 96), Figs. 1, 2, 8 (Family: none)	1, 5, 6
Y	JP, 7-218037, A (The Furukawa Electric Co., Ltd.), August 18, 1995 (18. 08. 95), Page 3, Par. No. [0018] (Family: none)	3, 6
A	JP, 7-24522, A (Sanyo Electric Co., Ltd. and others), January 27, 1995 (27. 01. 95), Fig. 1 (Family: none)	1-6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
March 3, 1998 (03. 03. 98)	March 17, 1998 (17. 03. 98)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/04554

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 63-6363, A (Tokyo Gas Co., Ltd. and others), January 12, 1988 (12. 01. 88), Figs. 1, 2 (Family: none)	1-6

Form PCT/ISA/210 (continuation of second sheet) (July 1992)