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(71) Applicant: **Daikin Industries, Ltd.
Osaka-shi, Osaka 530-8323 (JP)**

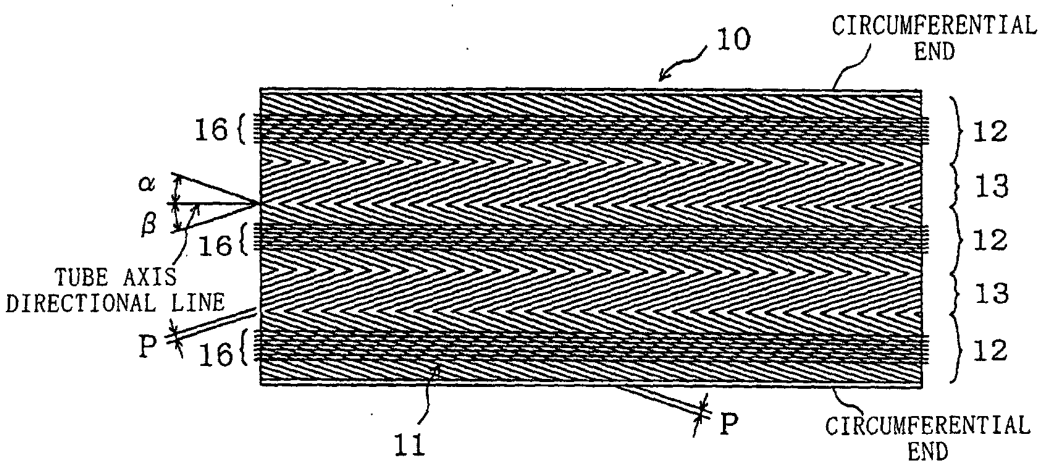
(72) Inventors:
- **AKAI, Kanji, c/o Kanaoka Factory, Sakai Plant Sakai-shi, Oaka 591-8511 (JP)**
- **FUJINO, Hirokazu, c/o Kanaoka Factory, Sakai Plant Sakai-shi, Osaka 591-8511 (JP)**
- **KASAI, Kazushige, c/o Kanaoka Factory, Sakai Plant Sakai-shi, Osaka 591-8511 (JP)**

(74) Representative: **Zinnecker, Armin, Dipl.-Ing.
Lorenz-Seidler-Gossel,
Widenmayerstrasse 23
80538 München (DE)**

(54) **HEATING TUBE WITH INNER SURFACE GROOVES**

(57) Disclosed is an inner grooved heat transfer tube **(10)** having a line groove **(11)** in which is formed a deformed portion **(13).** In order to upgrade the performance of heat transmission by securing an action of scattering liquid refrigerant by the deformed portion **(13)** when used in a condenser, and in order to reduce the loss of pressure when used in an evaporator, conditions (e.g., the ratio of a main groove **(12)** to the deformed portion **(13)** of the line groove **(11)** and the angle and length of the main groove **(12)** and the deformed portion **(13))** are specified so as to fall within predetermined ranges.

FIG. 2



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Description

TECHNICAL FIELD

[0001] The present invention relates to inner grooved heat transfer tubes for use in heat exchangers. More specifically, the invention relates to specific structures of the internal groove.

BACKGROUND ART

[0002] There is a conventional heat exchanger serving as an evaporator or as a condenser in a refrigerating apparatus such as an air conditioner. Such a heat exchanger employs for example an inner grooved heat transfer tube comprising an inner surface in which are formed a large number of helical line grooves. By virtue of these helical line grooves, the area of heat transfer of the inner grooved heat transfer tube is increased and, besides, the performance of heat transfer is upgraded by causing refrigerant to flow in the tube while forming an even and thin film of liquid.

[0003] However, if, when an inner grooved heat transfer tube of the above-described type is used in a condenser, the action of condensation makes progress as refrigerant flows forward from inlet port to outlet port in the tube, the refrigerant becomes an annular flow. This causes a layer of liquid refrigerant flowing along the tube inner surface to become thicker toward the downstream side. This increases thermal resistance, therefore reducing the performance of condensation.

[0004] To cope with such a problem, the Applicant made a proposal (see Japanese Patent *Kokai* No. H10-153360). The proposal discloses an inner grooved heat transfer tube capable of suppressing the decrement in condensation performance. In the inner grooved heat transfer tube, each line groove comprises a main groove of a first lead angle and a deformed portion of a second lead angle different from the first lead angle which are successively formed, and refrigerant is made to flow along the main groove while forming a thin film of liquid. When arriving at the deformed portion, the liquid refrigerant comes into collision with a groove side surface of the deformed portion and is scattered toward the center of the heat transfer tube. In accordance with such a configuration, since a thick layer of liquid refrigerant is less likely to be formed on the internal surface of the heat transfer tube, this accelerates the liquefaction of gas refrigerant.

[0005] However, if the ratio of the deformed portion to the main groove is too small in the inner grooved heat transfer tube of the above described configuration, then the effect of causing liquid refrigerant to be scattered at the deformed portion is hardly obtained. Consequently, there is no improvement in heat transfer performance. On the other hand, if the ratio of the deformed portion to the main groove is too large, this produces the problem of increasing the loss of pressure, particularly when used as an evaporator. As described above, in the above-mentioned conventional inner grooved heat transfer tube, it is intended to secure the performance of condensation by providing deformed portions in a part of the line groove. However, the performance of heat transfer and the loss of pressure vary greatly, depending on the configuration of a deformed portion, therefore producing the problem that it is difficult to stabilize the performance of heat exchange when used as a heat exchanger.

[0006] Bearing in mind the above-described problems, the present invention was made. Accordingly, an object of the invention is to make it possible to make the performance of heat exchange much steadier than conventional by specifying concrete configurations about the main groove and deformed portion of the line groove in the inner grooved heat transfer tube.

DISCLOSURE OF THE INVENTION

[0007] The invention provides first to twelfth problem-solving means. More specifically, in an inner grooved heat transfer tube according to each problem-solving means, a plurality of line grooves **(11)** are formed in an inner peripheral surface of the heat transfer tube and the line groove **(11)** comprises main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) differing from the first lead angle (α) which are successively formed, wherein the main groove **(12)** and the deformed portion **(13)** of the line groove **(11)** are set to predetermined relationships specified as follows.

[0008] More specifically, the first problem-solving means implemented by the invention is a means in which the percentage of the length of the deformed portion **(13)** to the length of a single round of the line groove **(11)** is so set as to fall in the range of 10 to 35% in the configuration as set forth above.

[0009] Further, the second problem-solving means is a means in which the length of the deformed portion **(13)** is so set as to fall in the range of five to fifteen times the pitch of the line groove **(11)**.

[0010] Furthermore, the third problem-solving means is a means in which from five to fifteen deformed portions **(13)** are so arranged as to intersect an extension of a single main groove **(12).**

[0011] Further, the fourth problem-solving means is a means in which a joint portion **(14)** of an electric welded tube and the deformed portion **(13)** are arranged at respective locations substantially equally dividing the direction of the circumference of the electric welded tube. By an "electric welded tube" is meant, in general, a tube formed by connecting a long strip-shaped material by electric resistance welding. However, in the Specification such an electric welded tube is taken in the wide sense. Therefore, the electric welded tube includes any type of tube connected along the longitudinal direction by any connecting technique.

[0012] Furthermore, the fifth problem-solving means is a means according to any one of the first to fourth problem-solving means in which the deformed portion **(13)** is formed at a plurality of positions in a single round of the line groove **(11)**.

[0013] Further, the sixth problem-solving means is a means according to any one of the first to fourth problem-solving means in which one of the first lead angle (α) and the second lead angle (β) is so set as to fall in the range of 5 to 30 degrees in one torsional direction with respect to a tube axis directional line whereas the other of the first lead angle (α) and the second lead angle (β) is so set as to fall in the range of 5 to 30 degrees in the other torsional direction with respect to the tube axis directional line.

[0014] Furthermore, the seventh problem-solving means is a means according to the sixth problem-solving means in which the first lead angle (α) and the second lead angle (β) are set in such a way that the main groove **(12)** and the deformed portion **(13)** of the line groove **(11)** are symmetrically directed with respect to the tube axis directional line.

[0015] Further, the eighth problem-solving means is a means according to the seventh solving means in which the first lead angle (α) and the second lead angle (β) are specified. More specifically, the first lead angle (α) and the second lead angle (β) are each set at 18 degrees in opposite directions with respect to the tube axis directional line.

[0016] Furthermore, the ninth problem-solving means is a means according to any one of the first to fourth problem-solving means in which a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming the main groove **(12)**.

[0017] Further, the tenth problem-solving means is a means according to the ninth problem-solving means in which the secondary groove **(16)** is centrally formed in the convexity **(15)** of the main groove **(12)** so that the secondary groove **(16)** is spaced a predetermined distance apart from the deformed portion **(13)**.

[0018] Furthermore, the eleventh problem-solving means is a mans according to the ninth problem-solving means in which the secondary groove **(16)** is formed to a depth of 0.25 to 0.75 times the depth of the line groove **(11).**

[0019] Furthermore, the twelfth problem-solving means is a means according to the ninth problem-solving means in which the secondary groove **(16)** is formed substantially along the tube axis directional line.

[0020] Further, the invention provides thirteenth to fifteenth problem-solving means. Each problem-solving means is an inner grooved heat transfer tube in which, as in the previous problem-solving means, a plurality of line grooves **(11)** are formed in an inner peripheral surface of the heat transfer tube and the line groove **(11)** comprises main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) differing from the first lead angle (α) which are successively formed.

[0021] And, the thirteenth problem-solving means is a means in which a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming the main groove **(12)** and the secondary groove **(16)** is centrally formed in the convexity **(15)** of the main groove **(12)** so as to be separated a predetermined distance apart from the deformed portion **(13)**.

[0022] Further, the fourteenth problem-solving means is a means in which a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming the main groove **(12)** and the secondary groove **(16)** is formed to a depth which is from 0.25 to 0.75 times the depth of the line groove **(11)**.

[0023] Finally, the fifteenth problem-solving means is a means in which a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming the main groove **(12)** and the secondary groove **(16)** is formed substantially along the tube axis directional line.

[0024] When an inner grooved heat transfer tube formed in accordance with each problem-solving means is used in a condenser, refrigerant in the heat transfer tube condenses from a gas phase, changes to a thin film of liquid, and flows in the line groove **(11)**. Upon arriving at the deformed portion **(13)**, the refrigerant comes into collision with a side surface of the deformed portion **(13)** and is scattered in the direction of the center of the heat transfer tube **(10)** because the first lead angle (α) of the main groove **(12)** differs from the second lead angle (β) of the deformed portion **(13).** Accordingly, thick layers of liquid are less likely to be formed on the inner surface of the heat transfer tube **(10)**, thereby preventing the occurrence of an annular flow.

[0025] Especially in the first problem-solving means, the percentage of the length of the deformed portion **(13)** to the length of a single round of the line groove **(11)** is so set as to fall in the range of 10 to 35%. If the percentage is less than 10%, liquid refrigerant is not scattered readily even when the deformed portion **(13)** is provided. However, the aforesaid setting provides a sufficient scattering action. On the other hand, if the percentage is greater than 35%, this increases the loss of pressure when used particularly in an evaporator. However, the aforesaid range suppresses the loss of pressure.

[0026] Further, in the second problem-solving means, the length of each deformed portion **(13)** is so set as to fall in the range of five to fifteen times the pitch of the line groove **(11).** As a result of such arrangement, liquid refrigerant flowing in the main groove **(12)** of the line groove **(11)** moves forward while climbing over a plurality of deformed portions **(13)**, during which the liquid refrigerant is scattered sufficiently. If the aforesaid value is less than five times the pitch of the line groove **(11),** the liquid refrigerant is not scattered readily even when the deformed portion **(13)** is provided. However, the aforesaid setting provides a sufficient scattering action. On the other hand, if the value is greater than fifteen times the pitch of the line groove **(11)**, this increases the loss of pressure when used particularly in an evaporator. However, the aforesaid setting suppresses the loss of pressure.

[0027] Further, like the second problem-solving means, in the third problem-solving means the liquid refrigerant flowing in the main groove **(12)** is sufficiently scattered when climbing over a plurality of deformed portions **(13)** (five to fifteen deformed portions **(13)**). Accordingly, it is possible to secure a refrigerant scattering action when used in a condenser and to suppress the loss of pressure when used in an evaporator.

[0028] Furthermore, in the fourth problem-solving means the joint portion **(14)** of the electric welded tube and the deformed portion **(13)** are arranged at respective locations substantially equally dividing the direction of the circumference of the electric welded tube. As a result of such arrangement, the liquid refrigerant flowing in the main groove **(12)** of the line groove **(11)** is evenly scattered at the joint portion **(14)** and the deformed portion **(13)** in the heat transfer tube **(10)**. As described above, the action of scattering liquid refrigerant is obtained throughout the entire inner surface of the heat transfer tube **(10)** and the arrangement that the deformed portion **(13)** and the joint portion **(14)** are disposed in a scattering manner suppresses the loss of pressure when used in an evaporator.

[0029] Further, if in the first to fourth problem-solving means the deformed portion **(13)** is formed at multiple positions in a single round of the line groove **(11)**, as set forth in the fifth problem-solving means, the action of scattering liquid refrigerant can be obtained at each deformed portion **(13)**. This further ensures that the liquid layer is prevented from growing thicker.

[0030] Furthermore, if in the first to fourth problem-solving means the first lead angle (α) and the second lead angle (β) are so set as to fall in the range of 5 to 30 degrees in opposite torsional directions respectively with respect to the tube axis directional line, as set forth in the sixth problem-solving means (particularly if these angles are set at 18 degrees as set forth in the eighth problem-solving means), the refrigerant flows in a helical direction by the main groove **(12)** and efficiently forms an even and thin layer of liquid and, at the same time, the action of scattering by the deformed portion **(13)** is obtained reliably.

[0031] Further, if in the first to fourth problem-solving means the secondary groove **(16)** is provided in the convexity **(15)** which forms the main groove **(12)**, as set forth in the ninth problem-solving means, this means that a plurality of intermittent recessed portions are defined in the convexity **(15)**. As a result, the area of heat transfer increases. Further, the provision of the secondary groove **(16)** reduces the loss of pressure because while producing a helical flow by a main groove **(12)** a part of the refrigerant is caused to flow into the next main groove **(12)** by the secondary groove **(16)**.

[0032] Further, if the secondary groove **(16)** is formed centrally in the convexity **(15)** of the main groove **(12)** so that the secondary groove **(16)** is spaced a predetermined distance apart from the deformed portion **(13)**, as set forth in the tenth problem-solving means, this ensures a helical flow action by the main groove **(12)**. In other words, if the secondary groove **(16)** is formed in close proximity to the deformed portion **(13)**, this causes refrigerant to escape from the secondary groove, and helical flows are less likely to occur. The above-mentioned configuration is free from such a danger.

[0033] Further, if the depth of the secondary groove **(16)** is less than 0.25 times the depth of the line groove **(11)**, the area of heat transfer will not increase as expected. On the other hand, if the depth of the secondary groove **(16)** is more than 0.75 times the depth of the line groove **(11)**, this will cause the refrigerant to readily escape from the secondary groove **(16)** thereby preventing a helical flow from being produced. However, if made to fall in the range of 0.25 to 0.75 times the depth of the line groove **(11)**, as set forth in the eleventh problem-solving means, this makes it possible to produce a helical flow while increasing the area of heat transfer.

[0034] Furthermore, if the secondary groove **(16)** is formed substantially along the tube axis directional line, as set forth in the twelfth problem-solving means, this makes it possible to suppress the loss of pressure while increasing the area of heat transfer because the flow of refrigerant becomes relatively less disturbed in the main groove **(12)**.

[0035] Further, in each of the thirteenth to fifteenth problem-solving means, the secondary groove **(16)** is formed in the convexity **(15)** which forms the main groove **(12)**. Accordingly, like the ninth problem-solving means, it is possible to reduce the loss of pressure while increasing the area of heat transfer. More specifically, the thirteenth problem-solving means ensures that helical flows are produced without fail by the same action as the tenth problem-solving means. The fourteenth problem-solving means produces helical flows while securing a heat transfer area by the same action as the eleventh problem-solving means. The fifteenth problem-solving means suppresses the turbulence of the flow of refrigerant by the same action as the twelfth problem-solving means, thereby reducing the loss of pressure.

[0036] In accordance with the first problem-solving means, the percentage of the length of the deformed portion **(13)** to the length of a single round of the line groove **(11)** is so set as to fall within the range between 10% and 35%. This provides a sufficient scattering action by the deformed portion **(13)** when used in a condenser and reduces the loss of pressure when used in an evaporator. In other words, if it is intended to obtain only a refrigerant scattering action in the condenser, it is sufficient for the inner surface of the heat transfer tube **(10)** to be formed into an irregular convex-concave shape. In such a case, however, the loss of pressure in the evaporator will increase. On the other hand, if the percentage is so set as to fall within the above-mentioned range, this makes it possible to maintain well-balanced relationships between the action of scattering refrigerant and the loss of pressure.

[0037] Further, with the second problem-solving means, the length of a single deformed portion **(13)** is so set as to fall within the range between five times and fifteen times the pitch of the line groove **(11)**, and liquid refrigerant flowing in a main groove of the line groove **(11)** moves forward while climbing over a plurality of deformed portions **(13)**, during which the liquid refrigerant is scattered sufficiently. Additionally, the relationship between the length of the deformed portion **(13)** and the pitch of the line groove **(11)** is not set greater than necessary but within the above-described range, thereby making it possible to suppress the loss of pressure while achieving a sufficient liquid refrigerant scattering action.

[0038] Furthermore, with the third problem-solving means, five to fifteen deformed portions **(13)** are so arranged as to intersect a main groove **(12)**. As a result of such arrangement, liquid refrigerant flowing in the main groove **(12)** is scattered sufficiently at the time of climbing over a plurality of deformed portions **(13)** and the loss of pressure is suppressed when used in an evaporator, as in the second problem-solving means.

[0039] Further, with the fourth problem-solving means, it is arranged in such a way that liquid refrigerant is scattered evenly at the joint portion **(14)** and the deformed portions **(13)** in the electric welded tube. As a result of such arrangement, it becomes possible to obtain an action of sufficiently scattering refrigerant in the condenser and, in addition, it is possible to suppress the loss of pressure in the evaporator because the deformed portions **(13)** and the joint portion **(14)** are arranged scatteredly. In such a case, liquid refrigerant and gas refrigerant are dispersed evenly, which has an effect, particularly on a drifted flow of refrigerant.

[0040] As described above, in accordance with the first to fourth problem-solving means, it is possible to provide improvement in heat transfer efficiency when used as a condenser by sufficiently scattering liquid refrigerant and to suppress the increase in pressure loss when used as an evaporator. In other words, by the use of the inner grooved heat transfer tubes of the above-mentioned problem-solving means, it is possible to improved the performance of heat exchangers.

[0041] Further, if the first lead angle (α) and the second lead angle (β) are so set as fall in the range of 5 to 30 degrees in opposite torsional directions respectively with respect to the tube axis directional line, as set forth in the sixth problem-solving means (particularly if these angles are set at 18 degrees as set forth in the eighth problem-solving means), this makes it possible to maintain well-balanced relationships between the heat transfer efficiency and the loss of pressure while securing the effect of a helical flow.

[0042] Furthermore, if the first lead angle (α) and the second lead angle (β) are set in order that the main groove **(12)** and the deformed portion **(13)** of the line groove **(11)** may be directed symmetrically with respect to the tube axis directional line, this makes the manufacture of the heat transfer tube **(10)** relatively easy. In other words, if the heat transfer tube **(10)** is an electric welded tube, this enables a roll for marking the line grooves **(11)** in a material of which the heat transfer tube **(10)** is made to have symmetrical grooves and ridge angles. This facilitates the manufacture of the roll itself and torsion of the material at the time of marking is less likely to occur.

[0043] Further, if the secondary groove **(16)** is formed in the convexity **(15)** which forms the main groove **(12)**, as set forth in the ninth problem-solving means, this makes it possible to improve heat transfer efficiency by expanding a heat transfer area. Besides, it is possible to reduce the loss of pressure. Particularly, if the position, the depth, and the angle of the secondary groove are set to the foregoing predetermined values, as set forth in the tenth to twelfth problem-solving means, this further ensures the aforesaid effects.

[0044] Furthermore, also in the thirteenth to fifteenth problem-solving means, the secondary groove **(16)** is formed in the convexity **(15)** of the main groove **(12)**, thereby making it possible to provide not only improvement in heat transfer efficiency by heat transfer area expansion but also reduction in pressure loss. More specifically, even when the percentage of the deformed portion **(13)** in the line groove **(11)** is made relatively large, it is possible to suppress the loss of pressure when used as an evaporator. Further, when used as a condenser, it is possible to obtain an effect of scattering liquid refrigerant without fail. Accordingly, like the first to fourth problem-solving means, it is possible to improve the performance of heat exchangers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045]

Figure **1** is a partially broken-out front view of an inner grooved heat transfer tube according to an embodiment of the invention;

Figure **2** is a development of a part of the heat transfer tube, showing a shape of the line groove;

Figure **3** is an enlarged cross-sectional schematic view taken along the lines III-III of Figure 1;

Figure **4** is an enlarged view showing a cross-sectional shape of the line groove;

Figure **5** is a partially enlarged view of Figure **2**;

Figure **6** is a perspective view roughly showing a shape of the secondary groove;

Figure **7** is a graph showing the capability of condensation as the performance of a single heat exchanger;

Figure **8** is a graph showing the capability of evaporation as the performance of a single heat exchanger; and

Figure **9** is a graph showing the loss of evaporation pressure with respect to the amount of refrigerant circulation.

BEST MODE FOR CARRYING OUT THE INVENTION

[0046] Hereinafter, embodiments of the invention will be described in detail with reference to the Figures.

[0047] Figure **1** is a partially broken-out front view of an inner grooved heat transfer tube **(10)** of the present embodiment. As shown in the Figure, the heat transfer tube **(10)** has a U-bent shape, in other words the heat transfer tube **(10)** is a so-called hairpin tube. Formed in the internal surface of the heat transfer tube **(10)** are a great number of line grooves **(11)** oblique to the tube axis directional line. And, a plurality of such heat transfer tubes **(10)** and a plate fin (not shown) are combined together, and opening ends of the heat transfer tubes **(10)** are connected appropriately to form a plate-fin coil type heat exchanger.

[0048] Figure **2** shows the inner grooved heat transfer tube **(10)** with a part thereof developed. As shown in the Figure, each of the line grooves **(11)** formed in the internal surface of the heat transfer tube **(10)** comprises an alternative series of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) which is different from the first lead angle (α).

[0049] The first lead angle (α) and the second lead angle (β) are formed in opposite directions relative to a tube axis directional line. More specifically, the first lead angle (α) and the second lead angle (β) are formed at 18 degrees with respect to the tube axis directional line in opposite directions. Because of such arrangement, the main groove **(12)** and the deformed portion **(13)** of the line grooves are symmetrically directed with respect to the tube axis directional line.

[0050] The deformed portion **(13)** is formed at two positions in a single round of the line groove **(11).** In other words, in the state in which the heat transfer tube **(10)** is developed, there are provided two deformed portions **(13)** in a line groove **(11)** extending from one circumferential end to the other circumferential end. Further, it is set such that the percentage of the total length of the two deformed portions **(13)** to the length of a single round of the line groove **(11)** is 28%.

[0051] It is set such that the length of each deformed portion **(13)** is about 8.5 times the pitch (P) of the line groove **(11)**. And, by virtue of these set values, about twelve deformed portions **(13)** are so arranged as to intersect an extension of a single main groove **(12)** of the line groove **(11)**.

[0052] The heat transfer tube **(10)** is an electric welded tube, wherein a joint portion **(14)** and each deformed portion **(13)** of the heat transfer tube **(10)** are arranged at respective locations substantially equally dividing the direction of the circumference of the heat transfer tube **(10)**, in other words they are spaced about 120 degrees apart from each other, as shown in Figure **3** which is an enlarged cross-sectional schematic view taken along the lines III-III of Figure **1.**

[0053] On the other hand, Figure **4** is an enlarged view showing a cross section of the line groove **(11)**. The line groove **(11)** is defined between adjoining convexities **(15)**. The convexities **(15)** have the same cross-sectional shape for both the main groove **(12)** and the deformed portion **(13)**.

[0054] Referring to Figure **5** which is a partially enlarged view of Figure **2** and to Figure **6** which is a schematic perspective view of the convexity **(15)**, a plurality of intermittent recessed portions are formed in the convexity **(15)** constituting the main groove **(12).** And, each recessed portion forms a secondary groove **(16)**. As shown in Figure **2,** the secondary groove **(16)** is formed only at a substantially central portion of the convexity **(15)** of each main groove **(12)** and is spaced a predetermined distance apart from both ends of each deformed portion **(13)**. Further, the secondary groove **(16)** is illustrated in Figure **2** in which only the region where it is formed is simplified.

[0055] Further, the secondary groove **(16)** is formed, having a depth of about 0. 5 times the groove depth of the line groove **(11).** Furthermore, the secondary groove **(16)** is formed substantially along the tube axis directional line.

[0056] Next, the flow of a refrigerant in the heat transfer tube **(10)** will be described.

[0057] When the heat transfer tube **(10)** is used in a condenser, the refrigerant changes to liquid from a gas phase as it moves forward through the condenser and then flows along the main groove **(12)** of the line groove **(11).** And, since the first lead angle (α) formed between the main groove **(12)** and the tube axis directional line is set at 18 degrees, this ensures that the refrigerant flows helically and forms a thin film of liquid. Furthermore, in such a setting of angle, the loss of pressure will not increase excessively by the angle of helix becoming too great.

[0058] And, when the refrigerant flows in the main groove **(12)** and reaches the deformed portion **(13),** the refrigerant comes into collision with a side wall of the convexity **(15)** of the deformed portion **(13)** and is scattered from the inner peripheral surface of the heat transfer tube **(10)** toward the center because the first lead angle (α) of the main groove **(12)** differs from the second lead angle (β) of the deformed portion **(13).** The deformed portion **(13)** is formed at a lead angle of 18 degrees in an opposite direction to the main groove **(12).** The percentage of the total length of the two deformed portions **(13)** to the length of a single round of the line groove **(11)** is 28%. Further, the length of each deformed portion **(13)** is so set as to be about 8.5 times the pitch of the line groove **(11)**. As a result of such arrangements, about twelve deformed portions **(13)** are arranged so as to intersect an extension of a single main groove **(12)** of the line groove **(11)**. And, the refrigerant, which is flowing in the main groove **(12)**, climbs over about twelve deformed portions **(13)** (twelve ridges).

[0059] These conditions, such as the percentage of the total length of the deformed portions **(13)** to the length of a single round of the line groove **(11),** the lead angle (α) of the main groove **(12)** and the lead angle (β) of the deformed portion **(13),** the relationship between the length of each deformed portion **(13)** and the pitch (P) of the line groove **(11)**, the number of deformed portions **(13)** which intersect an extension of one main groove **(12)**, and other condition, are set as described above. Accordingly, the refrigerant, which flows along the main groove **(12)** and forms a thin film of liquid, is scattered definitely when climbing over the convexities **(15)** of the deformed portions **(13)** many times (twelve times in the present embodiment), so that formation of a thick layer of liquid is less likely to take place on the inner surface of the heat transfer tube **(10)**, thereby preventing the occurrence of an annular flow.

[0060] As described above, the action of scattering refrigerant can be obtained sufficiently because the percentage of the total length of the deformed portions to the length of a single round of the line groove **(11)** is not set too small (28%), the ratio of the length of each deformed portion to the pitch of the line groove is not set too small (8.5 times), and the number of deformed portion ridges that the refrigerant climbs over is not set too small (12 ridges).

[0061] Further, the joint portion **(14)** and the plural deformed portions **(13)** of the heat transfer tube **(10)** are arranged at respective locations substantially equally dividing the direction of the circumference of the heat transfer tube **(10).** As a result of such arrangement, liquid refrigerant flowing in the main groove **(12)** of the line groove **(11)** is scattered evenly at the joint portion **(14)** and the deformed portions **(13)** in the heat transfer tube **(10)**. Accordingly, the action of equal scattering of liquid refrigerant can be obtained throughout the entire inner surface of the heat transfer tube **(10)**.

[0062] Furthermore, when used as an evaporator the loss of pressure can be suppressed because the percentage of the total length of the deformed portions **(13)** to the length of a single round of the line groove **(11)** is not set too large (28%), the ratio of the length of each deformed portion **(13)** to the pitch of the line groove **(11)** is not set too large (8.5 times), and the number of the convexities of the deformed portions **(13)** that the refrigerant climbs over is not set too many (12 ridges) in the aforesaid configuration.

[0063] Further, since the secondary groove **(16)** is formed in the convexity **(15)** which forms the main groove **(12)**, this provides an increased heat transfer area and reduces the loss of pressure by causing, while creating a helical flow by a main groove **(12),** a part of the refrigerant to flow to the next main groove **(12)** by the secondary groove **(16).** Further, the location, the depth, and the directionality of the secondary groove **(16)** are specified. This ensures that the loss of pressure is suppressed while at the same time definitely securing the action of a helical flow.

[0064] As described above, in accordance with the present embodiment, it is possible to sufficiently scatter liquid refrigerant when the heat transfer tube **(10)** is used as a condenser. As a result, the efficiency of heat transfer can be improved. On the other hand, when used as an evaporator, the increase in pressure loss can be suppressed. In other words, it is sufficient for the heat transfer tube **(10)** to have, as its inner surface, an irregularly rugged surface, when it is intended just to improve the efficiency of heat transfer by upgrading the action of scattering refrigerant. However, in such a case, there is an increase in pressure loss. On the other hand, by the use of the heat transfer tube **(10)** of the present embodiment, it is possible to maintain well-balanced relationships between refrigerant scattering action and pressure loss by specifying the structure of the deformed portion **(13)** to the aforesaid structure. Accordingly, it becomes possible to upgrade the performance of heat exchangers.

[0065] It is arranged such that liquid refrigerant is scattered evenly at the joint portion **(14)** and the plural deformed portions **(13)** of the heat transfer tube **(10)**, which effectively contributes to reducing the loss of pressure. Further, in such a configuration, there is created an action of evenly dispersing liquid refrigerant and gas refrigerant, which effectively contributes to preventing the occurrence of a drift.

[0066] Further, the first lead angle (α) and the second lead angle (β) are each set at 18 degrees in opposite torsional directions relative to the tube axis directional line, which makes it possible to maintain highly well-balanced relationships between heat transfer efficiency and pressure loss by scattering refrigerant while securing a helical flow effect.

[0067] Particularly, since the first lead angle (α) and the second lead angle (β) are set in such a way that the main groove **(12)** and the deformed portion **(13)** of the line groove **(11)** are symmetrically directed with respect to the tube axis directional line, this makes the manufacture of the heat transfer tube **(10)** relatively easy. In other words, if the heat transfer tube **(10)** is an electric welded tube, this enables a roll for marking the line grooves **(11)** in a material of which the heat transfer tube **(10)** is made to have symmetrical grooves and ridge angles. This facilitates the manufacture of the roll itself and torsion of the material at the time of marking is less likely to occur.

[0068] Further, since the secondary grooves **(16)** are formed in the convexity **(15)** forming the main groove **(12)**, this makes it possible to provide improvements in heat transfer efficiency by heat transfer area expansion. Besides, it is possible to reduce the loss of pressure. Especially, setting the location, the depth, and the angle of the secondary groove to the foregoing predetermined values further ensures the effects. The provision of the secondary groove **(16)** is effective particularly for suppression of the loss of pressure, even when making the size of the deformed portion **(13)** relatively large.

[0069] Next, a more concrete exemplary embodiment of the heat transfer tube **(10)** will be described. All the values described in the foregoing embodiment are applicable to the heat transfer tube **(10)** according to the present embodiment. Additionally, the following values are set: the outside diameter (D) = 9.52 mm; the wall thickness (t) = 0.30 mm; the number of line grooves **(11)** = 60; the depth of the line groove **(11)** (i.e., the height of the convexity **(15)**) = 0.24 mm; the pitch (P) = about 6 degrees, and the ridge angle (γ) of the convexity **(15)** = 25 degrees.

[0070] With the above-mentioned values, the following heat transfer tubes were prepared, namely a heat transfer tube (a comparative example) in which the line groove **(11)** comprises only a helical main groove **(12)** of 18 degrees; a heat transfer tube (the first embodiment) in which the line groove **(11)** comprises a main groove **(12)** and a deformed portion **(13)**; and a heat transfer tube (the second embodiment) which further comprises a secondary groove **(16)** in the first embodiment. These different heat transfer tubes were used in heat exchangers for comparison. The results are graphically shown in Figures 7-9. In these Figures, the heat transfer tube as a comparative example in which the line groove **(11)** comprising only a helical main groove **(12)** is formed is indicated by long dashed short dashed line, the heat transfer tube of the first embodiment in which the line groove **(11)** comprises a main groove **(12)** and a deformed portion **(13)** is indicated by broken line, and the heat transfer tube of the second embodiment in which the line groove **(11)** is provided with a deformed portion **(13)** and a secondary groove **(16)** is indicated by solid line.

[0071] As can be seen from Figure **7**, both the heat transfer tube of the first embodiment and the heat transfer tube of the second embodiment are superior in condensation capability to the comparative example heat transfer tube. More specifically, when the front surface wind velocity of the heat exchanger is relatively slow, the heat transfer tube of the second embodiment is slightly superior in condensation capability to the heat transfer tube of the first embodiment. On the other hand, when the front surface wind velocity of the heat exchanger is relatively fast, the heat transfer tube of the first embodiment is slightly superior in condensation capability to the heat transfer tube of the second embodiment. However, from the results, these numeric values are in the range of error, and it is believed that the provision of the deformed portion **(13)** has a sufficient effect on the improvement in condensation capability, regardless of whether the secondary groove **(16)** is formed.

[0072] Further, as can be seen from Figure **8**, the heat transfer tube of the first embodiment is superior in evaporation capability to the comparative example heat transfer tube in every wind velocity range used for measurement, and the heat transfer tube of the second embodiment provides further improved evaporation capabilities. In other words, the provision of the secondary groove **(16)** has a great effect on reducing the loss of pressure, thereby achieving improvement in evaporation capability.

[0073] This is clear from Figure **9** showing variations in evaporation pressure loss with respect to the increase in refrigerant circulation amount. More specifically, the heat transfer tube of the first embodiment undergoes a greater pressure loss in comparison with the comparative example heat transfer tube. However, in the heat transfer tube of the second embodiment in which the line groove **(11)** is provided with deformed portions **(13)** and secondary grooves **(16)**, the loss of pressure is reduced to a smaller value in comparison with the comparative example. The secondary groove **(16)** plays an extremely important role of reducing the loss of pressure.

[0074] Further, the invention is not limited to the foregoing embodiments. The invention may be embodied in various other manners.

[0075] For example, in the above-mentioned embodiments, it is set such that the percentage of the length of the deformed portion **(13)** of the line groove **(11)** to the length of a single round of the line groove **(11)** is 28%. However, it may be set such that the percentage falls in the range between 10% and 35%. Such setting provides a sufficient scattering action (if the percentage is less than 10%, liquid refrigerant is less likely to be scattered in the condenser even when the deformed portion **(13)** is provided), and suppresses the loss of pressure (if the percentage is more than 35%, this results in an increase in the loss of pressure when used in the evaporator).

[0076] Further, the length of each deformed portion **(13)** is not limited to 8.5 times the pitch of the line groove **(11).** The length of each deformed portion **(13)** may be set so as to fall within the range between five times and fifteen times the pitch of the line groove **(11).** Such setting provides a sufficient scattering action (if the deformed portion length is less than five times the line groove pitch, liquid refrigerant is less likely to be scattered in the condenser even when the deformed portion **(13)** is provided), and suppresses the loss of pressure (if the deformed portion length is more than fifteen times the line groove pitch, this results in an increase in the loss of pressure when used in the evaporator).

[0077] Further, the number of the convexities **(15)** of the deformed portions **(13)** intersecting an extension of a single main groove **(12)** of the line groove **(11)** is not limited to twelve. If the number is set so as to fall in the range of from five to fifteen, this not only secures an effect of scattering refrigerant when used in a condenser but also effectively suppresses the loss of pressure when used in an evaporator.

[0078] Furthermore, the invention is not necessarily required to meet all the above-mentioned conditions.

For example, if at least one of the conditions, such as the percentage of the length of the deformed portion **(13)** to the length of a single round of the line groove **(11)**, is satisfied, this makes it possible to achieve better heat exchange performance than conventional heat transfer tubes.

[0079] Particularly, the provision of the secondary grooves **(16)** provides a higher effect of preventing the increase in pressure loss. Therefore, as long as the secondary grooves **(16)** are provided, the conditions, such as the percentage of the length of the deformed portion **(13)** to the length of a single round of the line groove **(11),** the relationship between the length of each deformed portion **(13)** and the pitch of the line groove **(11),** and the number of deformed portions **(13)** intersecting a single main groove **(12),** may fall outside the aforementioned ranges.

[0080] Furthermore, in the previous embodiments, it is arranged such that two deformed portions **(13)** are provided in a single round of the line groove **(11)**. However, the number of deformed portions **(13)** may be one or not less than 3. Even in such a case, it is preferable that the joint portion **(14)** and the deformed portion(s) **(13)** of the heat transfer tube **(10)** implemented by an electric welded tube are arranged at respective locations substantially equally dividing the direction of the circumference thereof. However, they are not necessarily arranged at equal intervals in cases including a case in which the number of deformed portions **(13)** is two, as in the previous embodiments.

[0081] Further, the first lead angle (α) and the second lead angle (β) are each set at 18 degrees in opposite torsional directions relative to the tube axis directional line. However, such a set angle may fall within the range between 5 degrees and 30 degrees. Furthermore, the first lead angle (α) and the second lead angle (β) may not be set in such a way that the main groove **(12)** and the deformed portion **(13)** are symmetrically directed with respect to the tube axis directional line. Additionally, the first lead angle (α) and the second lead angle (β) may not be set in opposite directions, in other words they may be set in the same direction, having different values.

[0082] Further, the depth of the secondary groove **(16)** is not necessarily 0.5 times larger than the depth of the line groove **(11)**. As long as the secondary groove **(16)** is formed having a depth of 0.25 to 0.75 times the depth of the line groove **(11)**, it is possible to obtain a helical flow effect while increasing the area of heat transfer. Finally, the secondary groove **(16)** is not necessarily formed along the tube axis directional line. Even if the secondary groove **(16)** is formed in such a way that it is inclined about five degrees toward both sides with respect to the tube axis directional line, this still effectively reduces the loss of pressure.

Claims

1. An inner grooved heat transfer tube comprising an inner peripheral surface in which are formed a plurality of line grooves **(11)**, said line groove **(11)** being made up of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) different from the first lead angle (α) which are successively formed,

   wherein the percentage of the length of said deformed portion **(13)** to the length of a single round of said line groove **(11)** is so set as to fall in the range of 10 to 35%.

2. An inner grooved heat transfer tube comprising an inner peripheral surface in which are formed a plurality of line grooves **(11),** said line groove **(11)** being made up of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) different from the first lead angle (α) which are successively formed,

   wherein the length of each said deformed portion **(13)** is so set as to fall in the range of five to fifteen times the pitch of said line groove **(11)**.

3. An inner grooved heat transfer tube comprising an inner peripheral surface in which are formed a plurality of line grooves **(11)**, said line groove **(11)** being made up of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) different from the first lead angle (α) which are successively formed,

   wherein from five to fifteen deformed portions **(13)** are so arranged as to intersect an extension of a single main groove **(12)**.

4. An inner grooved heat transfer tube in which a plurality of line grooves **(11)** are formed in an inner peripheral surface of an electric welded tube and said line groove **(11)** is made up of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) different from the first lead angle (α) which are successively formed,

   wherein a joint portion **(14)** of said electric welded tube and said deformed portion **(13)** are arranged at respective locations substantially equally dividing the direction of the circumference of said electric welded tube.

5. The inner grooved heat transfer tube of any one of claims 1-4, wherein said deformed portion **(13)** is formed at a plurality of positions in a single round of said line groove **(11)**.

6. The inner grooved heat transfer tube of any one of claims 1-4, wherein one of the first lead angle (α) and the second lead angle (β) is so set as to fall in

the range of 5 to 30 degrees in one torsional direction with respect to a tube axis directional line whereas the other of the first lead angle (α) and the second lead angle (β) is so set as to fall in the range of 5 to 30 degrees in the other torsional direction with respect to the tube axis directional line.

7. The inner grooved heat transfer tube of claim 6, wherein the first lead angle (α) and the second lead angle (β) are set in such a way that said main groove **(12)** and said deformed portion **(13)** of said line groove **(11)** are symmetrically directed with respect to the tube axis directional line.

8. The inner grooved heat transfer tube of claim 7, wherein the first lead angle (α) and the second lead angle (β) are each set at 18 degrees in opposite directions with respect to the tube axis directional line.

9. The inner grooved heat transfer tube of any one of claims 1-4, wherein a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming said main groove **(12)**.

10. The inner grooved heat transfer tube of claim 9, wherein said secondary groove **(16)** is formed centrally in said convexity **(15)** of said main groove **(12)** so as to be spaced a predetermined distance apart from said deformed portion **(13)**.

11. The inner grooved heat transfer tube of claim 9, wherein said secondary groove **(16)** is formed to a depth of 0.25 to 0.75 times the depth of said line groove **(11).**

12. The inner grooved heat transfer tube of claim 9, wherein said secondary groove **(16)** is formed substantially along the tube axis directional line.

13. An inner grooved heat transfer tube comprising an inner peripheral surface in which are formed a plurality of line grooves **(11),** said line groove **(11)** being made up of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) different from the first lead angle (α) which are successively formed,
wherein:

a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming said main groove **(12)**, and
said secondary groove **(16)** is formed centrally in said convexity **(15)** of said main groove **(12)** so as to be spaced a predetermined distance apart from said deformed portion **(13).**

14. An inner grooved heat transfer tube comprising an inner peripheral surface in which are formed a plurality of line grooves **(11),** said line groove **(11)** being made up of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) different from the first lead angle (α) which are successively formed,
wherein:

a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming said main groove **(12),** and
said secondary groove **(16)** is formed to a depth of 0.25 to 0.75 times the depth of said line groove **(11).**

15. An inner grooved heat transfer tube comprising an inner peripheral surface in which are formed a plurality of line grooves **(11),** said line groove **(11)** being made up of main grooves **(12)** formed at a first lead angle (α) and deformed portions **(13)** formed at a second lead angle (β) different from the first lead angle (α) which are successively formed,
wherein:

a secondary groove **(16)** made up of a plurality of intermittent recessed portions is formed in a convexity **(15)** forming said main groove **(12),** and
said secondary groove **(16)** is formed substantially along the tube axis directional line.

FIG. 1

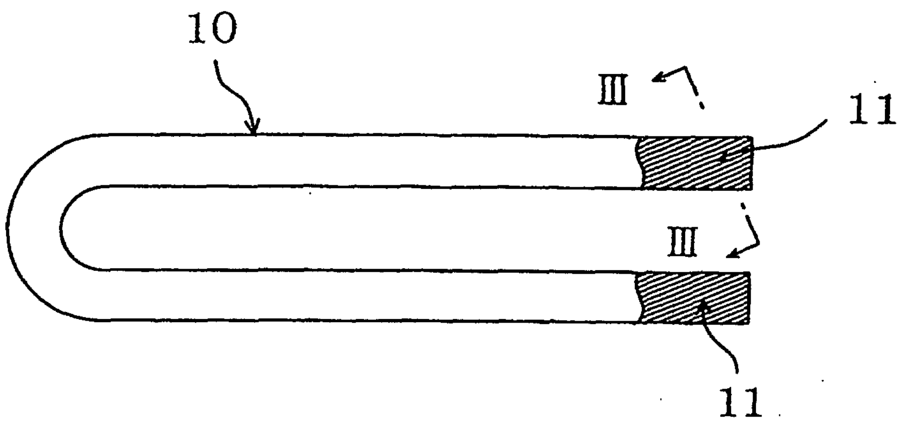


FIG. 2

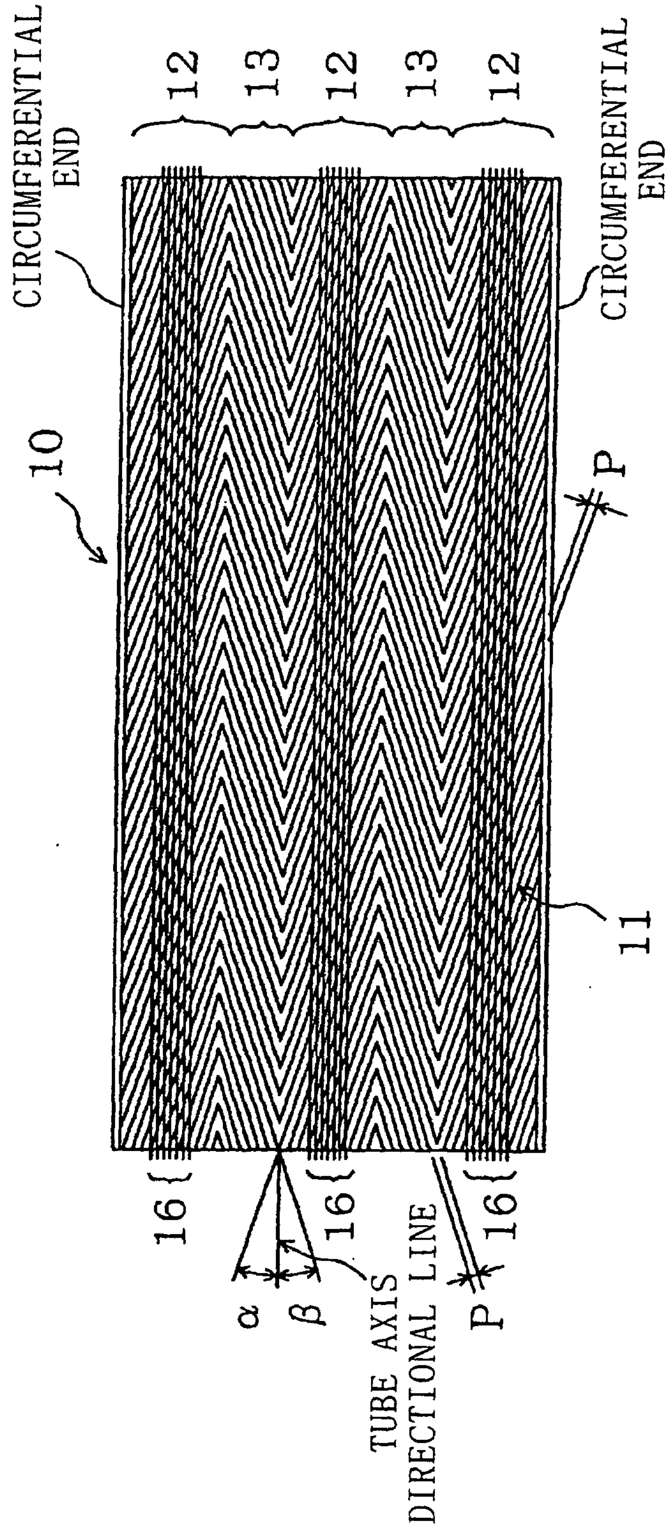

CIRCUMFERENTIAL END
12
13
12
13
12
CIRCUMFERENTIAL END
10
P
11
16
16
16
α
β
TUBE AXIS DIRECTIONAL LINE
P

FIG. 3

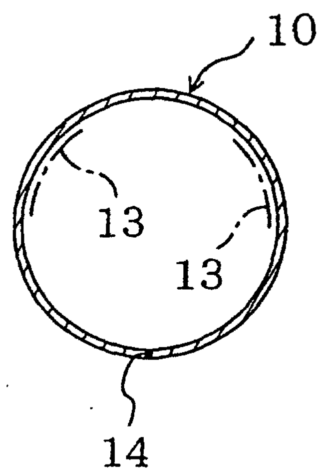


FIG. 4

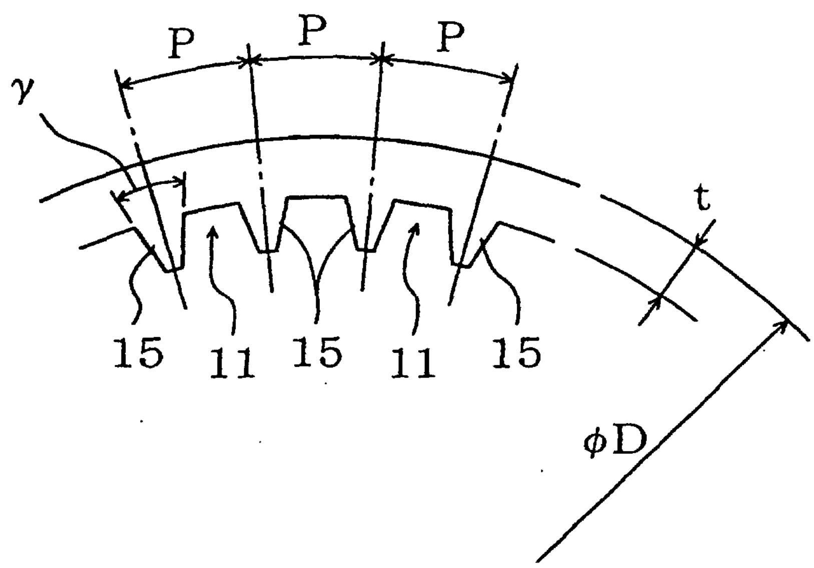


FIG. 5

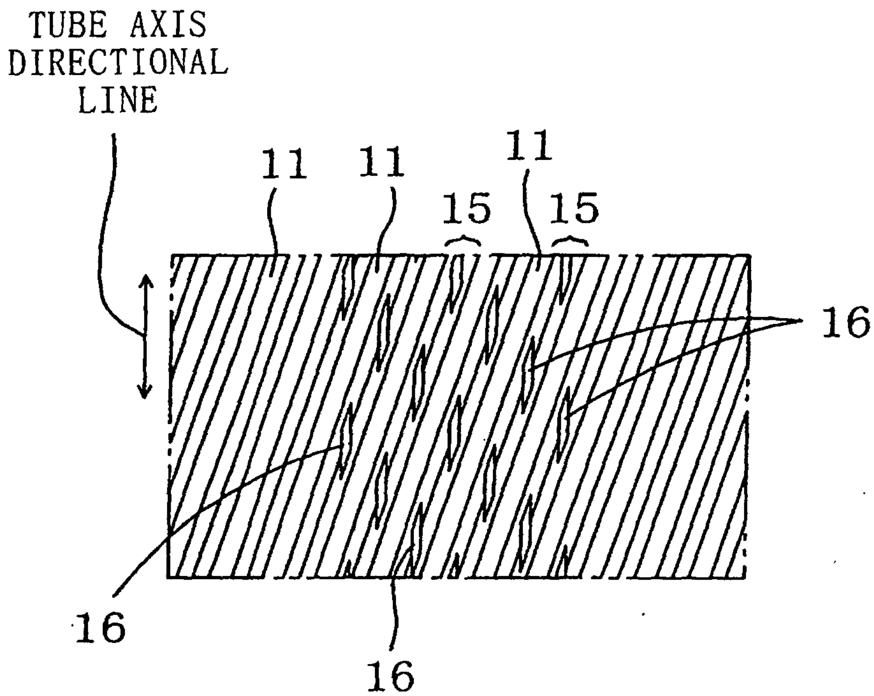


FIG. 6

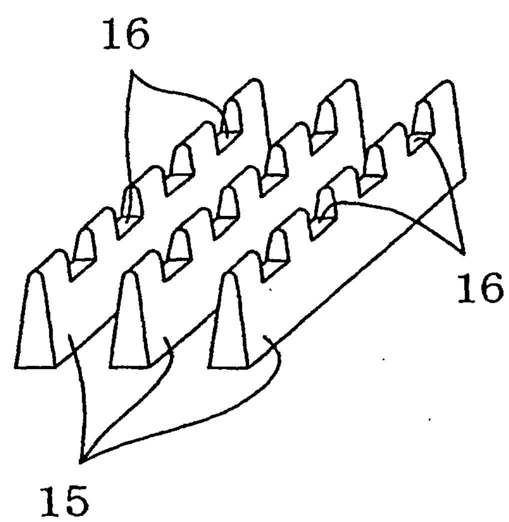
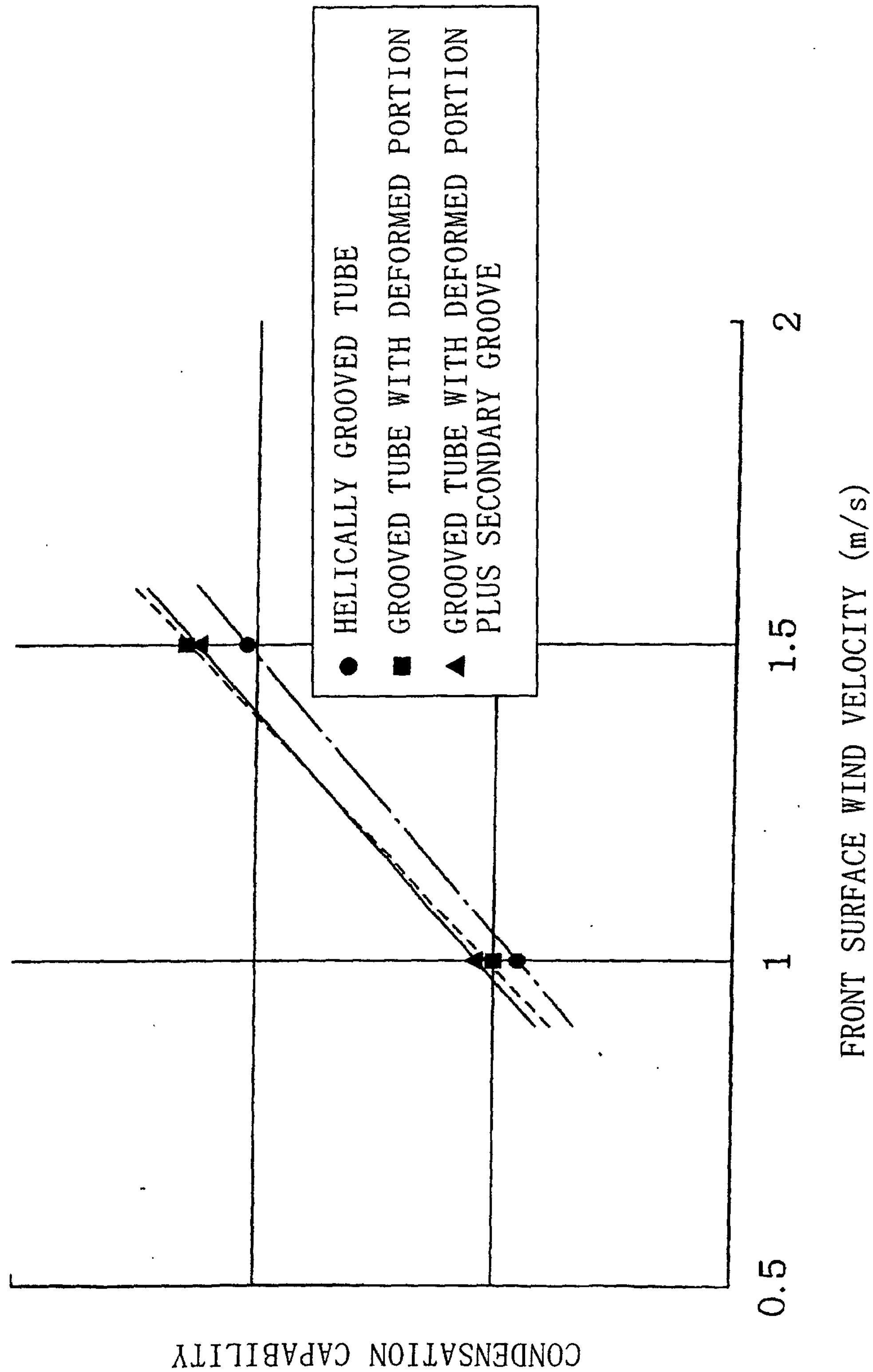


FIG. 7



● HELICALLY GROOVED TUBE
■ GROOVED TUBE WITH DEFORMED PORTION
▲ GROOVED TUBE WITH DEFORMED PORTION PLUS SECONDARY GROOVE
CONDENSATION CAPABILITY
FRONT SURFACE WIND VELOCITY (m/s)
0.5
1
1.5
2

FIG. 8

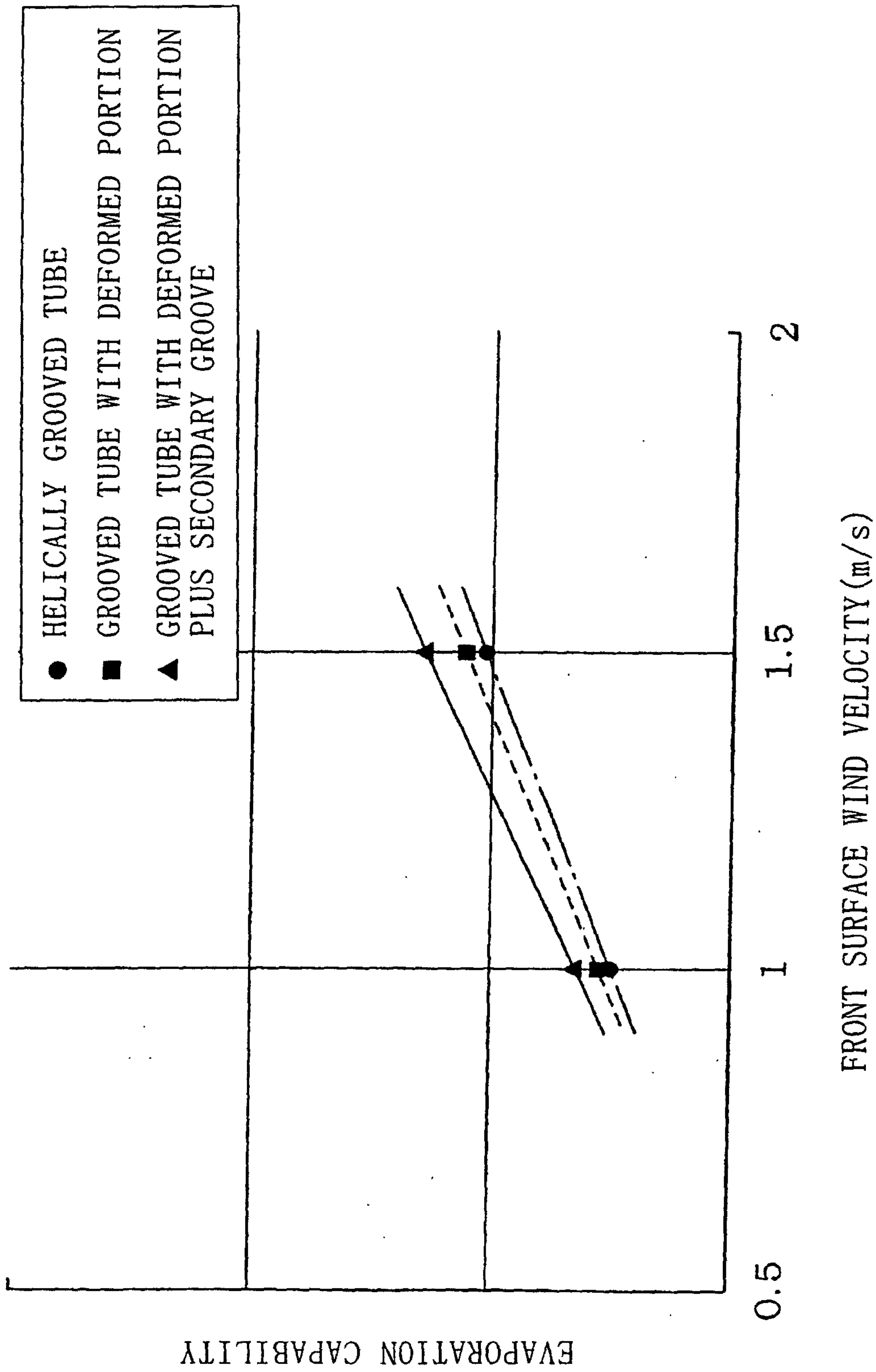
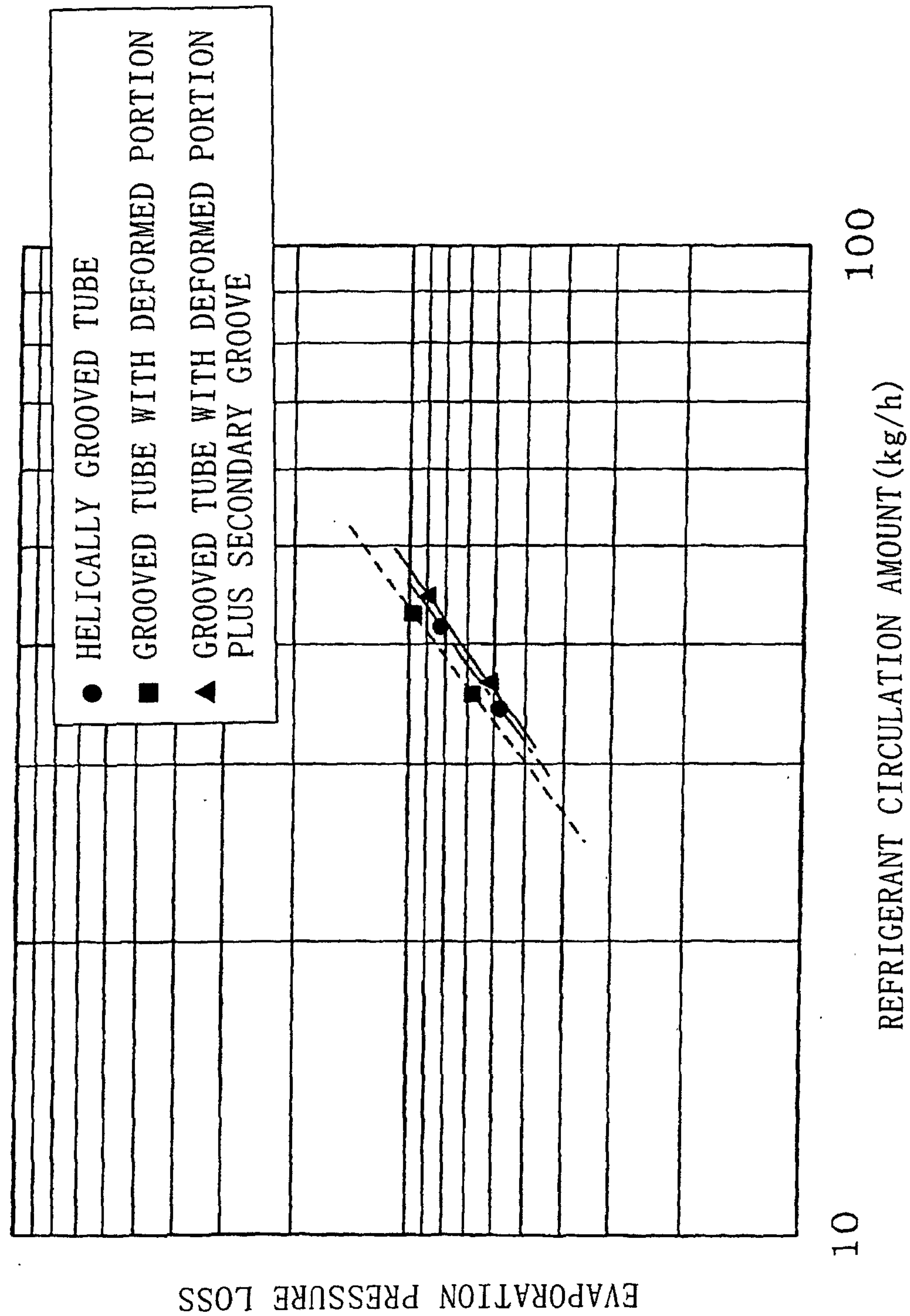

HELICALLY GROOVED TUBE
GROOVED TUBE WITH DEFORMED PORTION
GROOVED TUBE WITH DEFORMED PORTION PLUS SECONDARY GROOVE
EVAPORATION CAPABILITY
0.5
1
1.5
2
FRONT SURFACE WIND VELOCITY (m/s)

FIG. 9


● HELICALLY GROOVED TUBE
■ GROOVED TUBE WITH DEFORMED PORTION
▲ GROOVED TUBE WITH DEFORMED PORTION PLUS SECONDARY GROOVE
10
100
REFRIGERANT CIRCULATION AMOUNT (kg/h)
EVAPORATION PRESSURE LOSS

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP01/03019

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] F28F1/40

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[7] F28F1/40

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2001
Kokai Jitsuyo Shinan Koho 1971-2001 Jitsuyo Shinan Toroku Koho 1996-2001

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.
X	JP, 10-300379, A (Sumitomo Light Metal Industries, Ltd.), 13 November, 1998 (13.11.98) (Family: none)	1-15
X	JP, 11-108579, A (Kobe Steel, Ltd.), 23 April, 1999 (23.04.99) (Family: none)	1-9,11,12, 14,15
Y		10,13
A	JP, 9-318288, A (Sumitomo Light Metal Industries, Ltd.), 12 December, 1997 (12.12.97) (Family: none)	1-8
A	JP, 10-47880, A (Kobe Steel, Ltd.), 20 February, 1998 (20.02.98) (Family: none)	1-8
A	JP, 10-197184, A (Hitachi, Ltd.), 31 July, 1998 (31.07.98) (Family: none)	9-15
A	JP, 10-153360, A (Daikin Industries, Ltd.), 09 June, 1998 (09.06.98) (Family: none)	1-15

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

* Special categories of cited documents:
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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
03 July, 2001 (03.07.01)	10 July, 2001 (10.07.01)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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