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54 **Heat Exchangers.**

57 A heat exchanger tube (Figure 9) has an insert to increase the heat exchange surface area made from a strip of metal foil, which is first transversely corrugated, is then modified to provide an outward bulge on each flank of each corrugation, and is then rolled transversely to a generally star shape and inserted axially into the tube. A series of such inserts are posted into the tube one after the other.

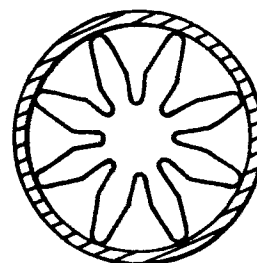


Fig.9

HEAT EXCHANGERS

This invention relates to heat exchangers in which tubes, intended for the flow of a first fluid of a heat exchange pair, are provided with an internal fin of somewhat star shape to provide an extended surface for heat exchange. U.S. Patent 3831247 discloses such an arrangement.

The object of the invention is to provide an improved manufacturing method to produce such heat exchange tubes.

According to the invention, a method of making a heat exchange tube comprises the steps of taking an elongated strip of metal foil, corrugating the foil transversely by passing the foil through a pair of continuously running meshed gears, modifying the corrugation shape so that the flanks of the corrugations are non-planar, cutting the strip into lengths, and forming the flat lengths into circular shape by bending them about an axis parallel to the length of the corrugations, and posting the so formed corrugations successively into the heat exchange tubes.

The invention is more particularly described with reference to the accompanying drawings wherein:-

Figure 1 is a somewhat diagrammatic plan view of an apparatus for these purposes;

Figure 2 is a side elevation of the same;

Figure 3 and Figure 4 are enlarged fragmentary views of the apparatus;

Figure 5 shows the corrugated strip;

Figure 6 shows the modified shape corrugated strip;

Figures 7 to 9 shows successive stages in the conversion of the flat strip to the circular shape for posting into a tube; and

Figure 10 shows a modification.

Referring to the drawings and particularly Figures 1 and 2, metal foil in strip form is fed from a spool head through tensioning rolls 12. A motor 14 via an angle gear set 16 drives primary forming rolls 18 which are generally in the form of a pair of meshed gears. The strip is transversely corrugated at 22 as it leaves the gears 18, and a stop and cutter device 24 is used to separate the strip into short sections 26 here shown as fed forwardly on conveyor 28 to rolling and insertion means. These comprises a guide 30, further explained hereinafter, a ram 32 for displacing the sections in the length of the corrugations into and along the guide 30, and heat exchange tube 34 into which the sections are inserted.

The primary form of the corrugation produced by the meshed gears 18 is shown in Figure 5 and comprises planar flanks connected by arcuate portions. Such formation can be rolled to star shape,

somewhat as later described herein, but is found to be unsatisfactory because the shape so produced is (relatively) fixed in diameter. It is a feature of the invention that the shape is modified so as to make the flanks non-planar, and so that as the rolling step proceeds, each "petal" of the somewhat daisy shape is outwardly bulged, as seen for example in Figure 8. This has the advantage that each "petal" becomes slightly resilient in a radial direction and this helps to ensure good contact between the strip and the tube which is essential for heat transfer.

The corrugation modifying or perfecting mechanism comprises a die in the form of a blade which is located below a strip guide or bed and the latter is reciprocated in the direction of the arrows A Figure 2 to lift the strip clear of the die 40 or lower the strip via lever 42 pivoted at 44 and having a cam follower 46 at its opposite end, to engage a corrugation with the die.

The perfecting mechanism further comprises a former 48 here shown as comprising a grooved roller or wheel, journaled on a carriage 50 which is crank 52 driven from the motor 14 and extends across the upper surface of the corrugated strip 22.

The strip is supported by the bed 41, having a suitable gap through which die 40 can project. When the carriage 50 moves to the left in Figure 3, cam surface 54 displaces the bed and vice versa. The onward progress of the strip at that point is halted because the movement of the carriage is synchronised with the forming gears 18. When strip is being bent into a new corrugation by the gears 18 the roll 48 is perfecting a corrugation, and as the formed corrugation leaves the gears the perfected corrugation leaves the roller and die. However a slight closing together or opening of the corrugations longitudinally can provide tolerance. At the same time as the die enters the corrugation, the roller 48 moves across the corrugation and the foil trapped between the roller and die is modified in shape according to the profiles of the die and roller. The chain dot line 56 Figure 3 shows the final position of the roller before the carriage is withdrawn by the crank 52, allowing the bed to return and the strip to be fed onwardly in the arrow B direction.

The bed may comprise an upper plate 41 slotted to allow the die 40 project through when the part 41 is in a lower plane, but located above the upper edge of die 40 at other times, i.e. when the strip is to be fed forwardly. Plate 41 may be connected to plate 43 by interposed springs 45, as plate 45 is contacted by the lever 42 via a further roller 47.

The illustrated mechanism for cutting the formed and perfected strip into sections comprises a stop bar 60 and a cutter blade 62 fixed in angular relation to one another and also to an operating member 64 (see particularly Figure 4). The stop 60 may be temporarily located in the path of the corrugated strip 22 as shown in Figure 2, and when contacted by the strip (as illustrated) member 64 may be actuated to displace the stop bar out of the plane of movement of the strip 22 and at the same time move the cutter 62 through that plane hence severing a portion of strip. As the parts 24 are returned to the Figure 2 position, the severed length of strip is fed onwardly and the remaining portion of strip continues to travel until stop 64 is again contacted when a repeat cycle can be initiated.

The stop and cutter mechanism 24 can be operated manually, or if the apparatus is to be made completely automatic, the stop bar 64 can incorporate a microswitch or can be associated with a proximity switch or counting mechanism causing the automatic operation at appropriate points in the feed of the strip 22.

The guide 30 tapers along its length from a maximum width at the end 70 which is sufficient to allow a severed but generally planar length of the strip to be inserted therein by movement of the ram 32 in the direction of the arrow C Figure 1. At the opposite end 72 the guide is generally circular in cross section and approximately equal or slightly smaller in internal diameter to the heat exchange tube 34 into which the insert is to be posted. Between the ends 70 and 72 the guide tapers in width and preferably increases in dimension transverse to the width being of generally elliptical cross section at all points for example as illustrated in Figures 7 and 8. As the strip is displaced along the guide it acts on the strip to take it out of a generally planar shape into a rolled configuration. The effect is to cause the corrugated strip to roll transverse from the Figure 7 position via the Figure 8 position to the Figure 9 position.

The actual displacement in the direction of the arrow C can continue to displace the insert into the heat exchange tube 34. Such displacement can continue until an insert contacts a previously entered insert, by using carefully adjusted pressure applied to the ram. However it is preferred to use a system of proximity switches indicated generally by the reference numerals 80 which detect the presence of an insert in the heat exchange tube 34 and cause termination of ram movement, or alternatively, a microprocessor programme connected to the valves controlling the supply of fluid to the ram and causing its displacement with proximity switches 82 sensing ram position, so that each successive ram stroke is shorter than the previous

one by a length approximately equal to one insert or less than one insert until a new exchange tube is positioned, when the cycle starts again with a full ram stroke followed again by successively shorter ram strokes.

Figures 9 and 10 illustrate the variation which is possible in the same size of heat exchange tube 34 using different lengths of the corrugated and perfected strip rolled into respectively 8 and 14 pointed stars which provide different amounts of additional heat exchange surface with minimal difference in pressure drop or flow restriction within the tube, and possibly both formed in one and the same apparatus or at least generally similar apparatus merely programmed so that the strip is cut off into greater lengths, for example by making the spacing along the length of the strip between the stop bar and the cutter blade adjustable: but a slightly different guide might be necessary, having a suitably larger inlet end, and it may be found useful to modify the perfecting step to crimp the corrugations more closely.

Metal foil of suitable thinness for the purposes of the present invention is likely to have an inherent resilience when formed into the shape illustrated particularly in Figures 8 to 10, and this results in the star or daisy shape of Figure 9 attempting to unroll to the Figure 8 configuration and itself inherently creating good metal-to-metal contact for heat flow between the insert and tube wall but the bulged petal shape makes each petal radially resilient additionally to or instead of relying on any uncurling action. Nevertheless it is preferred to employ a solder dipping, brazing or other fixing step subsequently since efficiency for heat exchange depends upon heat conduction between the insert and tube wall.

It is found that apparatus according to Figure 1 can operate substantially automatically without supervision and run continuously providing a high output of inserts; the apparatus can if desired be duplicated and driven from a single motor 14. The restriction on output rate is largely due to the time taken to post the inserts into the heat exchange tube. For this purpose it may be desirable in some circumstances to omit the cutting step and to take the formed and perfected strip in continuous lengths and recoil it, so that a single forming and perfecting machine can supply a series of separate cutting, rolling and inserting machines.

It can be expected that when a series of inserts is posted into the same tube one after the other, they will be slightly out of line (angularly) with one another. This creates a slight degree of turbulence and edge effects which improve the heat exchange. Gaps between successive inserts are useful for the same reason.

If desired, the strip may be one which has been perforated along its length which will provide edge effects and modify the flow of the fluid in the heat exchange tube in use.

Claims

1. A method of making a heat exchange tube comprises the steps of taking an elongated strip of metal foil, corrugating the foil transversely by passing the foil through a pair of continuously running meshed gears, modifying the corrugation shape so that the flanks of the corrugations are non-planar, cutting the strip into lengths, and forming the flat lengths into a circular shape by bending them about an axis parallel to the length of the corrugations, and posting the so formed corrugations successively into the heat exchange tubes, so that the non-planar flanks make each corrugation radially resilient for good conductive contact.

2. A method as claimed in Claim 1 wherein a series of like inserts are displaced axially into the tube bore into generally or near end to end contact.

3. A method as claimed in any preceding claim wherein the strip is perforated prior to forming.

4. A method as claimed in any preceding claim wherein the assembly of tube and inserts is soldered or brazed to secure the inserts in position.

5. Apparatus for carrying out the method claimed comprising means for feeding strip between a pair of rotating meshed gear-like formers, means for cutting the strip into separate pieces located before or after the forming gears, and means for displacing formed pieces into the tube bore.

6. Apparatus as claimed in Claim 5 wherein the secondary forming means comprise a die and a former which is reciprocated transversely of the strip to cooperate with the die when the strip is located therebetween.

7. Apparatus as claimed in any preceding claim wherein corrugated strip rolling means is provided in the form of a guide tube having a tapering shape with an internal mandrel so as to receive a generally planar strip at one end, and conform it into a rolled strip at the other end when the strip is displaced along the length of the guide.

8. Apparatus as claimed in Claim 7 wherein a ram is provided for displacing the section along the guide and into and along the heat exchange tube, the ram being provided with means for terminating the ram stroke at a position such that each successive insert is displaced towards or into contact with the previous located insert.

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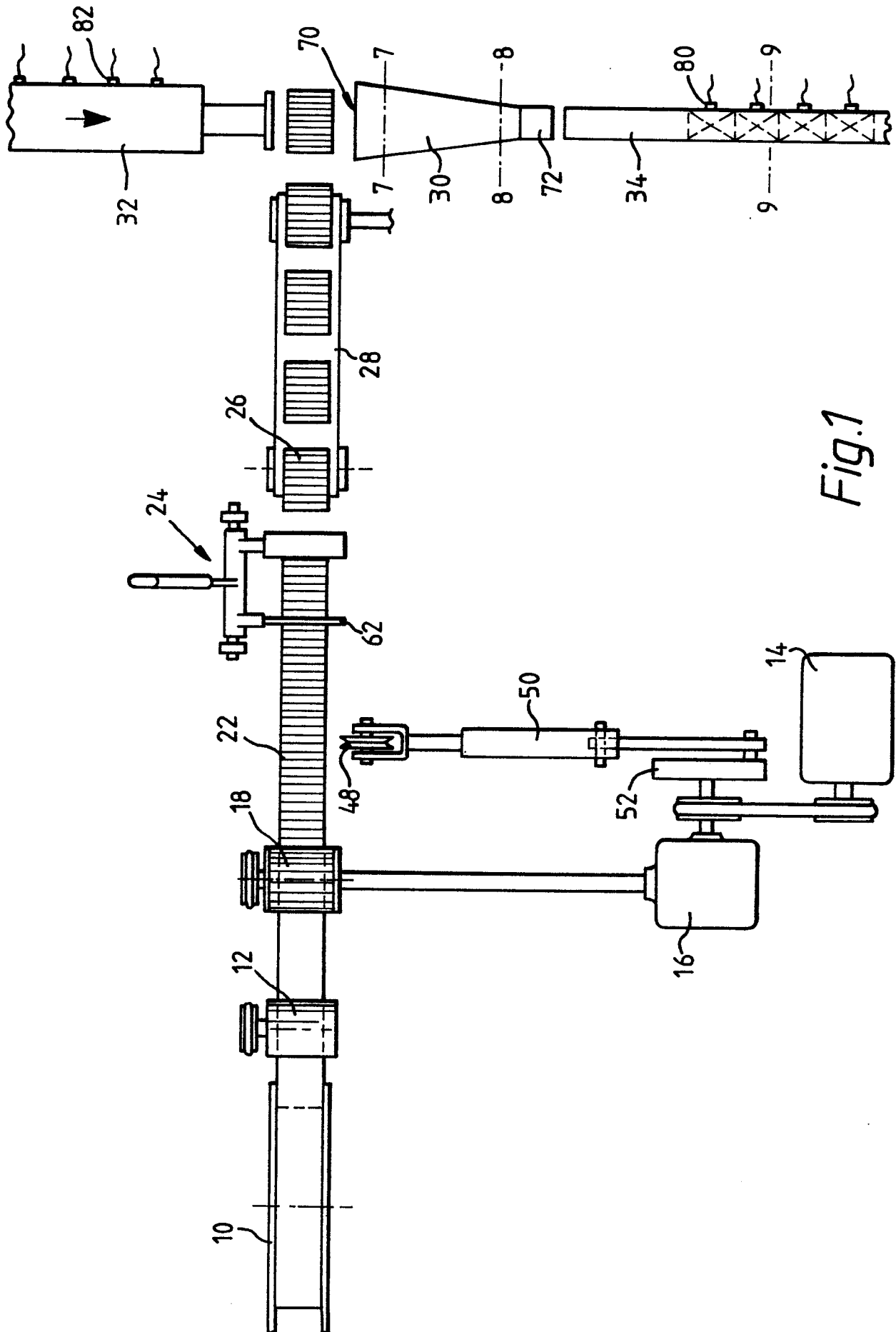


Fig.1

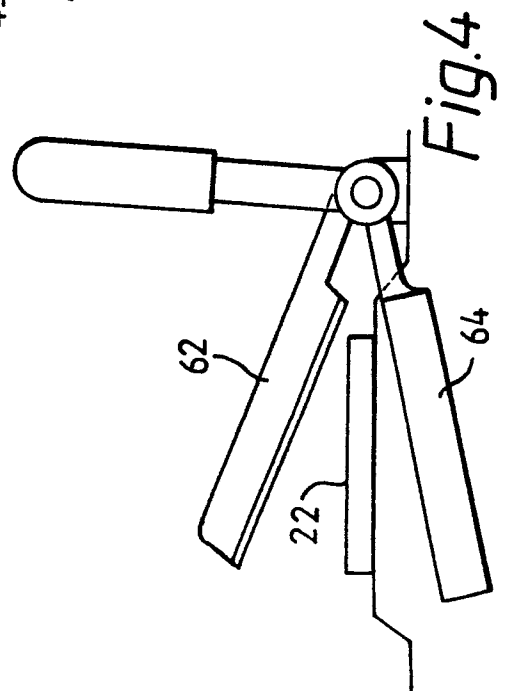
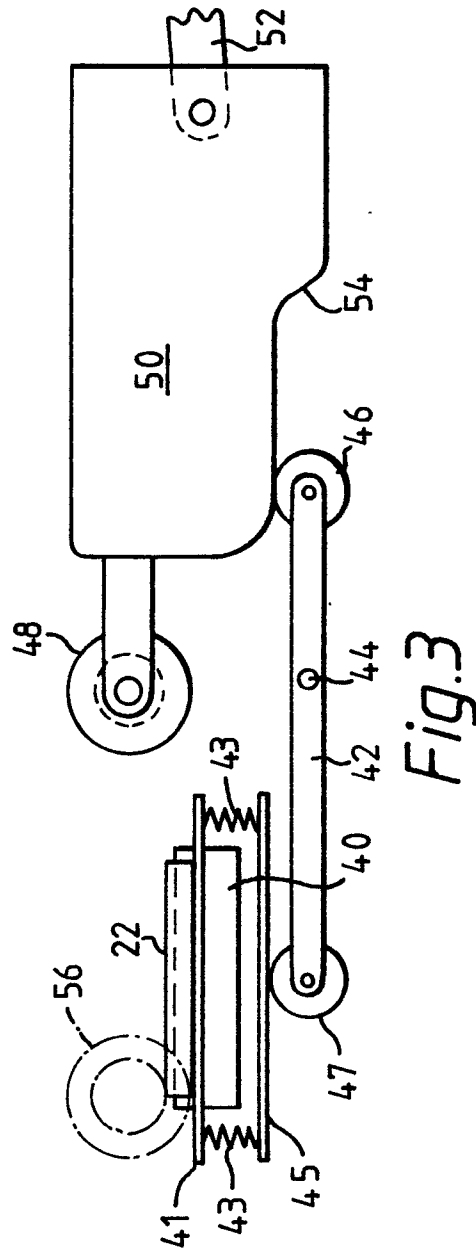
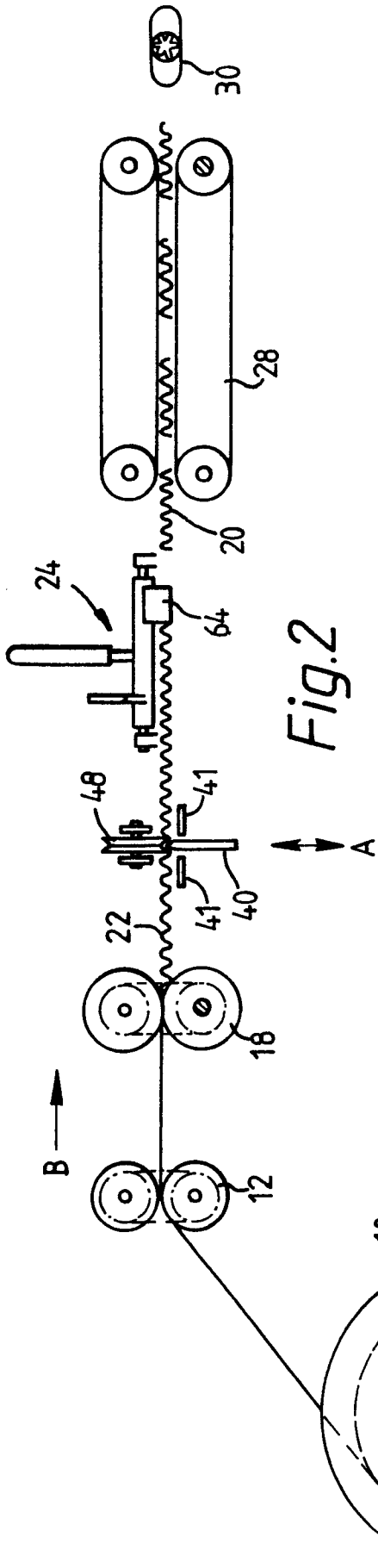




Fig.5



Fig.6

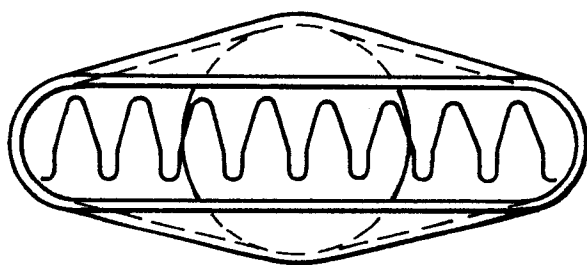


Fig.7

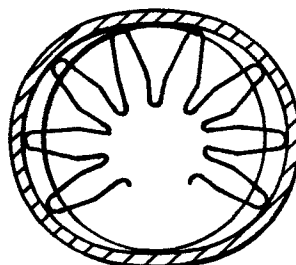


Fig.8

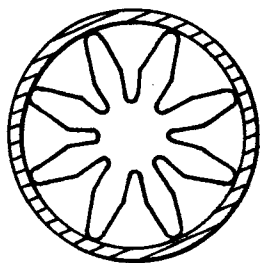


Fig.9

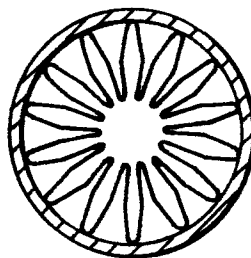


Fig.10