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(54) **Finned heat transfer device and method for making same.**

(57) The invention provides a fin structure (3), and a method and apparatus for forming a fin structure (3), for application to the exterior of a tube (4) to form a heat transfer device effective in minimizing frost bridging in refrigeration operations. The fin structure is wound helically onto a refrigerant-carrying tube (4), and comprises an integrally formed chain of looped fins (3), each looped fin having a mounting flange (8,9) at each end thereof and comprising two vertical fin portions (10a,10b) extending respectively from each mounting flange (8,9) and connected together by a bridge portion (10c,10s); the method and apparatus for making the same includes a unitary stretch preforming process to reform thin lanced sheet metal fin stock (2) into the final looped fin shape (3) in a single forming step.

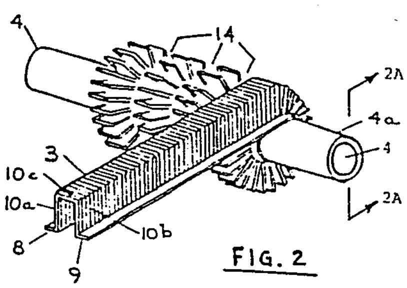

FIG. 2

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FINNED HEAT TRANSFER DEVICE AND METHOD FOR MAKING SAME

The present invention relates to an improved heat transfer fin for a finned heat transfer device, and to an improved process and apparatus for making and applying the same to a tube.

In refrigeration and air conditioning applications it is common to utilize a refrigerant-carrying tube as the means by which heat is removed from a chamber or areas to be cooled, and to flow air across the refrigerant-carrying tube to assist in transferring heat to or from the tube wall as imparted by the heat of vaporization or condensation of the refrigerant within the tube. In the applications just mentioned, the refrigerant carrying tubes usually constitute either a condenser or an evaporator.

The refrigerant has a significantly greater ability to transfer heat to the tube in which it is carried than does the air which flows across its exterior. As a result, it is an accepted practice in the refrigeration art to substantially increase the surface area provided on the outside, or airside, of the tube. Most often, the increased surface area is provided in the form of some sort of extended cooling surface or fin extending from the tube outer surface. Many types of finned tubing are commercially available for use in refrigerant-to-air heat exchangers (both evaporators and condensers). One type of extended surface fin is that known as a "spine fin", as disclosed in my prior U.S. Patent 2,983,300. The spine fin has a disadvantage in that it is mechanically weak and has a low resistance to bending and compressive forces. Therefore, to permit its practical utilization the spine fins are spaced very closely on the refrigerant tube. Other types of extended surface fins are disclosed for example in U.S. Patent No. 4,143,710, issued to LaPorte et al; these latter fins are complex geometric shapes, which are difficult to fabricate and have a higher degree of waste material in relation the heat transfer capacity provided.

These prior art fins have been used successfully for many years to increase the surface area of the air side of refrigerant carrying tubes in home refrigerators and air conditioning units, where the operating temperature of the air flowing across the air side of the tube is above the freezing point of water. However, they have not been so successful in environments where the air temperatures are below freezing, primarily for two reasons:

(1) because the moisture in the freezing air condenses out and forms a "frost bridge" between the closely spaced spine fins or portions of the geometric fins, which materially inhibits the air flow across and between the fins, and which in turn reduces the heat transfer capability; and

(2) if the fins are spaced far enough apart to prevent this frost bridging, the resulting structure is mechanically weak.

The present invention provides a new form of fin structure which facilitates a solution to the dual problems of frost bridging and insufficient mechanical strength.

Preferred forms of fin structure according to the invention greatly reduce frost bridging and will function in an environment where the convection air forced across the fins is below the freezing point of water, while at the same time maintaining sufficient mechanical strength to permit pragmatic utilization.

It is also an object of the present invention to provide a method of manufacturing a chain of looped fins in which the looped fin stock is applied to refrigerant-carrying tube stock immediately after its formation, so as to minimize the number of steps required in the manufacturing process.

According to the present invention there is provided a finned heat transfer device providing heat transfer to and from a tube for containing a heat transfer fluid and comprising an integrally formed chain of separate heat conductive fins wound helically around said tube so that the fins extend generally longitudinally of the tube, characterized in that:

the chain includes a pair of continuous mounting flanges extending outwards along opposed edges of the chain;

the chain is wound in tension around the tube so that the mounting flanges snugly engage the tube continuously therealong in heat transferring relation therewith; and

each fin comprises two transversely spaced leg members each extending outwardly from a respective mounting flange and connected at their outer ends by a bridge member of a minimum dimension for inhibition of frost bridging.

Also according to the invention there is provided a method of making a finned heat transfer device providing heat transfer to and from a tube for containing a heat transfer fluid comprising the steps of:

(a) providing an elongate strip of thermally conductive material;

and characterized by:

(b) transversely lancing said strip and forming it into an intermediate configuration having a pair of imperforate opposed side mounting flange portions interconnected by a lanced web portion;

(c) stretch preforming said intermediate configuration to reform the same into a subsequent configuration comprising an integrally formed chain of a plurality of looped fins between said mounting flanges, each of said fins comprising leg members extending outwardly from each of said mounting flanges and a bridge section connecting said leg members at the distal end of said leg members; and

(d) helically winding said chain under tension onto the exterior surface of a tube with the fins extending longitudinally of the tube.

Particular preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, wherein:

FIGURE 1 is a schematic perspective view of a first embodiment of apparatus of the invention for fabricating a looped fin structure and mounting it on a cylindrical tube, and also illustrates the corresponding method of the invention;

FIGURE 2 is a perspective view to a larger scale and showing the stage at which the looped fin structure is mounted on the tube;

FIGURE 2A is a cross section on the line 2A-2A in Figure 2;

FIGURE 2B is an end elevation of the assembled structure of Figure 2;

FIGURE 3A is a cross section through the looped fin structure of Figures 1 and 2, while Figures 3B through 3D are similar cross sections illustrating alternative structures of the invention;

FIGURE 4 is a plan view of lancing cutting work statior A of Figure 1, at which thin metal strip stock is lanced and changed to channel form;

FIGURE 5 is a side elevation of the work station A;

FIGURE 6 is a perspective view of the lanced and channel-formed thin metal strip after it emerges from work station A;

FIGURE 7 is a plan view of combined stretch forming and U-shape forming work station B of Figure 1;

FIGURES 7C, 7D and 7E are cross sections on the lines C-C, D-D and E-E of Figure 7 to show the progressive pre-forming of the lanced stock in the work station B;

FIGURE 8 is a side elevation of the work station B;

FIGURE 9 is a perspective view of the "looped fin" strip after it emerges from work station B;

FIGURE 10 is a perspective view of an alternative apparatus for forming the U-shape corresponding to station B of Figure 1, or station F of Figure 11, or station J of Figure 12;

FIGURE 11 is a perspective view of an alternative apparatus of the invention, and also illustrates a corresponding alternative method of the invention;

FIGURE 12 is a perspective view of a further alternative apparatus of the invention, and also illustrates a further alternative method of the invention;

FIGURE 13 is a perspective view of the flat lanced thin metal strip that emerges from station E of the apparatus of Figure 11, or station H of the apparatus of Figure 12;

FIGURE 14a shows the preferred angular relation (angle α) between a line through the lance roll centers and another line through the form roll centers;

FIGURE 14b shows the possible range of size of the angle α;

FIGURE 15 shows a transverse cross section of a loop fin of the invention and the manner in which if moisture is retained it is retained therein; and

FIGURE 16 shows a similar cross section of a prior art fin structure and the manner in which moisture is retained therein.

Description of the Preferred Embodiments

Referring particularly to Figure 1; the looped fin chain 3 of the present invention is fabricated in a unitary process employing apparatus that combines several work stations which cooperate to produce and apply the formed looped fin chain 3 immediately to a tube 4. In this embodiment a coil 1 of thin sheet metal 2 (fin stock), for example, aluminum of the 3003 or 1100 alloy type, is disposed horizontally around a series of work stations A through D arranged generally vertically over a table 15 and within the core of the coil 1, all of which rotate in the direction shown by arrow 16 around the tube 4, which is fed vertically longitudinally along its own axis at approximately the center of the coil 1 in the direction shown by arrow 5. An apparatus of this kind is described in U.S. Patent No. 3,134,166 issued to Venables.

The stock 2 is drawn from the coil 1 by its engagement between two lance cutter rolls 6 and 7 which comprise work station A and which cooperate in their rotation to pull the fin stock 2 therethrough. The equipment and processes for producing a series of slits through a moving thin metal strip are generally known, and in this embodiment the cutter rolls 6 and 7 are both equipped with radial cutting teeth 18 which intermesh as the fin stock 2 is fed therebetween, as is shown in more detail in Figure 5. The lance cutter 7 is equipped with flanges of selected vertical dimension and constitutes a "female" cutter, while the lance cutter 6 engages in the space between the flanges and constitutes a "male" cutter. The width of the fin stock 2 is greater than that of the lance cutters 6 and 7, so that it is formed into a shallow lanced generally channel shaped form shown in Figure 6, with the unlanced portions 8 and 9 of the fin stock extending perpendicularly to the lanced central portion, which has a series of closely spaced transverse fin preforms 10 formed therein by a series of parallel transverse slits 11 produced by the intermeshing teeth 18.

The lanced and channeled fin stock is then drawn between matched cooperating forming rolls 12 and 13 of selected dimension located at work station B, which stretch preform and final-U-form the fin preforms 10 to the required "looped fin" configuration. As discussed in more detail below, stretch preforming enables the lanced channel to be formed into the required deep U-form in a single processing step. This may be compared, for example, with the process described in U.S. Patent No. 4,224,984, issued to Sharp K. K., in which multiple forming steps are required to produce its shaped heat transfer fin.

The center line through the axes of the form rolls 12 and 13 of work station B is oriented at preselected angle α in relation to the center line through the axes of lance cutters 6 and 7 of work station A, with the result that the lanced channel 2 is placed in tension as it is pulled around the male forming roll 12 before being pulled through the interface of the two forming rolls. By placing work station B at this preselected angle in relation to work station A, and by operating the form rolls 12 and 13 of work station B at a slightly higher peripheral speed than the lance cutters 6 and 7 of station A, tension is applied to the unlanced mounting flange tips 8 and 9 between the stations A and B, and this tension urges the mounting flange tips to move toward each other in a direction to be disposed parallel to the corresponding peripheral face of form roll 12. This causes the stock to stretch and begin, prior to the point of its tangential contact with form roll 12, to form into a general U-shape which is finalized between the form rolls 12 and 13. The stretch preforming function and U-forming sequence is discussed in more detail below and is shown in Figures 7 to 9, and particularly in the progressive Figures 7C, 7D and 7E.

As the U-shaped fin stock emerges from work station B the product is now in its final configuration as shown in Figure 9, namely an integrally formed chain of looped fins separated by slits 11, each of which fins comprises a pair of generally vertical leg members 10a and 10b connected by a bridge portion 10c, and having relatively short mounting flanges 8 and 9 substantially parallel to the bridge portion 10c extending perpendicularly from each vertical leg member. The integral chain is then fed around guide roll 11 at work station C, preparatory to being helically wound under tension around the tube 4 at work station D in an inverted fashion, the base flanges 8 and 9 of the looped fins being applied in contact with the outer periphery 4a of the tube 4, the looped fins being disposed generally longitudinally of the length of the tube, and the bridge portions 10c of the looped fins being disposed generally circumferentially and outwardly in relation to the tube periphery 4a. As the chain 3 is wound on the tube the fins separate from one another with a progressively increasing circumferential spacing as the radial distance increases from surface 4a of the tube. The chain is wound so that the immediately adjacent portions of base flanges 8 and 9 of successive turns butt as closely as possible tightly against one another, so as to minimize the space between them. The tension applied to the chain 3 as it is wound around the tube assures adequate contact between the base flanges of the looped fin stock and the outer periphery of the tube stock which promotes mechanical contact providing a good heat transfer relationship between the looped fin and the tube. Guide roll 11 is disposed with its rotation axis at a selected angle B which permits the looped fin structure to approach the tube stock at the selected helix angle θ. For example, the angle θ is 19° when wrapping at a pitch of 1 looped fin per centimetre (2 1/2 looped fins per inch).

Referring now to Figures 2 and 3, in order to provide the most resistance to frost bridging, the looped fin chain 3 is made to preselected dimensions and is helically wound around the refrigerant tube 4 at a preselected pitch or distance between adjacent rows, so that the fins are spaced far enough apart in all three directions, namely radially from the mounting flange tips 8 and 9 to the bridge portion 10c, circumferentially between the generally parallel vertical members 10a and 10b and longitudinally between successive helical wraps (spaces 14 in Figures 2 and 2A). For example, when 0.018 cm (0.007 inch) thick aluminum strip 2 of 2.5 cm (1 inch) width is used for the fin stock, the lancing of such stock with slits 11 that are 2 cm (0.80 inch) long and spaced 0.076 cm (0.030 inch) apart results in unlanced mounting flange tips 8 and 9 each of 0.25 cm (0.100 inch) width. The resultant fins are very narrow, and this close spacing of the slits results in an increase in available air-contacting area of about 20% to 25%, because the height of the vertical edges thus generated when the fins are formed is added to the area of the top and bottom of the initial strip. This may be contrasted with prior art methods in which metal is removed during the forming process with consequent loss of available air-contacting area. In this example, when such a lanced channel is stretch preformed and worked into the final looped fin chain configuration 3, the bridge portion 10c will be approximately 0.5 cm (0.200 inch) wide, while the vertical members 10a and 10b will each be approximately 0.75 cm (0.300 inch) in length. In this example, the resultant element is to be used for a domestic refrigerator or air conditioner and the diameter of the tube 4 employed is 0.94 cm (0.375 inch), the fins being wound at a pitch of 2 per cm (5 per inch). In another example employed with the same size tube 4, but with the fins wound at a pitch of 3 per cm (8 per inch), the length of each flange 8 and 9 is 0.16 cm (0.0625 inch), the length of each leg member is 0.95 cm (0.375 inch), while the bridge member reduces to 0.32 cm (0.125 inch). The distance from the exterior surface 4a of the tube to the outermost part of the bridge member 10c can be characterized as about equal to the tube diameter. The distance 14 (Figures 2 and 2A) between the helical rows is generally controlled by the width to which the mounting flange tips 8 and 9 have been formed, the pitch of the rotation of fin stock 2 and the rate of longitudinal feed of the tube stock 4 being arranged so that the tips 8 and 9 of adjacent turns are contiguous to each other; the distance between adjacent helical rows 14 will therefore be nominally double the length of each connecting flange, namely 0.5 cm (0.200 inch) and 0.32 cm (0.125 inch) in these examples. These dimensions, which are exemplary only, have been found effective to prevent frost bridging with a refrigerant tube, while providing sufficient mechanical strength to permit pragmatic industrial use. Alternative materials for the fin stock are copper and steel.

In commercial practice a refrigerator or air conditioner heat exchanger assembly will comprise a predetermined length of the pipe 4 having a corresponding length of the chain 3 mounted thereon while straight and then bent to the required shape. The tensioned chain is fastened to the pipe at least at its two ends by any suitable means, such as mechanical clamps, welding, or a suitable glue or cement. The chain can also be retained under tension on the tube by fastening the butting mounting flanges 8 and 9 to one another by any of these means so as to prevent relative longitudinal movement between them, at least at the two ends of the chain, and perhaps also at intermediate points.

It is found that the lancing of the strip produces a small stretch of the unlanced side portions 8 and 9, but to an extent of less than about 0.5% of the strip length. A much greater extension is produced during the stretch forming between the form rolls 12 and 13, and the amount of tension that is required usually is such as to produce an extension of about 1% to 2.5% in length of the flanges 8 and 9, usually in the range 2% to 2.5%.

Another extension is produced by the wrapping tension of the order of 1% to 1.5% in length. The total extension produced by the process must of course be within the yield limit of the material, and for a hard aluminum (or alloy) this will be about 4%, while for softer aluminum (or alloy) this will be of the order of 5% to 6%. The extension produced by the lancing is due to the spreading action of the cutting blades, irrespective of their speed, and appropriate forming and wrapping tensions may be maintained by adjusting the respective drive to feed out the required smaller length of lanced fin stock than would be required in the absence of tension, or by utilizing tension sensing devices controlling variable speed mechanisms between the lance cutter drive, the forming roll drive, and the tube rotating drive.

It is preferred that the fin leg members 10a and 10b be essentially parallel to each other as shown in Figure 3A to provide optimum distance between fin members to minimize frost bridging. The bridge portion 10c is optimum when it is essentially flat and substantially parallel to the mounting flange tips 8 and 9, again as shown in Figure 3A, but variations to this optimum configuration can be tolerated with only slight degradation in performance, as measured by resistance to frost bridging promotion and resistance to deformation during fabrication and application. For example, a slight radius 10r at the intersections of portions 10a and 10b with portion 10c, as shown in Figure 3A, will have only a slight effect in reducing resistance to frost bridging. Extending that radius to one half the distance between portions 10a and 10b to form an arch shaped bridge section 10s, as shown in Figure 3B, will also permit only slightly increased frost bridging. Fin members in which the portions 10a, 10b and 10c merge smoothly with one another to constitute a general semi-circle (not shown) would also be effective in preventing frost bridging. When the looped fins each comprise geometric shapes such as shown in Figures 3C and 3D, of a dimension approaching that of fin pitch spacing 14, the propensity to form frost bridging begins to increase. In addition, geometric shapes such as shown in Figures 3C and 3D offer less resistance to deformation. Decreasing the length of cross portion 10c as shown in Figures 3C and 15 decreases the resistance to frost bridging, and when cross portion 10c is reduced to zero to form an inverted V-shape as shown in Figure 16, which is the structure disclosed in U.S. Patent No. 4,184,544, issued to Ullmer, the resulting vertex tips provide a nucleating site or focal point which promotes frost formation, which in turn accelerates frost bridging, and shapes with such highly reduced bridge portions 10c are accordingly not effective in minimizing frost bridging. Decreasing the length of portion 10c, for example as shown in Figure 3C by utilizing angular leg portions 10d, and as shown Figure 3D by inclining the leg portions 10a and 10b toward one another, results in shapes which have a greater tendency to hold defrost water by surface energy within the shortened dimension. The water is held in the form of a meniscus 17, which shields the fin legs and bridge portion and thereby reduces the effective fin surface area available for effective heat transfer as shown by the cross-hatched area of Figures 15 and 16. In practice the dimension of the bridge 10c, or the equivalent dimension between the leg portions is correlated with the fin pitch, or the number of turns per unit length of tube. For refrigerator and air conditioning applications the practical maximum is about 3 turns per cm (about 8 turns per inch). Thus, with the particular examples described, it is preferred that the approximate minimum dimension of portion 10c to prevent such water meniscus retention and frost bridging should not be reduced below 0.32 cm (0.125 inch). Such dimensions, of course, are exemplary only.

Stretch preforming as employed in this invention is a novel process whereby the lanced channel produced from the strip 2 is progressively formed into an approximate U-shape in a single forming step as the lanced channel progresses around the circumference of male roll 12 in its approach to the tangent contact point with female roll 13. Stretch preforming is accomplished in this embodiment by providing the two rolls with complementary shoulders 12s and 13s between which the flange tips 8 and 9 pass and are gripped thereby, and by operating the work station B form rolls 12 and 13 at approximately 1% to 2.5% higher peripheral speed than the rate at which the lanced channel is fed out of the lance cutters 6 and 7 at work station A. This tension acts to progressively bend the lanced center strips 10 into a sufficiently preformed U-shape appropriate for entering the intermesh of form rolls 12 and 13 where the final U-shape is produced at their point of tangency. A distance C D (Figure 8) between the centers of the form rolls 12 and 13 is selected which provides sufficient contact friction of the rolls to mounting flange tips 8 and 9 to provide sufficient tension in preforming the U-shape, but which allows adequate slippage to prevent exceeding the elastic limit of the selected fin material.

An alternative method of providing adequate frictional drive without exceeding the elastic limit of the selected fin material involves spring loading the bearing support of either roll 12 or 13 to provide a floating or variable center distance C D, such spring loading accommodating minor variations in the thickness of the fin stock 2 and the imperforate unlanced mounting flange tips 8 and 9. A second alternative to accomplish the same result can be the provision of a slip clutch in the drive shaft of the drive to the form rolls 12 and 13. Other methods generally known in the art could also be employed to provide the needed tension and, if needed, slippage of the generally U-shaped fin stock as it passes through form rolls 12 and 13.

Figure 10 shows an alternative arrangement of forming rolls for employment at station B to provide final U-forming after stretch preforming, in which the single female form roll 13 is replaced by two angular rolls 13a, 13b, which respectively engage the side portions 10a and 10b, and back up roll 13c which engages cross portion 10c and maintains it flat.

Reference to Figures 7 and 14a shows that, when the angle α is approximately 90°, stretch preforming of the lanced channel is accomplished through an arc γ of the circumference of the forming roll 12, the preforming being substantially completed at cross section E-E, before the actual intermesh between the rolls. Where α is approximately 90°, the stretch preforming is accomplished through an arc γ of approximately 85° when proper tension is maintained. The stretch preforming of the lanced channel commences at a leading angle ω (Figure 14a) prior to intersection of the lanced channel with a line 20 through the axis of forming roll 12 at cross section C-C, which line 20 is parallel to a line 19 through the axes of lance cutters 6 and 7. By the time the lanced channel has progressed around male form roll 12 to point C-C, the imperforate unlanced mounting flange tips 8 and 9 are already upwardly disposed, as shown in Figure 7C. As the lanced channel continues to be pulled around the forming roll 12 the flange tips 8 and 9 move continuously toward one another, as illustrated by sections D-D and E-E, so that final forming of the lanced channel may be accomplished by a single pass through the intermesh of rolls 12 and 13. In the preferred arrangement, as shown in Figure 14a, when angle α is approximately 90°, stretch preforming occurs throughout an arc of γ of between 80° and 90°, preferably approximately 85°, and the corresponding leading angle ω is between 20° and 30°, with a preferred value of approximately 25°. Figure 14b shows that angle α may range from a minimum 60° to a maximum of at least 180° when the two lines are parallel so as to accommodate work stations in other arrangements besides that described above.

Alternative machinery arrangements for different methods of making the looped fin chain 3 of the present invention are disclosed in Figures 11 and 12. In the apparatus of Figure 11 both the rotational and the directional motions are provided to the refrigerant tubing 4. In this apparatus and with this method there are only two work stations, E and F, before the looped fin 3 is helically applied to the tubing 4. This provides more working or maintenance space between work stations. The required helix approach angle θ with respect to the tubing 4, determined by the rotational and longitudinal feed rate of tube 4, is provided by appropriate angular placement of the stations E and F with respect to the plane of travel of the tubing 4. It would also be possible to maintain all axes of rotation in parallel orientation by adding an idler roll oriented to the helix angle such as the idler roll 11 of station C in the apparatus of Figure 1.

Another alternative apparatus and method of making the loop fin of the present invention is shown in Figure 12. In this embodiment, a lance station H performs only the lancing function and all final loop fin forming is performed at a forming station J. Lance station H is similar to that described earlier in relation to Figures 4 and 5 except that the flanges have been removed from "female" lance cutter 7. Since the width of the fin stock 2 is greater than the width of the lance cutters 6 and 7, it emerges from lance station H as a flat center lanced strip with fin preforms 10a, the imperforate unlanced portions 8a and 9a extending on each side of the slits 11, as shown in Figure 13.

An idler roll 20 at station I is located in such a manner as to guide the flat center lanced stock and cause it to approach form roll 12 at the required approach angle α prior to contact therewith. As the stock contacts form roll 12 it is stretch preformed around an arc γ of the roll until stretch preforming is complete prior to the intermesh between the two rolls, where any remaining final U-forming is accomplished, and the stock emerges in the loop fin configuration 3 as shown in Figure 9.

In the apparatus of Figure 12 it will be seen that the employment of an idler roll 20 allows parallel alignment of the lance and form stations. Idler roll 20 aids in the critical step of stretch preforming in the process depicted in Figure 12 by providing an adequate angle of approach α. As with the apparatus of Figure 1, the tension on imperforate unlanced portions 8a and 9a is provided by operating the cooperating forming rolls 12 and 13 or work station J at a slightly higher peripheral speed than the cooperating lance cutters 6 and 7 of work station H. For example, sufficient stretch preforming occurs if work station J is operated at a peripheral speed approximately 1% greater than work station H. Work station J functions and operates essentially the same as work station B of Figure 1 to provide the final looped fin configuration 3. After exiting from work station J the looped fin chain 3 is wound onto the tubing 4 at work station K, with the helix angle controlled by the longitudinal speed of the tube 4 along the line of arrow 5 and the rate of rotation of tube 4 as it travels in that direction.

The above description and drawings should not be construed as limiting the ways in which this invention may be practiced, but should be inclusive of many other variations that do not depart from the broad scope and intent of the invention.

CLAIMS

1. A finned heat transfer device providing heat transfer to and from a tube (4) for containing a heat transfer fluid and comprising an integrally formed chain of separate heat conductive fins wound helically around said tube so that the fins extend generally longitudinally of the tube, characterized in that:

the chain includes a pair of mounting flanges (8, 9) continuously extending outwards along opposed edges of the chain;

the chain (3) is wound in tension around the tube (4) so that the mounting flanges snugly engage the tube continuously therealong in heat transferring relation therewith; and

each fin comprises two transversely spaced leg members (10a and 10b) each extending outwardly from a respective mounting flange (8, 9) and connected at their outer ends by a bridge member (10c) of a minimum dimension for inhibition of frost bridging.

2. A heat transfer device as claimed in claim 1, characterized in that the chain is wound upon the tube in sufficient tension to produce an elongation of about 1% to 1.5% in length of the mounting flanges (8, 9).

3. A heat transfer device as claimed in claim 1 or 2, characterized in that the chain (3) is stretch formed by stretching a transversely lanced strip (Figure 13) as it is passed between mating form rollers (12, 13) which convert the

lanced portion of the strip in a single pass to a general U-shape comprising said leg members (10a, 10b) and said bridge member (10c).

4. A heat transfer device as claimed in claim 3, characterized in that the chain is stretch formed with the application of tension such as to produce an elongation of about 1% to 2.5% in length of the mounting flanges.

5. A heat transfer device as claimed in any one of claims 1 to 4, characterized in that said leg members (10a, 10b) are substantially perpendicular to said tube (4).

6. A heat transfer device as claimed in any one of claims 1 to 5, characterized in that the chain (3) of fins is made of aluminum.

7. A heat transfer device as claimed in any one of claims 1 to 6, characterized in that said bridge member (10c) is substantially straight and substantially parallel to the outer surface (4a) of said tube (4).

8. A heat transfer device as claimed in any one of claims 1 to 6, characterized in that said bridge member (10c) is radiused at the points of intersection (10r, Figure 3A) between said leg members (10a, 10b) and said bridge member (10c).

9. A heat transfer device as claimed in any one of claims

1 to 6, characterized in that said bridge member (10c) is connected to the said leg members (10a, 10b) by intermediate portions (10d) to comprise a substantially arched shape (Figure 3B).

10. A heat transfer device as claimed in any one of claims 1 to 6, characterized in that the said bridge member (10s) is smoothly merged with said leg members (10c, 10b) in a generally semi-circled fashion.

11. A heat transfer device as claimed in any one of claims 1 to 10, characterized in that said leg members (10a, 10b) and said mounting flanges (8, 9) are provided in preselected dimensions in relation to each other to substantially reduce frost bridging between adjacent fins.

12. A heat transfer device as claimed in claim 11, characterized in that the distance between the two leg members (10a, 10b) of a fin is substantially the same as the distance between the helical rows of said fins wrapped on said tube (4).

13. A heat transfer device as claimed in claim 11, characterized in that the distance from the exterior surface (4a) of the tube (4) to the outermost part of the bridge member (10c) is about equal to the diameter of the tube (4).

14. A method of making a finned heat transfer device providing heat transfer to and from a tube (4) for containing a

heat transfer fluid comprising the steps of:

(a) provided an elongate strip (2) of thermally conductive material;

and characterized by:

(b) transversely lancing (11) said strip and forming it into an intermediate configuration having a pair of imperforate opposed side mounting flange portions (8, 9) interconnected by a lanced web portion (10);

(c) stretch preforming said intermediate configuration to reform the same into a subsequent configuration comprising an integrally formed chain (3) of a plurality of looped fins (10) between said mounting flanges, each of said fins comprising leg members (10a, 10b) extending outwardly from each of said mounting flanges and a bridge section (10c) connecting said leg members at the distal end of said leg members; and

(d) helically winding said chain (3) under tension onto the exterior surface of a tube (4) with the fins (10) extending longitudinally of the tube (4).

15. A method according to claim 14, characterized in that the chain is stretch formed with the application of tension such as to produce an elongation of about 1% to 2.5% in length of the mounting flanges.

16. A method according to claim 15, characterized in that the chain is wound upon the tube in sufficient tension to produce an elongation of about 1% to 1.5% in length of the mounting flanges (8, 9).

17. A method according to any one of claims 14 to 16, characterized in that said intermediate configuration comprises a shallow generally channeled cross section.

18. A method according to any one of claims 14 to 17, characterized in that said lanced web portion is reformed from said intermediate configuration of said subsequent configuration by stretch preforming comprising pulling said strip around a male forming roll adapted to initially contact the center of said lanced web portion, whereby tension on the imperforate side mounting flange portions and the pressure of the forming roll on the center of said web portion gradually reforms said web portion to conform to said male forming roll.

19. A method according to claim 18, characterized in that said stretch preforming occurs as the center of said lanced web portion contacts said male forming roll through an arc between 80° and 90°.

20. A method according to claim 19, characterized in that said arc is 85°.

21. A method according to any one of claims 18 to 20, characterized in that said male forming roll comprises a central forming section and a shoulder on each side of said central forming section, and said strip is pulled around said male forming roll by being gripped between said shoulders and complementary shoulders on a female forming roll.

22. A method as claimed in any one of claims 14 to 21, characterized in that the distance between the two leg members (10a, 10b) of each fin is substantially the same as the distance between the helical rows of said fins wrapped on said tube (4).

23. A method as claimed in claim 28, characterized in that the distance from the exterior surface (4a) of the tube (4) to the outermost part of the bridge member (10c) is about equal to the diameter of the tube (4).

24. A heat transfer device comprising a tube for the conveyance of a heat transfer fluid and a heat transfer structure wound helically under tension about the tube, said heat transfer structure comprising a chain of heat conductive elements each comprising two leg portions spaced transversely of the chain and interconnected at their (outer) ends remote from the tube by a bridge portion, and two continuous mounting flanges to which the opposite (inner) ends of the two leg portions are respectively connected and which are in intimate contact with the outer surface of the tube.

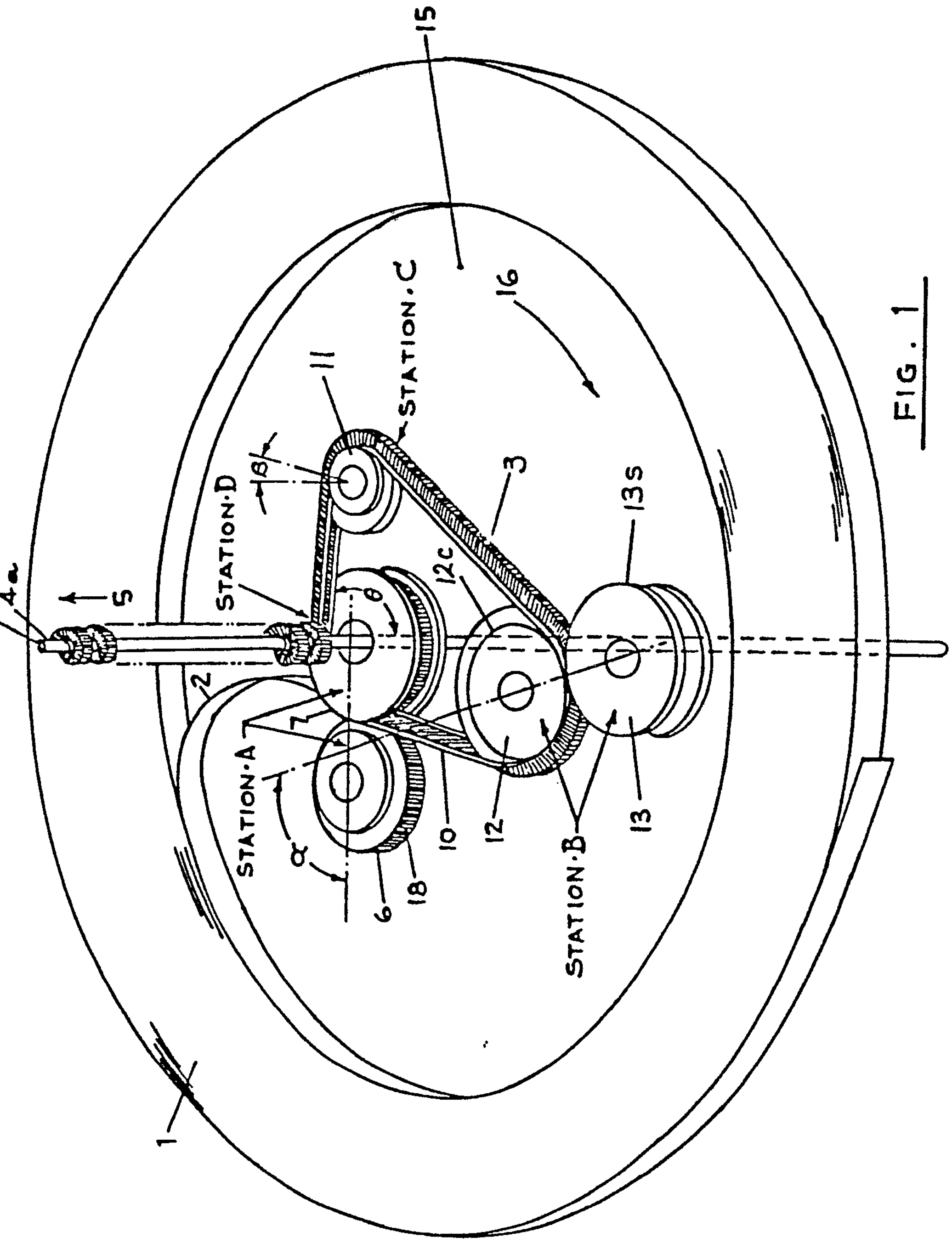

15
16
STATION·C
11
STATION·D
3
13S
4
4a
S
2
12c
7
STATION·A
α
6
18
10
12
STATION·B
13
1

FIG. 1

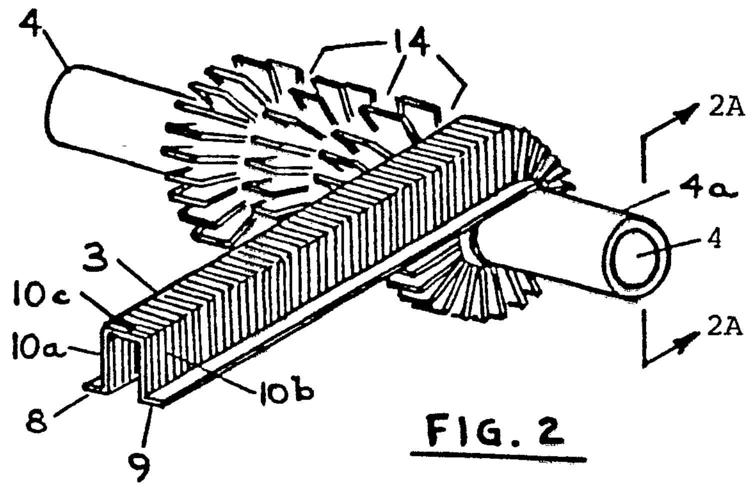


FIG. 2

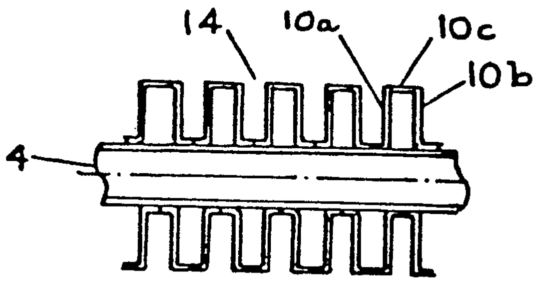


FIG. 2A

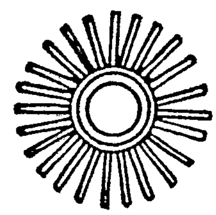


FIG. 2B

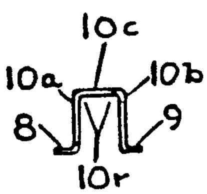


FIG.3A

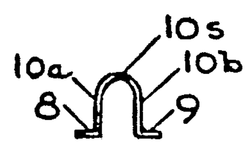


FIG.3B

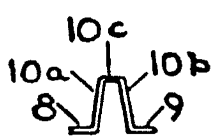


FIG.3D

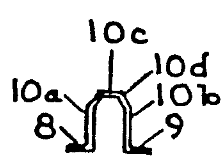


FIG.3C

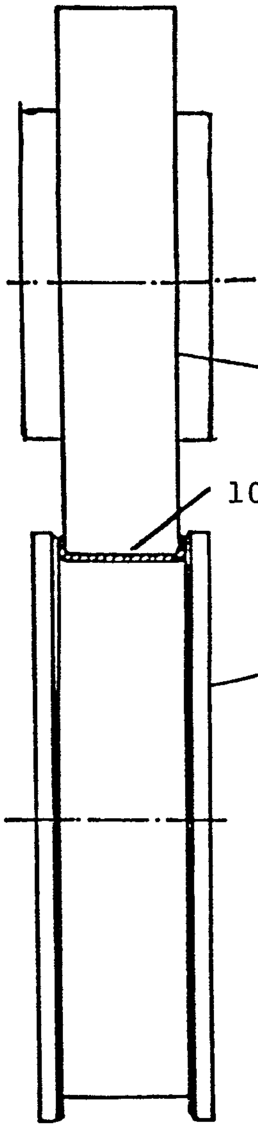


FIG. 4

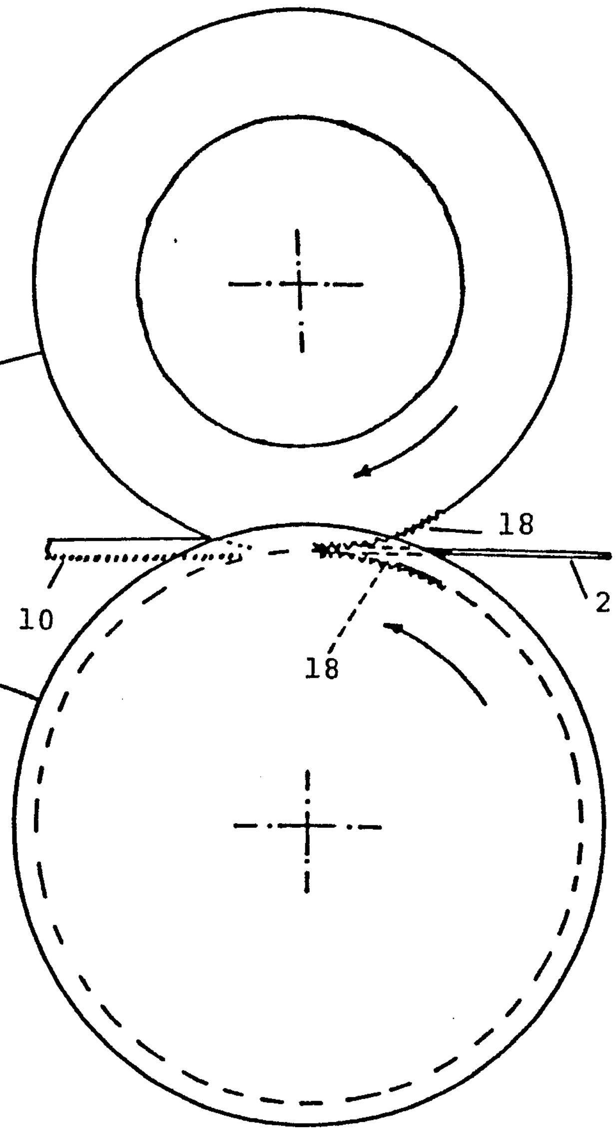


FIG. 5

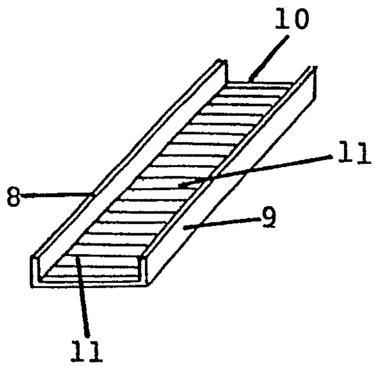


FIG. 6

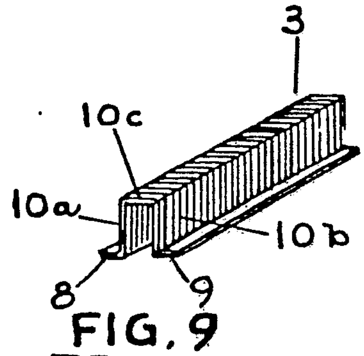


FIG. 9

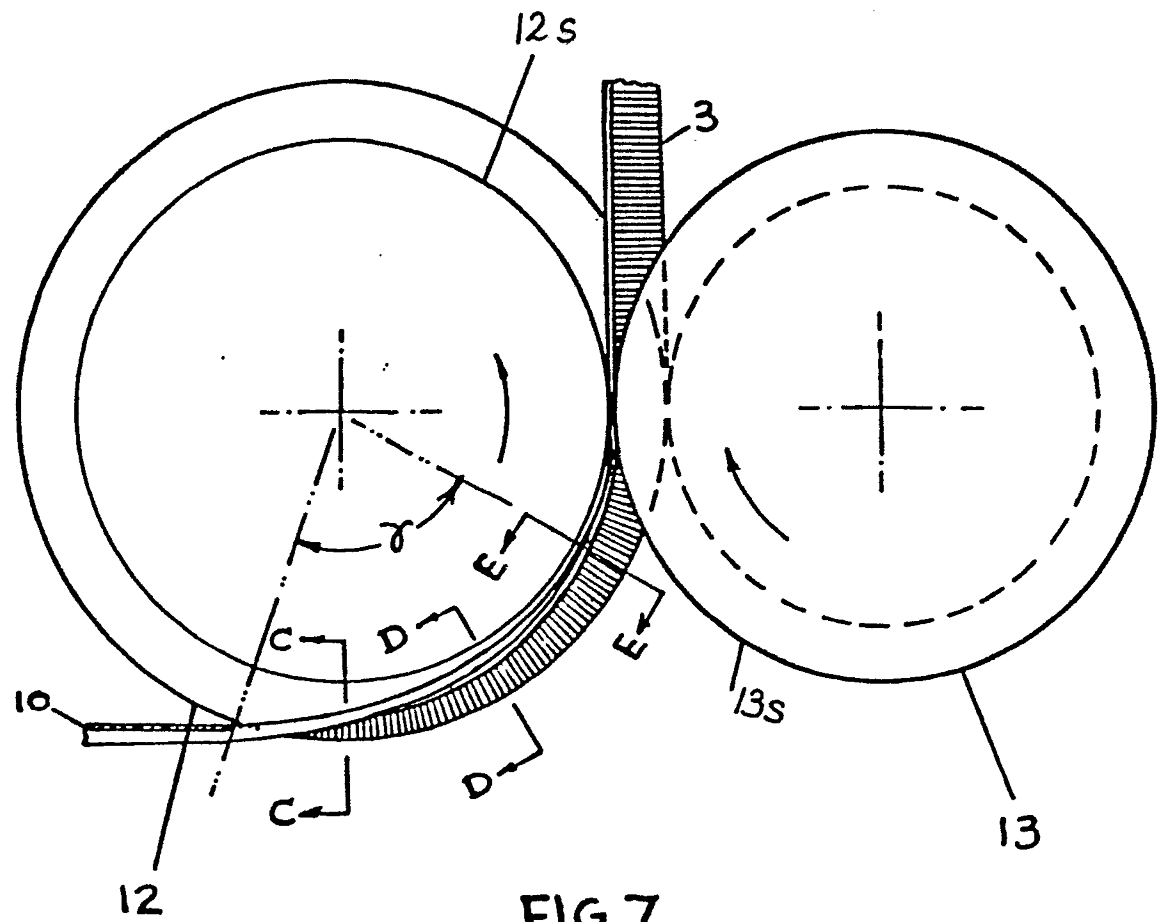


FIG.7

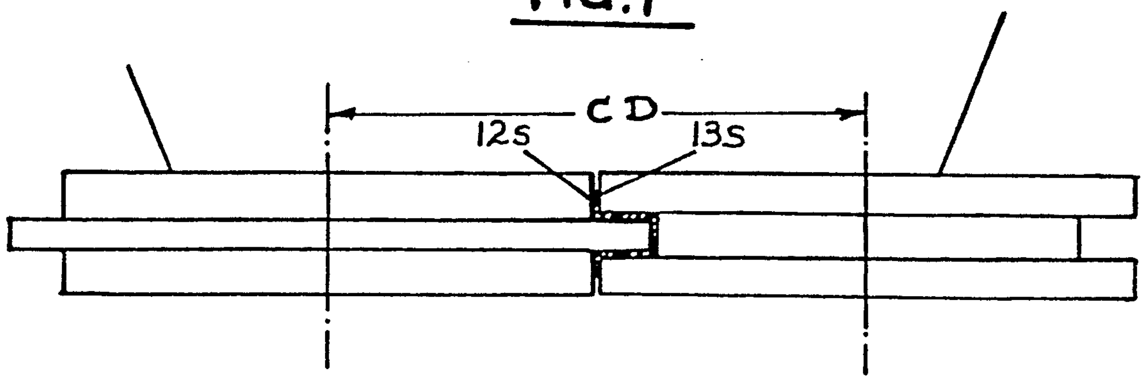
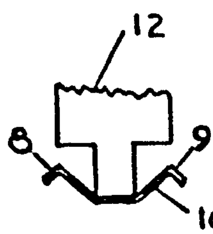


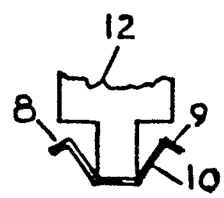
FIG.8

FIG. 7C



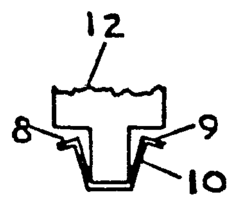
SECTION C·C

FIG. 7D



SECTION D·D

FIG. 7E



SECTION E·E

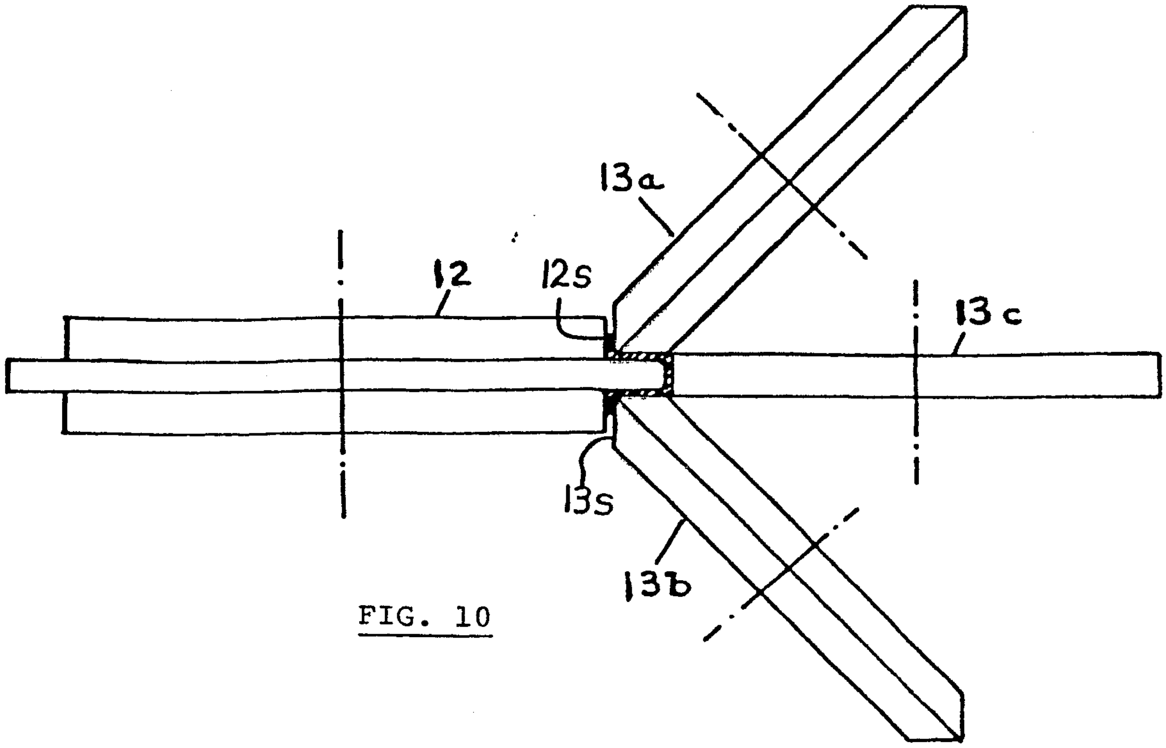


FIG. 10

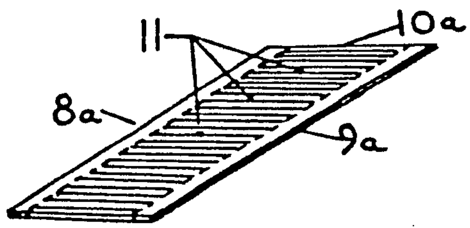


FIG. 13

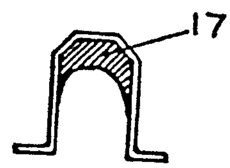


FIG. 15

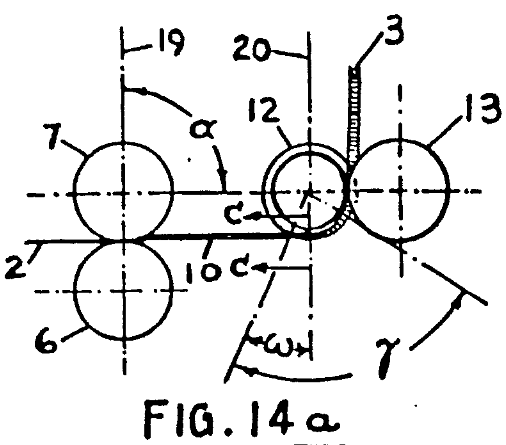


FIG. 14a

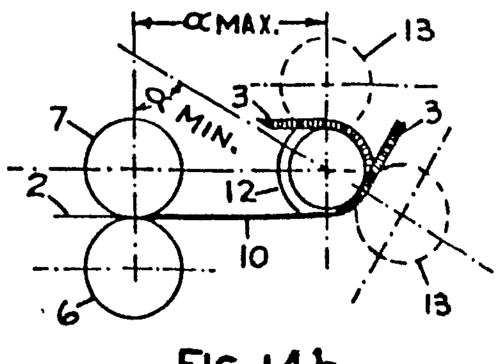


FIG. 14b

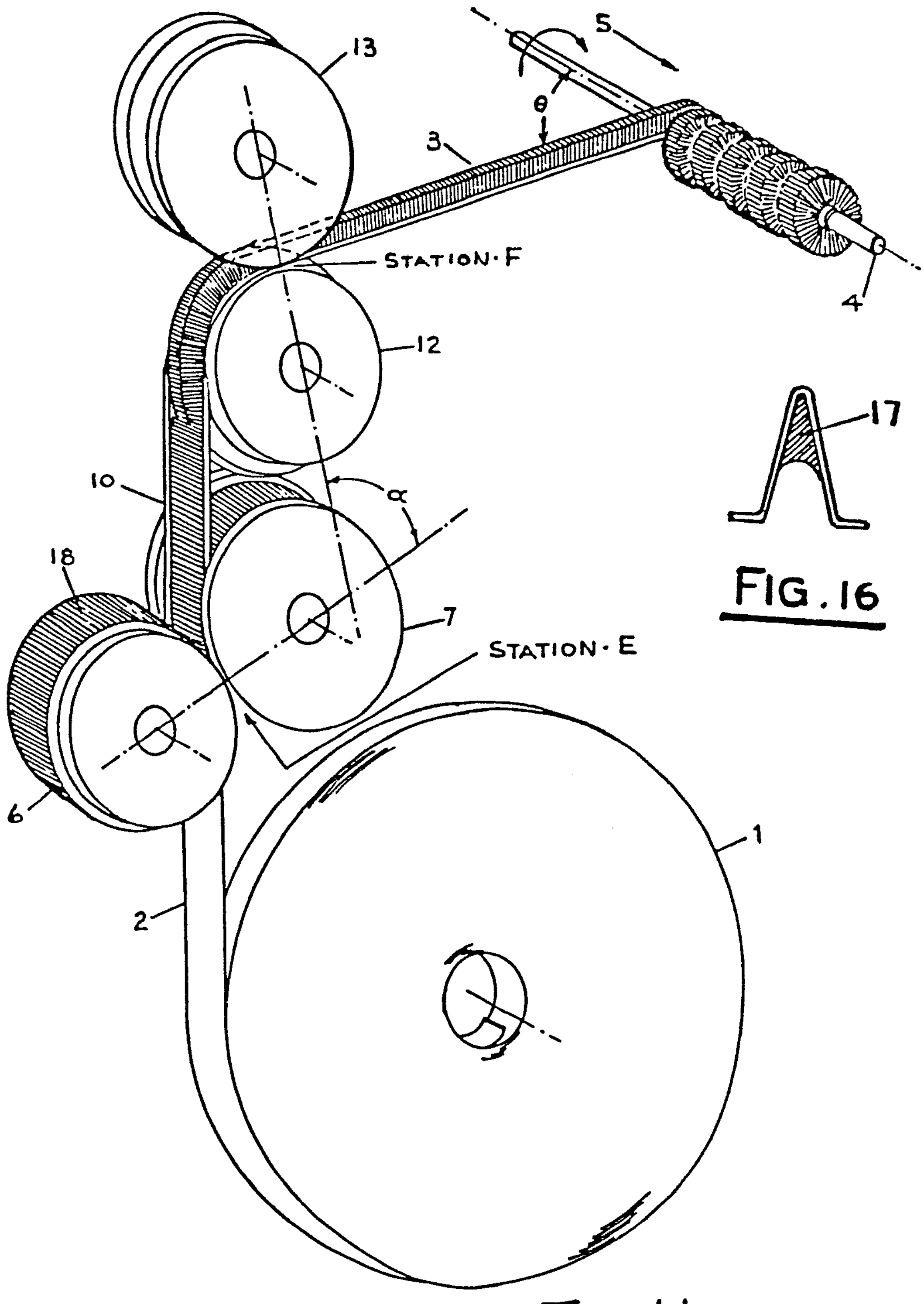


FIG. 16

FIG. 11

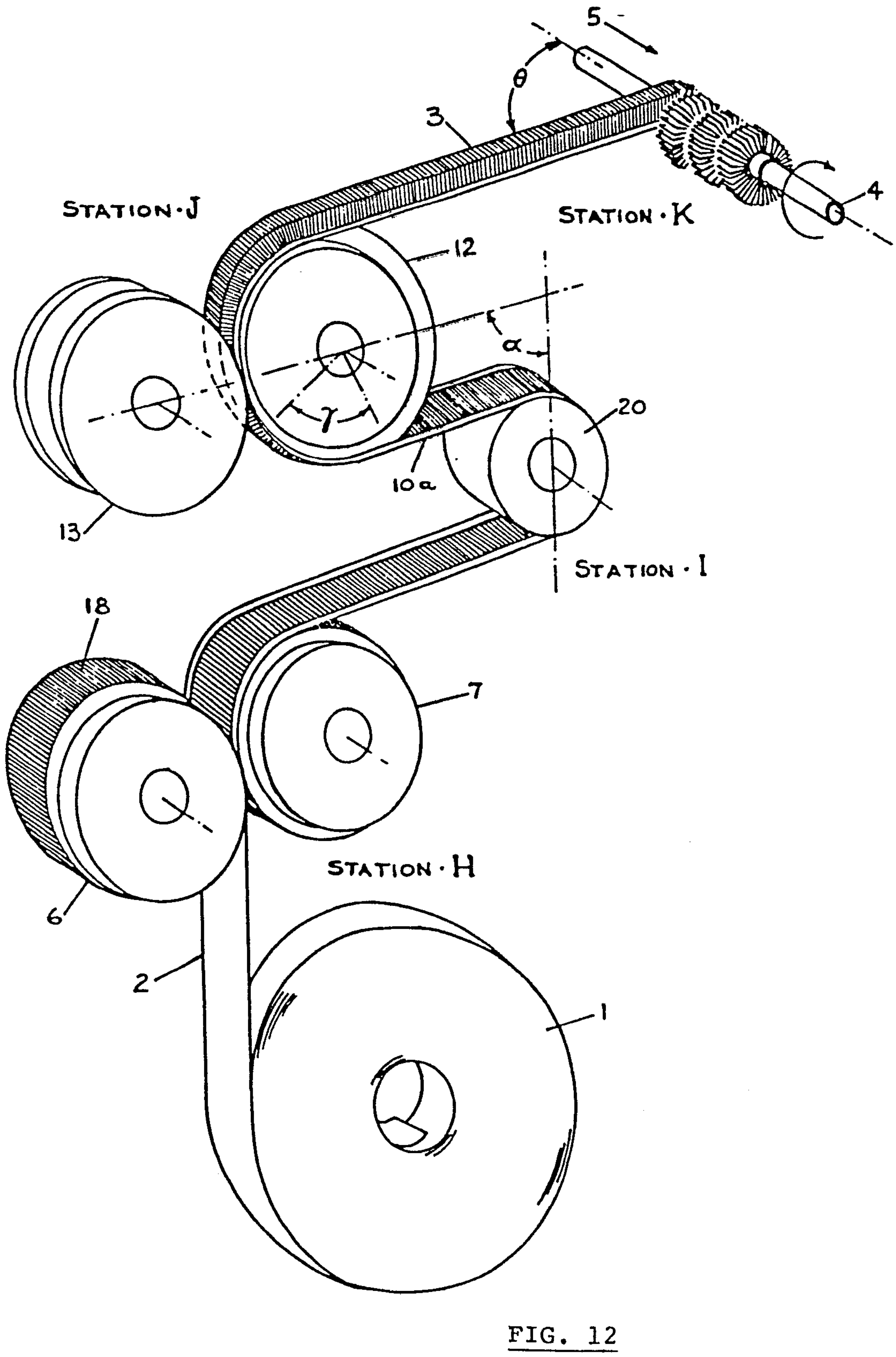

5
θ
3
4
STATION · J
STATION · K
12
α
γ
20
10a
13
STATION · I
18
7
STATION · H
6
2
1

FIG. 12

European Patent Office

0214784

Application number

EUROPEAN SEARCH REPORT

EP 86 30 6379

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	US-A-2 196 186 (BERG et al.) * Page 2, column 1, lines 71-75; column 2, lines 1-22; figure 10 * ---	1,5-7, 11,14, 17	F 28 F 1/36 B 21 C 37/26
Y	DE-C-1 108 716 (GENERAL ELECTRIC) * Column 1, lines 50-52; column 2, lines 25-35; column 3, lines 18-30; column 4, lines 3-34; figures 1-4 * ---	1,5-7, 11	
Y	US-A-3 288 209 (LINCOLN) * Column 2, lines 9-27; figures 1-3 * ---	14,17	
Y	US-A-3 005 253 (VENABLES) * Column 4, lines 22-63; column 8, lines 10-62; claim 1; figures 5,10,11,14 *	14,17, 24	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)** F 28 F B 21 C B 21 D
A		2-4,15 ,16	

D,Y	US-A-4 184 544 (ULLMER) * Abstract; figures 2,3,6 * --- -/-	24	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27-11-1986	HOERNELL, L.H.

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P : intermediate document

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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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0214784

Application number

European Patent Office

EUROPEAN SEARCH REPORT

EP 86 30 6379

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	FR-A-1 288 056 (SCHILD) * Figures 4-6,12 * ---	18,21	
A	US-A-3 201 847 (RASMUSSEN) * Figures 7a-7d,9a-9e * ---	18,21	
D,A	US-A-3 134 166 (VENABLES) ---		
A	FR-A-2 352 599 (CARRIER CORP.) ---		
A	US-A-3 550 235 (JARVIS et al.) ---		
A	GB-A- 800 265 (DAVIES) -----		TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

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