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Method of and apparatus for forming the end of a flat metal tube, and closing and sealing the end thereof.

A method of forming the end of a flat metal tube (10) includes mechanically forming a corner region (10a, 10b) of the flat metal tube, by forming the corner with an impressing tool (21) having a corner forming workface so that the corner is thereby given a shape corresponding to all or part of the workface. The method of forming the corner region includes initiating a seam by folding together, or partially folding together, the cut edges of the flat metal tube and forming a curved vee-shape which is located centrally about a plane parallel to the flat sides of the tube and with the apex of the vee-shape towards the adjacent tube corner by using a lead-in surface (22) on the impressing tool (20) which blends with the corner forming workface and which comprises a centre line (24) which describes an angle (25) greater than 20° as measured against the width of the flat tube to be formed.

All or part of the remaining tube end is closed and sealed by subsequent operations. The invention includes apparatus for carrying out the method and also provides a flat metal tube having at least one formed corner of a rounded shape.

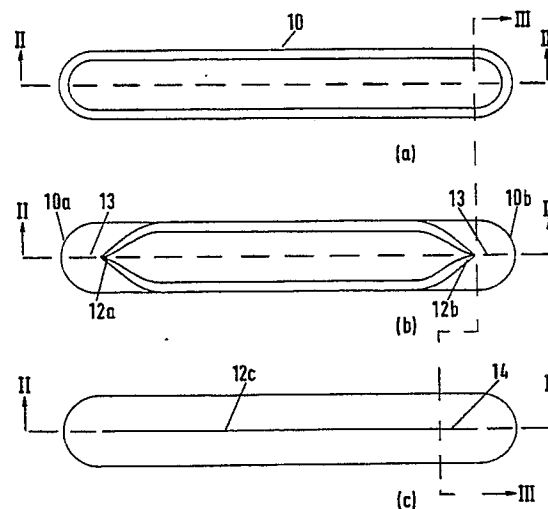


FIG. 1

METHOD OF, AND APPARATUS FOR, FORMING THE END OF A FLAT METAL TUBE; AND CLOSING AND SEALING THE END THEREOF

The present invention relates to a method of and apparatus for forming the ends of "flat" metal tubes and for closing and sealing the open ends of such tubes. By "flat" tubes is meant tubes which, as viewed end on, comprise two flat parallel closely spaced apart side walls joined by shorter end walls. Flat tubes may be made, for example, by flattening round tubes. Flat tubes have a large surface to volume ratio and are thus useful in heat exchangers, for example in central heating radiators. In such applications, a heat exchange element is made from a length of flat tubing, by closing and sealing the two open ends of the length, and providing a small hole or holes at or adjacent each end of the length as an entry and exit for the heat exchange fluid. The dimensions of the end of a flat metal tube for use in a central heating radiator may typically be 60 to 70mm by 10mm or 11mm.

One aspect of the invention provides a method of forming the end of a flat metal tube including mechanically forming a corner region of the flat metal tube, the method of forming the corner region comprising forming the corner with an impressing tool having a corner forming workface so that the corner is thereby given a shape corresponding to all or part of the workface.

Another aspect of the invention provides an apparatus for forming the end of a flat metal tube including apparatus for mechanically forming a corner region of the flat metal tube, the apparatus for forming the corner region comprising a clamp or positioning device for holding or locating a flat metal tube and an impressing tool having a corner forming workface, the impressing tool being operable to be applied to and withdrawn from the corner of the flat metal tube so as to mechanically form the corner of the tube to a shape corresponding to all or part of the workface.

The method and apparatus of the invention allow corners of a variety of different shapes to be produced, and in particular allow rounded corners to be produced which are aesthetically pleasing, both visually and to the touch, and safe, for example, in the event of a person accidentally colliding with the installed product or in the event of accidental collision with other items or persons during manufacture, transport and installation of the product.

The method and apparatus of the invention allow corners of consistent shape and dimensions to be produced, which facilitates subsequent assembly of radiators. Consistent shape and dimensions are particularly advantageous in the case of panel radiators, in which the tubes lie edge to

edge, and any lateral variation in shape and dimensions would be particularly noticeable. Rounded corners have a further advantage in the case of panel radiators in that they will render less noticeable any small longitudinal variations in the relative positioning of lengths of the flat tubes of the panel.

A further advantage occurs in the instance in which a tube end has a rounded corner which is subsequently welded. No edge is provided which is likely to be subsequently disfigured on melting of metal during a welding process.

Additionally, the step of forming the corner region comprises initiating a seam by folding together, or partially folding together, the cut edges of the flat metal tube.

Additionally, the apparatus comprises means for initiating a seam by folding together, or partially folding together, the cut edges of the flat metal tube.

This facilitates the subsequent closure of the adjacent tube end into a seam or seams comprising the cut edges of the tube, such that the formed corner and adjacent subsequent closure region form a continuous closure seam. Additionally, the step of forming the corner region comprises forming a curved vee-shape which is located centrally about a plane parallel to the flat sides of the tube and with the apex of the vee-shape towards the adjacent tube corner.

Additionally, the apparatus comprises means for forming a curved vee-shape which is located centrally about a plane parallel to the flat sides of the tube and with the apex of the vee-shape towards the adjacent tube corner.

This allows the corner and adjacent region at the end of the tube to be formed and closed neatly and symmetrically about a plane through the centre of the tube and parallel to its flat sides. This symmetry further assists in balancing forces as the closure seam is formed and in ensuring evenly sized and positioned abutting material edges in the seam. Where two corners are formed on the tube end it facilitates subsequent closure and sealing by providing all closure seams to be continuous in a single plane.

Additionally, the step of forming the corner region comprises forming a blend region extending from the formed corner where substantial plastic flow of the metal has taken place to the open region of the tube end which has been unaffected by the corner forming operation, and where the blend region forms a smooth transformation between the formed corner and open region of the tube end and comprises material in which little or

no stretching or upsetting of the material has taken place.

Additionally, the apparatus for forming the corner region comprises means for forming a blend region extending from the formed corner where substantial plastic flow of the metal has taken place to the open region of the tube end which has been unaffected by the corner forming operation, and where the blend region forms a smooth transformation between the formed corner and open region of the tube end and comprises material in which little or no stretching or upsetting of the material has taken place.

This facilitates the subsequent closure of the adjacent tube end permitting a variety of closure methods which require relatively light forming forces.

It also facilitates the subsequent closure such that the formed corner and subsequent closure region form a continuous shape and surface avoiding wrinkling or bulging of the material in the transformation region.

It also facilitates a subsequent closure method which operates progressively across the remaining open end of the tube by mimicing that condition at the commencement of the subsequent closure method from the formed corner inwards.

Additionally, the step of forming the corner region includes using on the impressing tool a lead-in surface which blends with the corner forming workface and which comprises a centre line which describes an angle greater than 200 as measured against the width of the flat tube to be formed.

Additionally, the impressing tool of the apparatus for forming the corner region comprises a lead-in surface which blends with the corner forming workface and which comprises a centre line which describes an angle greater than 20° as measured against the width of the flat tube to be formed.

The lead-in surface facilitates the preparatory formation of the corner region in readiness for the final impressing of the desired shape by the corner forming workface, thus ensuring its success.

A lead-in surface with an angle greater than 20° facilitates the said preparatory formation by ensuring that the centre region of the corner is not formed in advance of the side regions which could prevent correct formation of the seam initiation, curved vee-shape or blend region.

Finally, the defining of the potentially complex three-dimensional lead-in surface in the relatively simple terms of a centre line angle and a blend facilitates the specification, manufacture and maintenance of the impressing tools.

Additionally, the step of forming the corner region comprises avoiding the formation of an arched shape in the material of the blend region so

as to minimize rigidity of the blend region material.

Additionally, the apparatus for forming the corner region comprises means for avoiding the formation of an arched shape in the material of the blend region so as to minimize rigidity of the blend region material.

This facilitates a subsequent closure method, such as rolling, which operates progressively across the remaining open end of the tube by minimising rigidity in the blend region which would not occur further across the open end, and the overcoming of which could cause a discontinuity in surface shape and appearance along the closed end of the tube.

Additionally, the step of forming the corner region comprises inseting the seam initiation from the end corner of the flat tube by the action of the impressing tool.

Additionally, the apparatus for forming the corner region comprises means for inseting the seam initiation from the end corner of the flat tube by the action of the impressing tool.

This provides several advantages related to subsequent closing and sealing of the seam.

Inseting shortens the seam to be subsequently sealed.

It moves the seam to be sealed away from the curved corner region, thus allowing a straight line seam to be formed which can more readily be sealed by automatic methods.

It also facilitates the sealing method by providing a region at the beginning and end of the seam where sealing conditions can be established and tailed-off respectively without injury to the sealing of the seam itself.

It improves the potential appearance of the corner region by dispensing with the seam and sealing operation in that area.

Additionally, the step of forming the corner region comprises forming a land in the region adjacent the seam initiation and end corner of the flat tube in an orientation approximately at right angles to the longitudinal axis of the flat tube.

Additionally, the apparatus for forming the corner region comprises means for forming a land in the region adjacent the seam initiation and end corner of the flat tube in an orientation approximately at right angles to the longitudinal axis of the flat tube.

This facilitates a subsequent closure and sealing method by providing a region at the beginning and end of the seam where sealing conditions can be established and tailed-off respectively without injury to the sealing of the seam itself.

The provision of lands also facilitates the operation and control of subsequent closing methods of the adjacent open ends of the tubes, principally by ensuring that most or all significant plastic for-

mation of the tube material associated with forming and closing the corner regions is isolated from the subsequent closure of the adjacent region of the open tube end, by regulating the position of the land at or below the level of the subsequent closure operation.

Additionally, the method of the invention further comprises forming the corner with the impressing tool in a straight line in a direction parallel to the plane of the flat sides of the flat tube and at, or approximately at, ninety degrees to the longitudinal axis of the flat tube.

Additionally, the apparatus of the invention further comprises means for forming the corner with the impressing tool in a straight line in a direction parallel to the plane of the flat sides of the flat tube and at, or approximately at, ninety degrees to the longitudinal axis of the flat tube.

Straight line motion simplifies the design and construction of apparatus to carry out the method.

Motion parallel to the plane of the flat sides of the flat tubes and at ninety degrees to the longitudinal axis of the flat tube also simplifies the design and construction of the apparatus and furthermore reduces the recoil of the tube away from the forming tool in a direction along the longitudinal axis of the tube. This direction of motion of the impressing tool has also been found to facilitate the even formation of the seam initiation, the curved vee-shape and blend region mentioned earlier.

Additionally, both corners of the end of a flat tube are formed simultaneously.

Additionally, at least two impressing tools form both corners of the end of a flat tube simultaneously.

In addition to providing a faster operation this facilitates the balance of forces on the tube end and on the apparatus and reduces the possibility of the tube end being marked or distorted during the operation.

Additionally, an internal support die is inserted into the end of the tube for use during corner formation.

Additionally, the apparatus comprises an internal support die which is insertable into the end of the tube for use during corner formation.

This facilitates corner forming where otherwise the tube lacks sufficient material thickness and ductility to be formed to a desired shape without collapsing inwardly, wrinkling or buckling.

Additionally, the step of forming the corner or corners of a flat metal tube is effected in a series of progressive steps.

Additionally, the apparatus comprises means for forming the corner or corners of a flat metal tube in a series of progressive steps.

This also facilitates corner forming where otherwise the tube lacks sufficient material wall thick-

ness or ductility to be formed to a desired shape without collapsing inwardly, wrinkling or buckling.

Additionally, the method of the invention further includes a method of forming the end of a flat metal tube comprising forming one or both corners of the tube end and then closing all or part of the remaining open tube end.

Additionally, the apparatus of the invention further includes an apparatus for forming the end of a flat metal tube comprising means for forming one or both corners of the tube end and then closing all or part of the remaining open tube end.

Additionally, closing a tube end with two formed corners is effected by a single roller pass across the end of the tube.

Additionally, said closing means comprises a roller which is operable to pass across the end of a tube with two formed corners in a single pass.

This has the advantage of providing a rapid method using simple apparatus to close the remaining open end of a tube comprising two formed corners.

Additionally, the method of the invention comprises forming both corners of the end of the flat tube but initially forming the corner of the flat tube at which the roller pass exits deeper than that at the entry of the roller pass to compensate for lateral movement of material, caused by the roller pass.

Additionally, the apparatus of the invention comprises means for forming both corners of a flat tube said apparatus having means for initially forming the corner of the flat tube at which the roller pass exits deeper than that at the entry of the roller pass to compensate for lateral movement of material, caused by the roller pass.

This has the advantage of providing equal or very similar corner shapes on a tube end which has had its middle region closed by a single roller pass which would otherwise have caused noticeably different shaped corners to result from its entry onto and exit off the tube end.

Alternatively, a tube end with two formed corners is closed by two roller passes in opposing directions and the first roller pass being retracted before the second roller makes a complete pass across the tube end.

Said closing means may comprise two rollers which are operable to pass in opposing directions across a tube end with two formed corners with the first roller being retractable before the second roller makes a complete pass across the tube end.

Compared to use of a single roller pass this has the advantage of providing equal or very similar corners but without the need for different shaped corner forming tools. Against this it has the relative disadvantages of taking longer to perform the operation, of requiring more complicated ap-

paratus, and the possibility of resulting in a discontinuity on the tube surface where the two roller passes overlap.

Additionally, the method of the invention further comprises initially forming lands in the region at or adjacent the corners of the flat tube in orientations approximately at right angles to the longitudinal axis of the flat tube such that the lands are set at, or further into, the lengths of the tube than the locus of the contact between the tube end and the root of the roller profile, and subsequently closing the tube end by one or more roller passes.

Additionally, the apparatus of the invention further comprises means for initially forming lands in the region at or adjacent the corners of the flat tube in orientations approximately at right angles to the longitudinal axis of the flat tube such that the lands are set at, or further into, the lengths of the tube than the locus of the contact between the tube end and the root of the roller profile, and means for subsequently closing the tube end by one or more roller passes.

As discussed previously, this facilitates a subsequent sealing method by providing a region at the beginning and end of the seam where sealing conditions can be established and tailed-off respectively without injury to the sealing of the seam itself.

Again as discussed previously, the provision of lands also facilitates the operation and control of the subsequent closing method of the adjacent open ends of the tubes, principally by ensuring that most or all significant plastic formation of the tube material associated with forming and closing the corner regions is isolated from the subsequent closure of the adjacent region of the open tube end, by regulating the position of the land at or below the level of the subsequent closure operation.

Additionally, the closed metal tube is sealed by autogenous welding or any suitable sealing technique.

Additionally, means for sealing the closed metal tube are provided such as an autogenous welding apparatus or any suitable sealing apparatus.

Sealing has the advantage of allowing the closed tube to be used where fluid-tight closures are required, such as in central heating radiator applications.

Where fluid-tight closures are not required but where the tube is to be subsequently painted or pretreated for painting sealing can have the advantage of preventing troublesome fluids or contaminants entering or leaving the unsealed seam.

Autogenous welding has several advantages, including the following:-

- It obviates the need for additional materials.
- It is suitable for automation.

- It provides a smooth even finish and eliminates the need for subsequent redressing methods such as grinding.

A further aspect of the invention provides a closed or partially closed flat metal tube having four corners comprising at least one formed corner of a rounded shape.

Advantageously, said round shape approximates to a quarter sphere.

The invention also provides flat metal tubes the corners of which have been formed by the method or apparatus of the invention.

The invention also provides flat metal tubes the ends of which have been closed or closed and sealed by the method, apparatus or tools of the invention.

The invention will now be described more particularly, by way of example only, with reference to the accompanying drawings. In the drawings:

Figures 1a - 1c each show an end view of a flat metal tube after successive stages of closing using a corner forming method carried out in a single step;

Figures 2a - 2c correspond to Figures 1a to 1c respectively, but each show a sectional elevation of the tube end, taken on II - II of Figure 1;

Figures 3a - 3c correspond to Figures 1a to 1c respectively, but each show a sectional elevation of the end tube, taken on III - III of Figure 1;

Figures 4a and 4b show, in section, corner forming tools which may be used for example at a corner forming workstation of the apparatus, Figures 4a illustrating the tools when withdrawn from a workpiece and Figure 4b illustrating the tools when engaged with the workpiece;

Figure 5 is an enlarged sectional view of the workface of a corner forming tool shown in Figures 4a and 4b.

Figures 6a, 6b and 6c show, in section, how a roller may be used to close the end of a tube after the corners have been formed;

Figure 7 is a schematic elevation of apparatus including a number of workstations, for converting flat metal tubes into radiator elements including workstations for mechanically forming the corners and closing and sealing the ends;

Figures 8a - 8e each show an end view of a flat metal tube after successive stages of closing using a corner forming method carried out in three steps; and

Figure 9 is a sectional elevation of an alternative workstation for corner forming in a single step using a support die.

Referring first to Figures 1a to 1c, 2a to 2c and 3a to 3c, the method steps involved in mechanically forming the corners of the open end of the tube in a single step and without the use of a support die and of subsequently closing and seal-

ing the end will now be described. Figures 1a, 2a and 3a show the open end of the flat metal tube 10 before the commencement of operations. Figures 1b, 2b and 3b show the end of the tube after a first forming operation has been carried out at both corners 10a, 10b simultaneously by a pair of tools (not shown in Figures 1, 2 and 3) each of which approached a corner at an angle of about 90 degrees to the axis of the flat tube and in the plane of the tube.

It will be seen in Figures 1b, 2b and 3b that the corners 10a, 10b have each been shaped into approximate quarter spheres (and this shape is retained on the closed tube end shown in Figures 1c, 2c and 3c).

It will be seen that a seam initiation point 12a, 12b formed by the folding together or partial folding together of the cut edges of the flat metal tube, is present adjacent each corner 10a, 10b respectively and lies at the apex of a curved vee-shape comprising the cut edges and adjacent side walls extending from the seam initiation point to the open centre region of the tube end respectively. This shape facilitates the subsequent closure of the remaining open tube end into a single continuous seam comprising the abutting cut edges of the tube. The symmetry of the apexes and seam initiation points about a central plane parallel to the flat sides of the tube facilitates even abutment of the cut edges in the seam which also lies in this plane.

The edges and side walls of the tube 10 diverge gradually from the approximate quarter sphere formed corner region in the direction of the middle of the open end and this blend region is shaped such as to minimize stretching or upsetting of the side wall material in order to facilitate a subsequent closure operation which will result in a smooth unpuckered surface.

The blend region is also shaped such as to avoid the formation of a rigid arched shape which could pucker the material when subsequently overcome by a roller pass closing operation across the width of the tube.

It will be seen that the seam initiation is inset from the corner of the tube and a land 13 is formed in the region adjacent the seam initiation points in an orientation approximately at right angles to the longitudinal axis of the tube. These features provide several advantages related to subsequent closing and sealing of the seam and will be explained later.

The corner form and blend regions are formed by applying to and withdrawing from the corner an impressing tool having a workface corresponding to their required shape, the motion of the tool being parallel to the width of the tube. Advantageously, both corners of the tube end are formed simultaneously to help balance forces in the supporting

clamp. Further advantage can be gained by forming both ends of the tube simultaneously, thus balancing the longitudinal thrust on the tube in addition to obvious productivity benefits.

Figures 4a and 4b depict such corner formation in cross-section where both corners of the tube end are formed simultaneously and Figure 5 similarly shows a cross-section through one of the impressing tools.

Figure 4a shows the tube end prior to the forming operation. The tube end is firmly gripped between two clamps 20, one of which is shown in Figures 4a and 4b behind the tube end. The clamps 20 serve to locate the tube end in the correct position relative to the forming tools and to prevent movement of the tube end during the forming operation. In addition to holding and locating the tube end, the clamps 20 also contain the tube end and thereby restrict outward bulging or distortion of the side walls of the tube taking place during the forming operation. To assist this containment, the clamps 20 are provided with an extension 20a in the region of the centre of the tube end. To restrict inward bulging or distortion of the side walls in the region of the centre of the open end, a tongue piece (not shown) may be inserted into the open end of the tube.

The tools 21 describe a straight line movement at 90° to the tube length, Figure 4a showing the retracted tool position and Figure 4b showing the impressed tool position.

The forming tools 21 each comprise a cavity 21a whose shape corresponds to the shape described on the tube corner after the forming operation. Allowance is made for the resilience of the tube material. The cavity 21a is made from hardened material to reduce tool wear and distortion. Figure 4b shows the cavity 21a in engagement with the tube corner on completion of the forming of the corner.

Making reference to Figure 5, the workface of the impressing tool comprises a corner region 23 approximately in the shape of a quarter sphere, a blend region comprising a small land 26 and a lead-in surface 22 which blends smoothly into the land 26 and corner region 23. The centre line 24 of the lead-in surface 22 should describe an angle 25 greater than 20° as measured against the width of the tube, to ensure correct formation of the seam initiation, curved vee-shape and blend regions. An angle of 30°-40° has been found satisfactory in practice. Too great an angle should be avoided where the centre region is to be subsequently closed by a rolling operation, as the resulting steep blend region may result in a discontinuity of the tube surface following rolling.

The rear surface of the tool is shaped to match the desired contour of the tube end where contact

takes place. The centre line 27 of the rear surface is made parallel to the length of the tube in the instance where the middle region of the tube is to be subsequently closed by a roller pass entering the tube end at that corner and is made to describe an angle 28 of about 5° to the length of the tube where the middle region is to be subsequently closed by a roller pass which exits the tube end at that corner.

Closure of the middle part may be effected by means of, for example, a single pass of a flanged roller 30 as shown in Figure 6, two opposing passes of flanged rollers or by impressing tools in similar manner to the corners.

The corner forms shown in Figure 1b, 2b and 3b are well suited to closure of the middle part by a flanged roller pass. In this instance the depth of the lands 13, in a direction parallel to the length of the tube, is made equal to or greater than the depth of the locus of the contact between the tube end and the root of the roller profile 14. This ensures that most or all significant plastic formation of the tube material associated with forming and closing the corner regions is isolated from the roller pass operation. Otherwise the roller pass would carry out significant plastic deformation in the corner region but not so in the middle region of the tube. In addition to the possibility of spoiling the impressed corner shape, this variation in forming by the roller pass would lead to it being heavily loaded in the corner region and much more lightly loaded in the middle region. Inevitable flexing of the workpiece and apparatus would be likely to cause this variation in load to result in an uneven closure of the tube end. Where the middle region is closed by a single roller pass, as shown in Figure 6, it will be found that if equal formed corners are created in the first operation, the roller pass operation will tend to slightly distort the material in the region of the corner where the roller exits the tube end laterally outwards in a manner which does not occur at the corner where the roller enters the tube end. This potential problem can be readily overcome by both cradling the tube with a support block 32 extending as far as possible into the throat of the roller and by forming a deeper corner on the exit side in the first operation as described earlier. Satisfactory forms have been achieved by forming the corner inwards by an amount equal to the outward distortion which would otherwise occur and which can be observed by simple trial and error. Arranging the centre line 27 of the rear surface of the impressing tool at an angle 28 of about 5° to the length of the tube has been found satisfactory in practice.

An alternative solution is to employ two roller passes from opposite directions with the first roller pass being retracted before making a complete

pass across the tube end. This has the advantage of employing equal rolling conditions at each corner and allowing use of equal shaped corners in the first operation, but has the disadvantages of requiring more complex apparatus and the possibility of resulting in a discontinuity on the tube surface where the two roller passes overlap.

After closure of the middle part there remains a single straight line seam 12c, shown in Figures 1c to 2c, between the abutting edges of the flat side walls. The seam 12c may be sealed by various methods but preferably by an autogenous method such as tungsten inert gas (TIG) welding, or alternatively by, for example, other types of welding, brazing, soldering or by means of an adhesive or sealing compound.

As previously mentioned, the seam 12c is inset from the corners of the tube end which facilitates the sealing operation in several ways. Firstly, it shortens the length of seam to be sealed. Secondly, it moves the seam to be sealed away from the curved corner region, thus providing a straight seam which is ideal for automation. Thirdly, it improves the potential appearance of the corner region by removing the seam from that region. Fourthly, together with the feature whereby lands 13 are created adjacent the seam initiation points, it provides a region at the beginning and end of the seam where sealing conditions can be safely established and tailed-off respectively without risk to the integrity of the seal itself.

The preferred sealing method is autogenous welding and more particularly tungsten inert gas (TIG) welding. This has various advantages including the following. It requires no additional materials and is suitable for automation. It provides a smooth even finish and eliminates the need for redressing methods such as grinding.

Referring now to Figure 7 an automatic apparatus for use in converting flat metal tubes into radiator elements by the method in which corner forming is carried out in a single step without the use of an internal support die will now be described in general terms. Figure 7 is a side elevation of the apparatus, showing flat tubes 10, viewed end on, passing from left to right (as seen in the drawing) through a series of workstations for performing different operations. It should be appreciated that the apparatus includes a second series of workstations (not shown) for performing corresponding operations on the other ends of the tubes. The two sets of workstations are mounted on a machine frame so as to be relatively movable towards or away from one another, so that radiator elements of different lengths can be made in the apparatus. Thus a length of flat metal tubing enters from the left and emerges as a radiator element on the right. In the step by step description which follows refer-

ence will be made to one end only of the tube, but it will be understood that a corresponding operation is taking place at the other end of the tube. The separation of the two sets of workstations can be set using a tube from a batch of tubes which are to be converted into radiator elements.

Still referring to Figure 7, the operation of the apparatus will now be described step by step.

The first step is an optional aperture punching step. A first flat metal tube 10 from a stack 110 is conveyed to a first aperture punching workstation 111 which provides apertures which will enable the finished radiator element to be used as part of a panel radiator. These apertures are intended to serve as water entry or exit holes for water entering or leaving a radiator header. A die (not shown) is automatically inserted into the end of the tube before the punching operation and automatically retracted after the punching operation. The flat metal tube then moves onto a conveying chain 112 which takes the tube stepwise through successive workstations 113, 113a and 113b at which no operations are performed until the tube reaches a forming workstation 114. At this forming workstation 114 a forming operation, the results of which are illustrated in Figures 1b, 2b and 3b, is carried out. It will be noted that the tube is oriented so that its side walls lie in the vertical plane. This vertical orientation helps to prevent any distortion due to gravity taking place while the tube is subjected to the significant compression forces involved in the forming operation.

Two corner forming tools 21 are simultaneously impressed, one on each of the two corners at the end of the tube. Simultaneous impression of these two tools 21, together with the two tools at the other end (not shown) of the tube, assists in balancing forces and preventing movement of the tube during the forming operation. The tools 21 describe a straight line movement at 90° to the tube length. The forming tools 21 are powered by hydraulic rams (not shown). The forming tools 21 are guided in their straight line movement by heavy duty guides (not shown) capable of withstanding the side forces generated during the forming operation.

Referring back to Figure 7, after the forming operation the next step is a rolling step. The tube is conveyed to a rolling workstation 130. The tube is positioned and held by a fixed rest underneath (not shown) and a powered movable forked clamp (not shown) which descends on the tube from above. The roller 131, which is free to rotate, is mounted in a carriage 132 which is constrained to move in a vertical direction only and is powered down and up by means of a hydraulic ram 133 or a mechanical screw. The roller 131 makes a single pass along the end of the tube and is then withdrawn. The

roller 131 has a profile very similar to that desired on the finished closed tube end, but a tapered clearance is desirable between the tube side walls and the side cheeks of the roller 131 to prevent rubbing between them, and to allow easy access of the roller 131 onto the tube end. The diameter of the roller 131 is also important in producing a good finish. Too large a diameter will produce too much downward pressure lengthwise to the tube under the roller 131 relative to the necessary forward widthwise pressure and may cause collapse of the tube side walls. A roller diameter of 25mm has been found suitable for the mild steel tube profile which has been described. In the example of the mild steel tube and roller under discussion, a suitable distance between roller paths, when both ends of the tube are rolled simultaneously, has been found to exist where, as a result of the simultaneous rolling operations, the lengths of the tube is reduced by between about 5.0 and 6.0mm in length. A rolling operation is illustrated in Figure 6.

After rolling, the tube is conveyed to an optional second aperture workstation 140 which is intended to provide apertures which will enable the finished radiator element to be used in a column radiator. The second aperture punching workstation 140 operates to produce a single aperture for fluid entry or exit, near the end of the curved wall of the tube. The aperture is at least 5 mm in diameter and may be produced by drilling or by punching.

After the second optional aperture step, the next step is welding which takes place on every third cycle of the machine. The tubes advance to welding workstations 150, 151 and 152 until a tube is located in each workstation. The apparatus now operates such that the closed ends of the three tubes in the three welding workstations 150, 151, 152 are sealed simultaneously by TIG welding. Meanwhile the apparatus performs the mechanical operations on the following tubes in the other workstations. The reason for having three welding workstations 150, 151, 152 is that the welding operation takes much longer than the mechanical operations. By employing three welding workstations 150, 151, 152, only every third cycle of the apparatus needs to last as long as it takes to perform a welding operation. The other two cycles take only as long as is required to perform the mechanical operations. Movement of the TIG welding torches of the welding workstations 150, 151, 152 is effected by means of linear movement devices. The tubes are clamped in a similar manner to those in the rolling workstation 130. It will be noted that the tubes in the welding workstations 150, 151, 152 are oriented so that their side walls are horizontal. Horizontal welding has the advantage that the seam weld is less likely to be effected by gravity and will thus be neater and

more even, whereas vertical welding may exhibit a slight bulging at the lower end of the weld. The horizontal welding method is particularly suitable for elements used in panel radiators, where the elements lie one against the other and even a small unevenness would be noticeable. The heat exchange elements are now complete and are discharged from the apparatus.

Figures 6a, 6b and 6c show how the middle part of the end of a tube may be closed using a roller 30. The corners have already been formed by any of the method elsewhere described. The roller 30 makes a single pass. Figure 6a shows the roller 30 before the pass commences. Figure 6b shows the roller 30 during the pass. Figure 6c shows the roller 30 after the pass has been completed.

Various considerations involved in selecting the arrangement of steps and of tools will now be described. The use of a number of forming steps to form the corners allows more control of the movement of the material and reduces the effect of uneven tool wear. The number of steps required is generally less for more ductile material, thicker walls, less rounded corners and the more the walls are supported against bulging or distortion during forming. The use of different angles of approach, which are chosen to minimize relative movement of the tools and the material being formed, facilitates formation and reduces tool wear. Where closing of the middle part is done by impressing tools, the corners and the middle part may be formed simultaneously in a manner similar to that described above for forming the corners only. Pairs of tools are again applied in sequence. Each tool of a pair, however, extends from a corner along the middle part of the open end, so that the pair of tools together form material along the open end. To give a good finish, each pair of tools may meet at a different location along the same open end, instead of each pair meeting at the same location.

Figures 8a to 8e give an example of how the corner forming operation on a tube end may be performed in three steps.

The use of an internal support tool also permits more control of the movement of material during corner forming and may be used in either single or multiple stage operations where the tube lacks sufficient material thickness and ductility to be formed to a desired shape. The internal support die achieves this by preventing inward collapse, wrinkling or buckling of the material in the corner region.

Figure 9 diagrammatically illustrates an arrangement of tool 90 and support die 91, useful for example in manual production of small volumes of radiators. In this case, the support die 91 is fixed. The end of the tube 10 is fitted over the support

die 91 manually. A semicylindrical stop 92 on the die 91 engages the end edges of the tube 10 to ensure correct relative location of the tube 10 and die 91. The tool 90 is then impressed to form one corner and is retracted. The tube 10 is then removed. The operation is then repeated for each of the other three corners.

Claims

1. A method of forming the end of a flat metal tube including mechanically forming a corner region of the flat metal tube, the method of forming the corner region comprising forming the corner with an impressing tool having a corner forming workface so that the corner is thereby given a shape corresponding to all or part of the workface.

2. A method according to Claim 1, whereby the step of forming the corner region comprises initiating a seam by folding together, or partially folding together, the cut edges of the flat metal tube.

3. A method according to Claim 1 or 2, whereby the step of forming the corner region comprises forming a curved vee-shape which is located centrally about a plane parallel to the flat sides of the tube and with the apex of the vee-shape towards the adjacent tube corner.

4. A method according to any one of Claims 1, 2 or 3, whereby the step of forming the corner region comprises forming a blend region extending from the formed corner where substantial plastic flow of the metal has taken place to the open region of the tube end which has been unaffected by the corner forming operation, and where the blend region forms a smooth transformation between the formed corner and open region of the tube end and comprises material in which little or no stretching or upsetting of the material has taken place.

5. A method according to Claim 4, whereby the impressing tool comprises a lead-in surface (A) which blends with the corner forming workface (B) and which comprises a centre line (C) which describes an angle (D) greater than 20° as measured against the width of the flat tube to be formed.

6. A method according to Claim 4 or 5, whereby forming the corner region comprises avoiding the formation of an arched shape in the material of the blend region so as to minimize rigidity of the blend region material.

7. A method according to any one of Claims 2 to 6, whereby the step of forming the corner region comprises insetting the seam initiation from the end corner of the flat tube by the action of the impressing tool.

8. A method according to any one of Claims 2 to 7, whereby the step of forming the corner region

comprises forming a land in the region adjacent the seam initiation and end corner of the flat tube in an orientation approximately at right angles to the longitudinal axis of the flat tube.

9. A method according to any one of the preceding claims comprising forming the corner with the impressing tool in a straight line in a direction parallel to the plane of the flat sides of the flat tube and at, or approximately at, ninety degrees to the longitudinal axis of the flat tube.

10. A method according to any one of the preceding claims, comprising forming both corners of the end of a flat tube simultaneously.

11. A method according to any one of the preceding claims, comprising inserting into the end of the tube an internal support die for use during corner formation.

12. A method according to any one of the preceding claims, whereby the step of forming the corner or corners of a flat metal tube is effected in a series of progressive steps.

13. A method of forming the end of a flat metal tube according to any one of the preceding claims, and additionally including closing all or part of the remaining open tube end.

14. A method according to Claim 13, comprising forming both corners of an end of a flat tube and closing the tube end by a single roller pass across the end of the tube.

15. A method according to Claim 14, comprising initially forming the corner of the flat tube at which the roller pass exits deeper than that at the entry of the roller pass to compensate for lateral movement of material, caused by the roller pass.

16. A method according to Claim 13, comprising closing a tube end with two formed corners by two roller passes in opposing directions and retracting the first roller pass before making a complete pass across the tube end.

17. A method according to any one of Claims 13 to 16, comprising initially forming lands in the region at or adjacent the corners of the flat tube in orientations approximately at right angles to the longitudinal axis of the flat tube such that the lands are set at, or further into, the lengths of the tube than the locus of the contact between the tube end and the root of the roller profile, and subsequently closing the tube end by one or more roller passes.

18. A method according to any one of Claims 13 to 17, comprising sealing the closed metal tube by autogenous welding or any suitable sealing technique.

19. Apparatus for forming the end of a flat metal tube including apparatus for mechanically forming a corner region of the flat metal tube, the apparatus for forming the corner region comprising a clamp or positioning device for holding or locating a flat metal tube and an impressing tool having

a corner forming workface, the impressing tool being operable to be applied to and withdrawn from the corner of the flat metal tube so as to mechanically form the corner of the tube to a shape corresponding to all or part of the workface.

20. Apparatus according to Claim 19, comprising:

means for initiating a seam by folding together, or partially folding together, the cut edges of the flat metal tube;

means for forming a curved vee-shape which is located centrally about a plane parallel to the flat sides of the tube and with the apex of the vee-shape towards the adjacent tube corner;

means for forming a blend region extending from the formed corner where substantial plastic flow of the metal has taken place to the open region of the tube end which has been unaffected by the corner forming operation, and where the blend region forms a smooth transformation between the formed corner and open region of the tube end and comprises material in which little or no stretching or upsetting of the material has taken place;

means for avoiding the formation of an arched shape in the material of the blend region so as to minimize rigidity of the blend region material;

means for insetting the seam initiation from the end corner of the flat tube by the action of the impressing tool;

means for forming a land in the region adjacent the seam initiation and end corner of the flat tube in an orientation approximately at right angles to the longitudinal axis of the flat tube;

means for forming the corner with the impressing tool in a straight line in a direction parallel to the plane of the flat sides of the flat tube and at, or approximately at, ninety degrees to the longitudinal axis of the flat tube; and in which

the impressing tool comprises a lead-in surface which blends with the corner forming workface and which comprises a centre line which describes an angle greater than 20° as measured against the width of the flat tube to be formed.

21. Apparatus according to any one of Claims 19 or 20, comprising at least two impressing tools for forming both corners of the end of a flat tube simultaneously.

22. Apparatus according to any one of Claims 19 to 21, comprising an internal support die which is insertable into the end of the tube for use during corner formation.

23. Apparatus according to any one of claims 19 to 22, comprising means for forming the corner or corners of a flat metal tube in a series of progressive steps.

24. Apparatus for forming the end of a flat metal tube according to any one of Claims 19 to 23 and additionally including means for closing all or

part of the remaining open tube end.

25. Apparatus according to Claim 24, in which said closing means comprises a roller which is operable to pass across the end of a tube with two formed corners in a single pass.

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26. Apparatus according to Claim 25, comprising means for initially forming the corner of the flat tube at which the roller pass exits deeper than that at the entry of the roller pass to compensate for lateral movement of material, caused by the roller pass.

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27. Apparatus according to Claim 24, in which said closing means comprises two rollers which are operable to pass in opposing directions across a tube end with two formed corners with the first roller being retractable before the second roller makes a complete pass across the tube end.

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28. Apparatus according to any one of Claims 24 to 27, comprising means for initially forming lands in the region at or adjacent the corners of the flat tube in orientations approximately at right angles to the longitudinal axis of the flat tube such that the lands are set at, or further into, the lengths of the tube than the locus of the contact between the tube end and the root of the roller profile, and means for subsequently closing the tube end by one or more roller passes.

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29. Apparatus according to any one of Claims 24 to 28, comprising means for sealing the closed metal tube such as an autogenous welding apparatus or any suitable sealing apparatus.

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30. A closed or partially closed flat metal tube having four corners comprising at least one formed corner of a rounded shape or a shape approximating to a quarter sphere.

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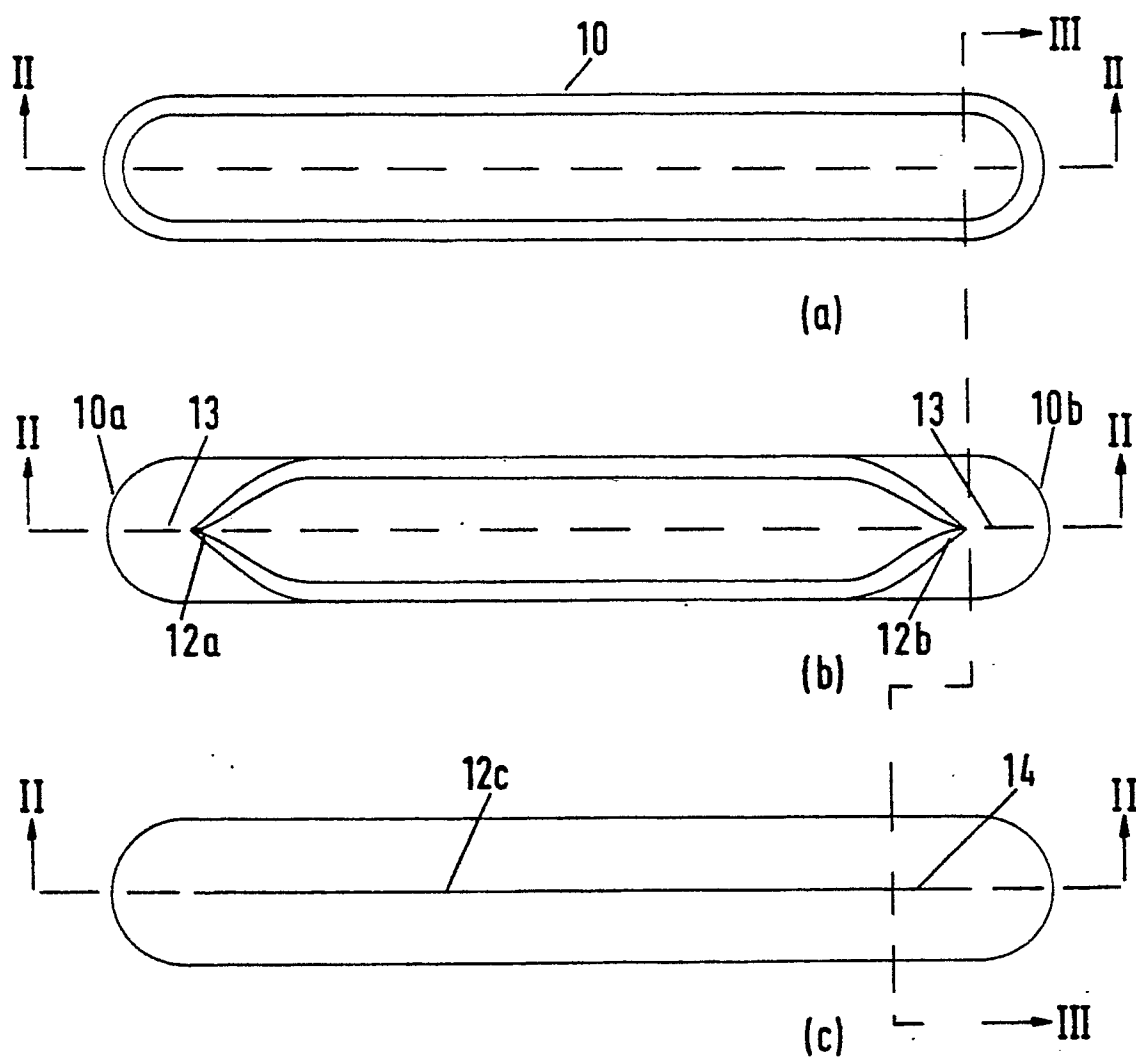


FIG 1

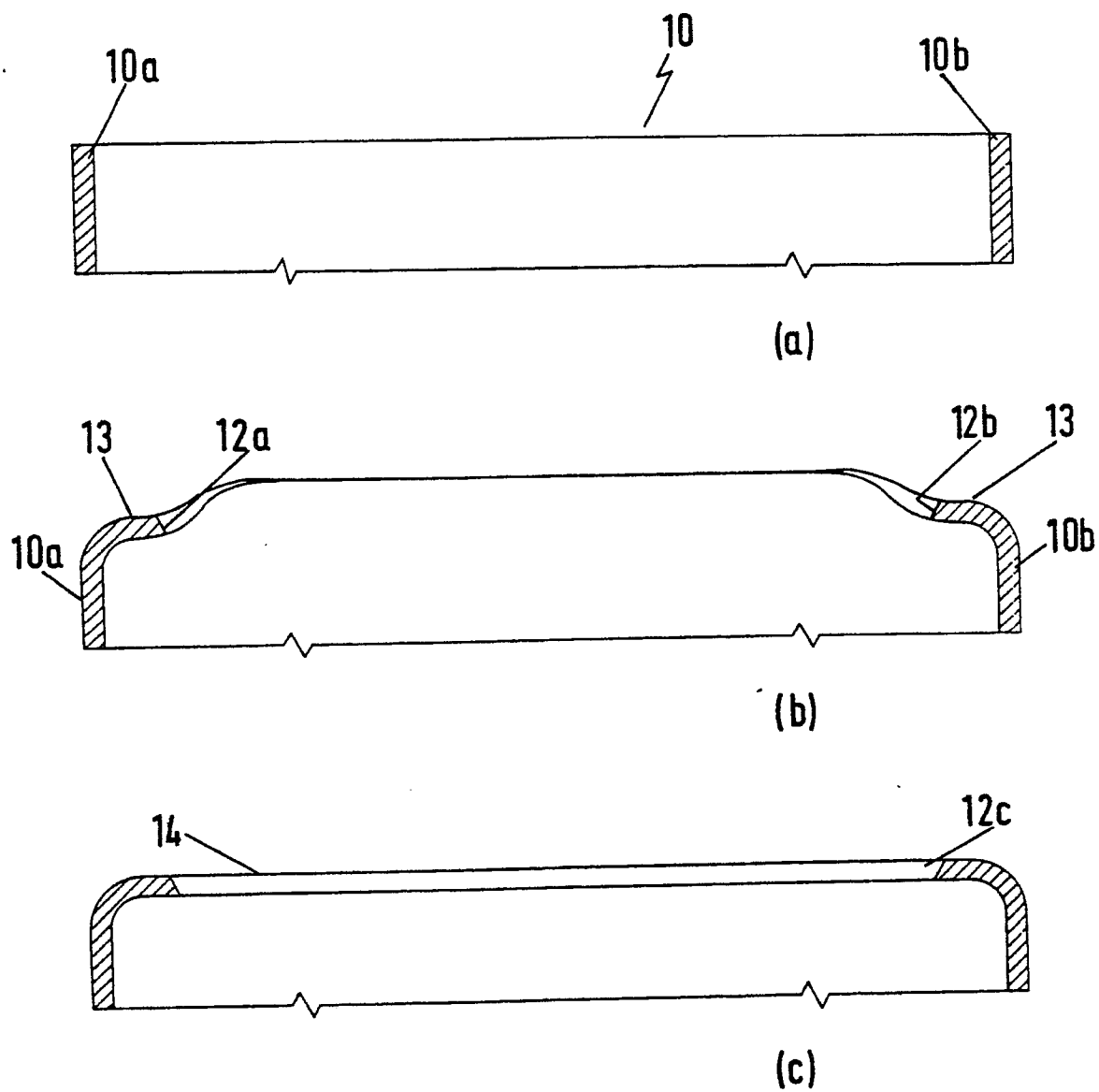


FIG 2

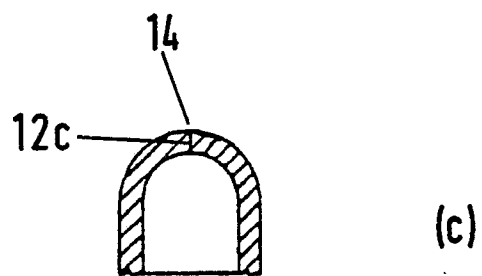
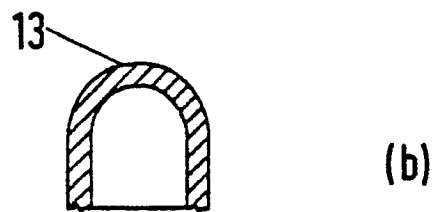
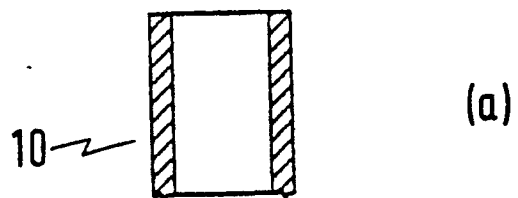


FIG 3

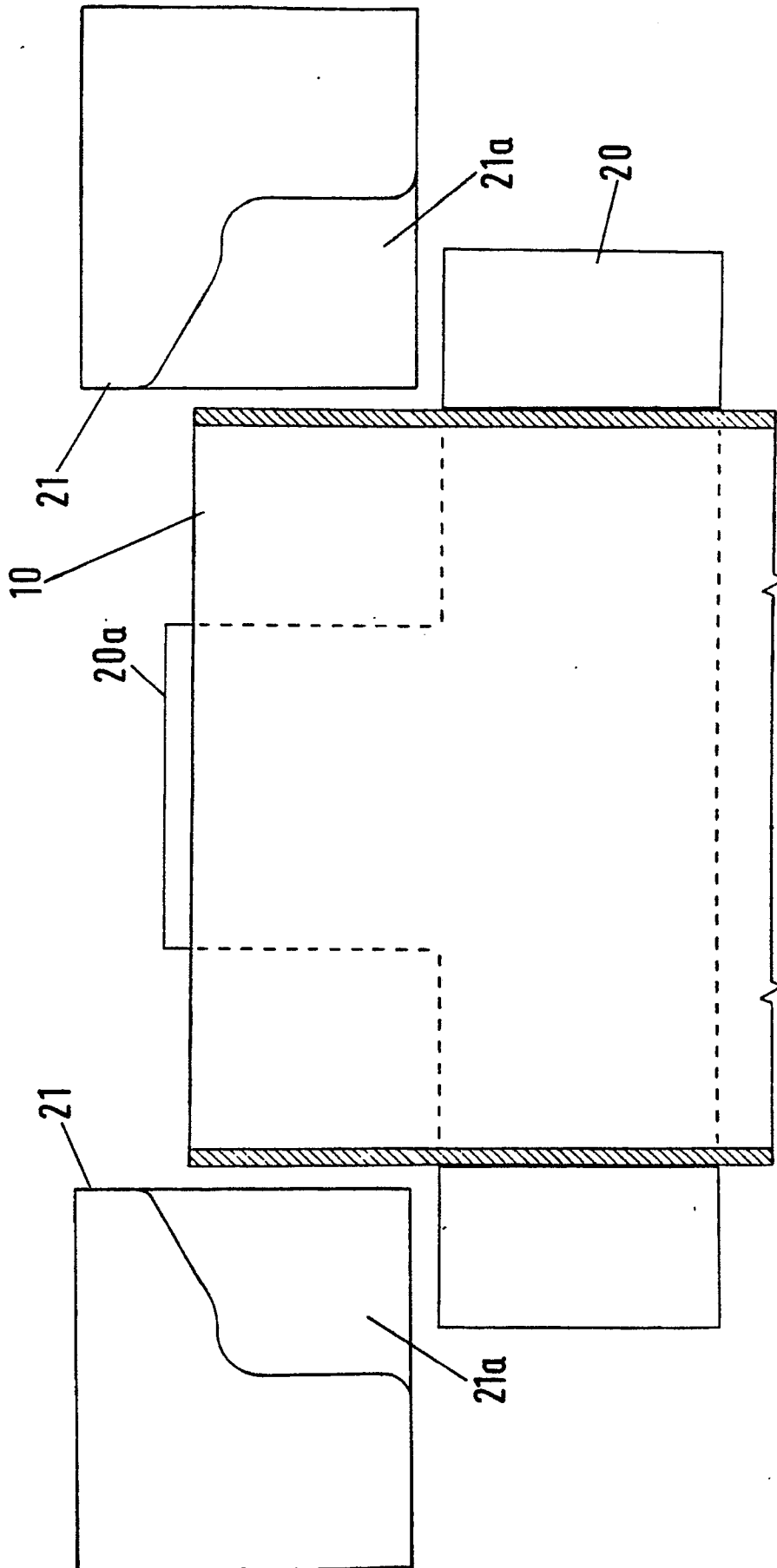


FIG 4a

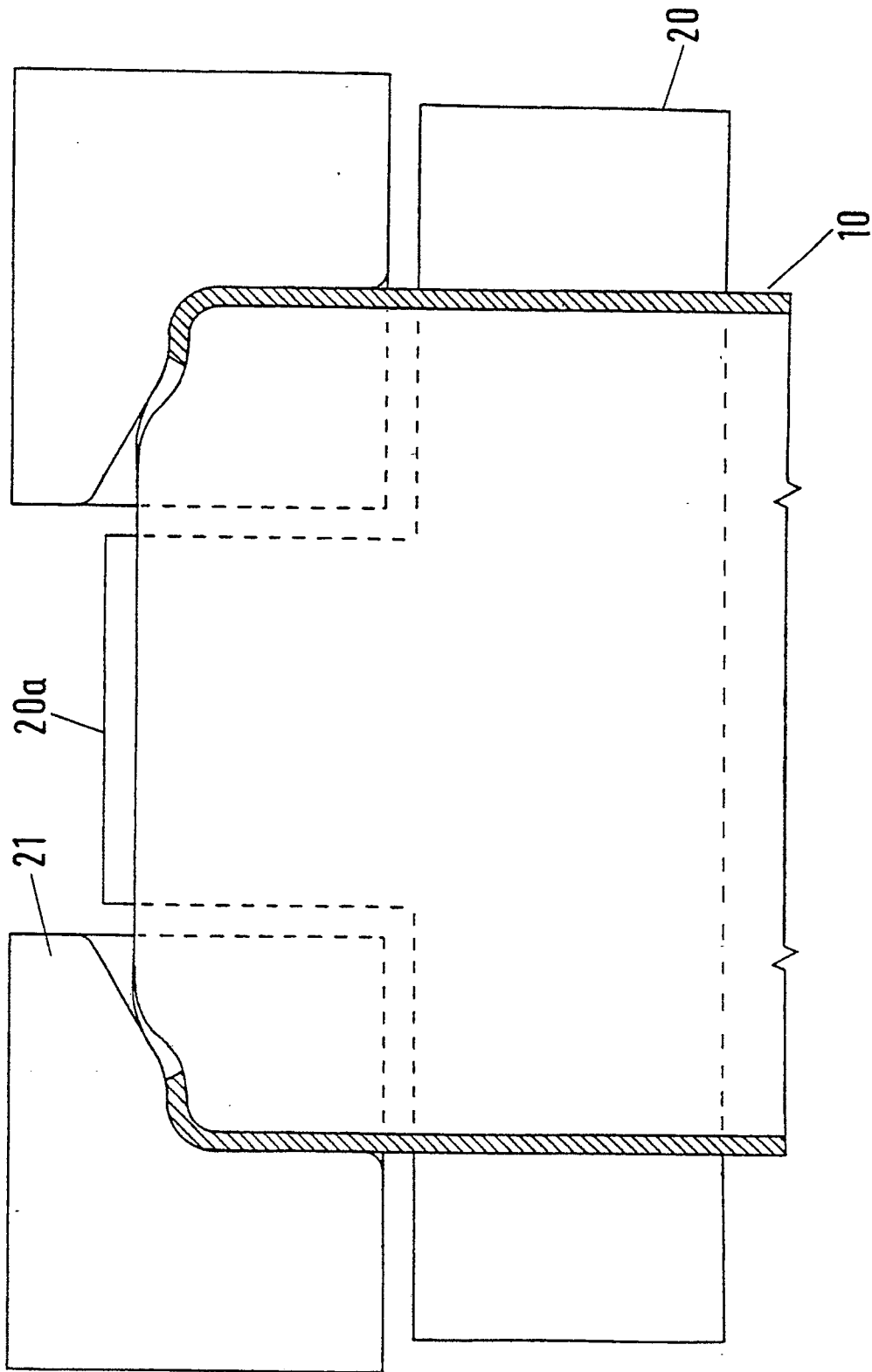


FIG 4b

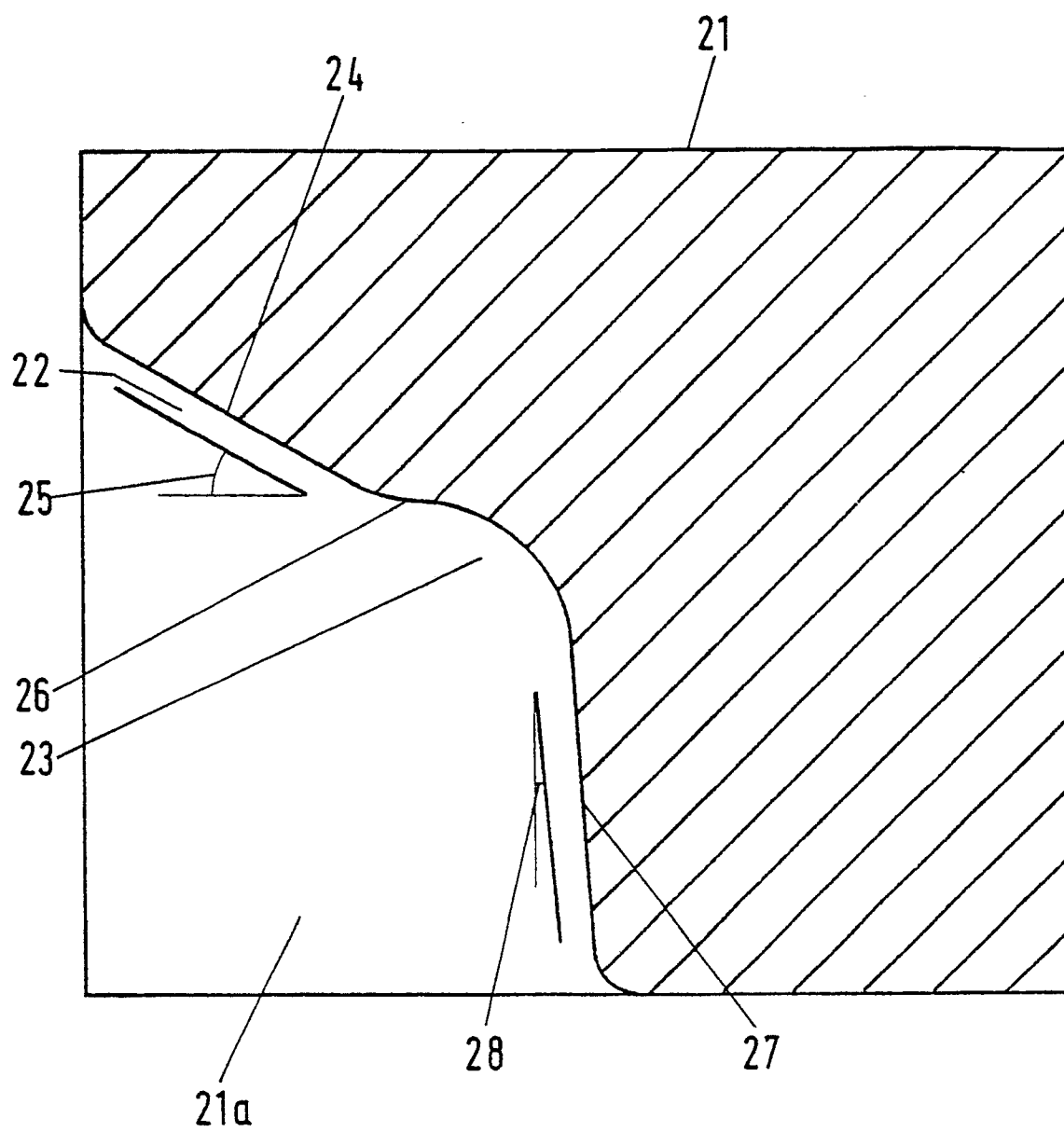


FIG 5

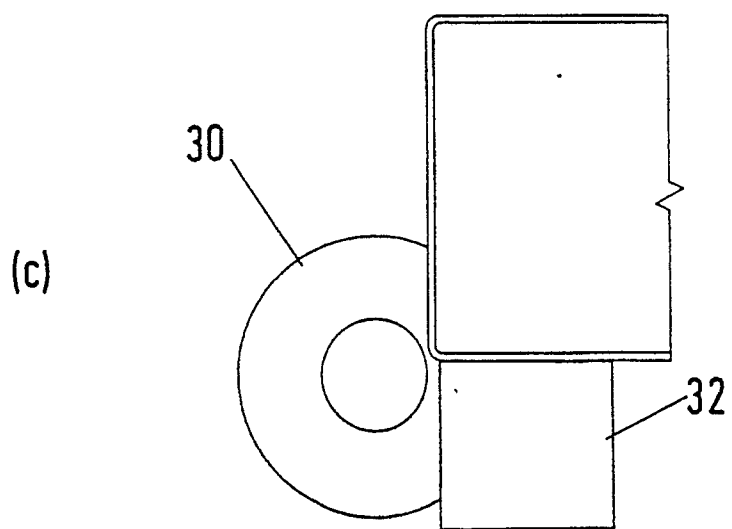
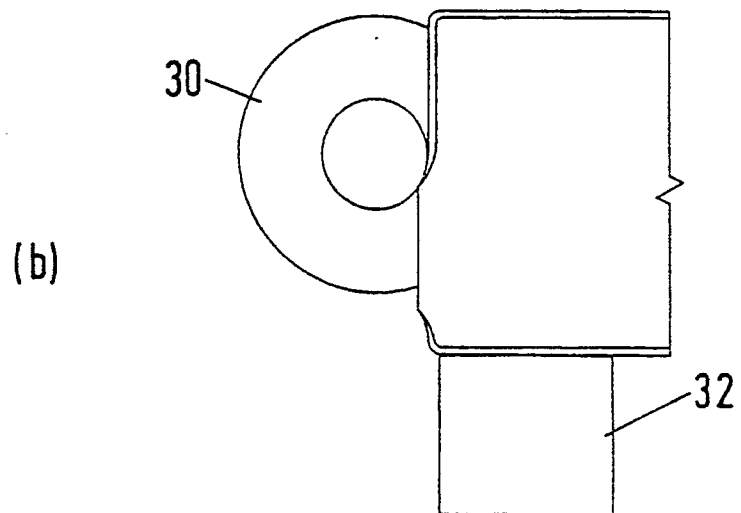
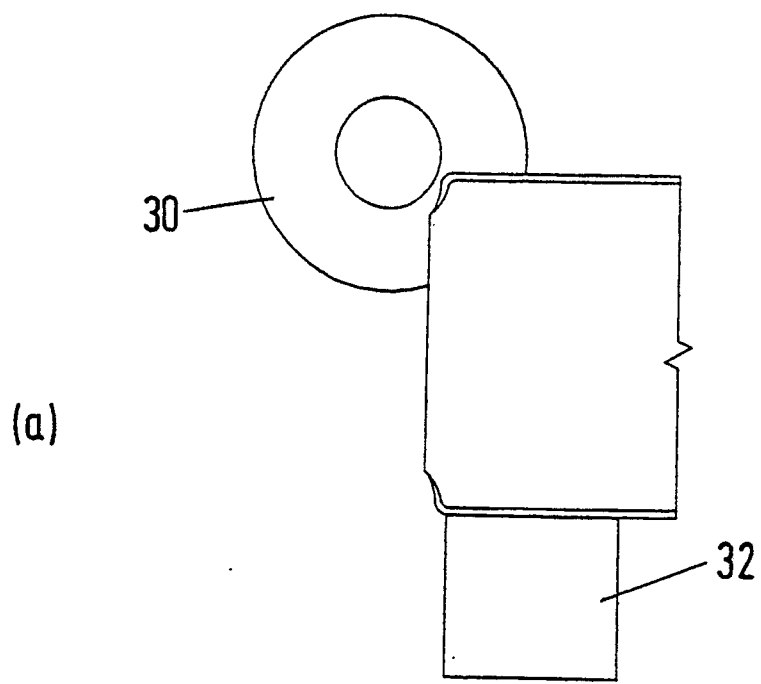
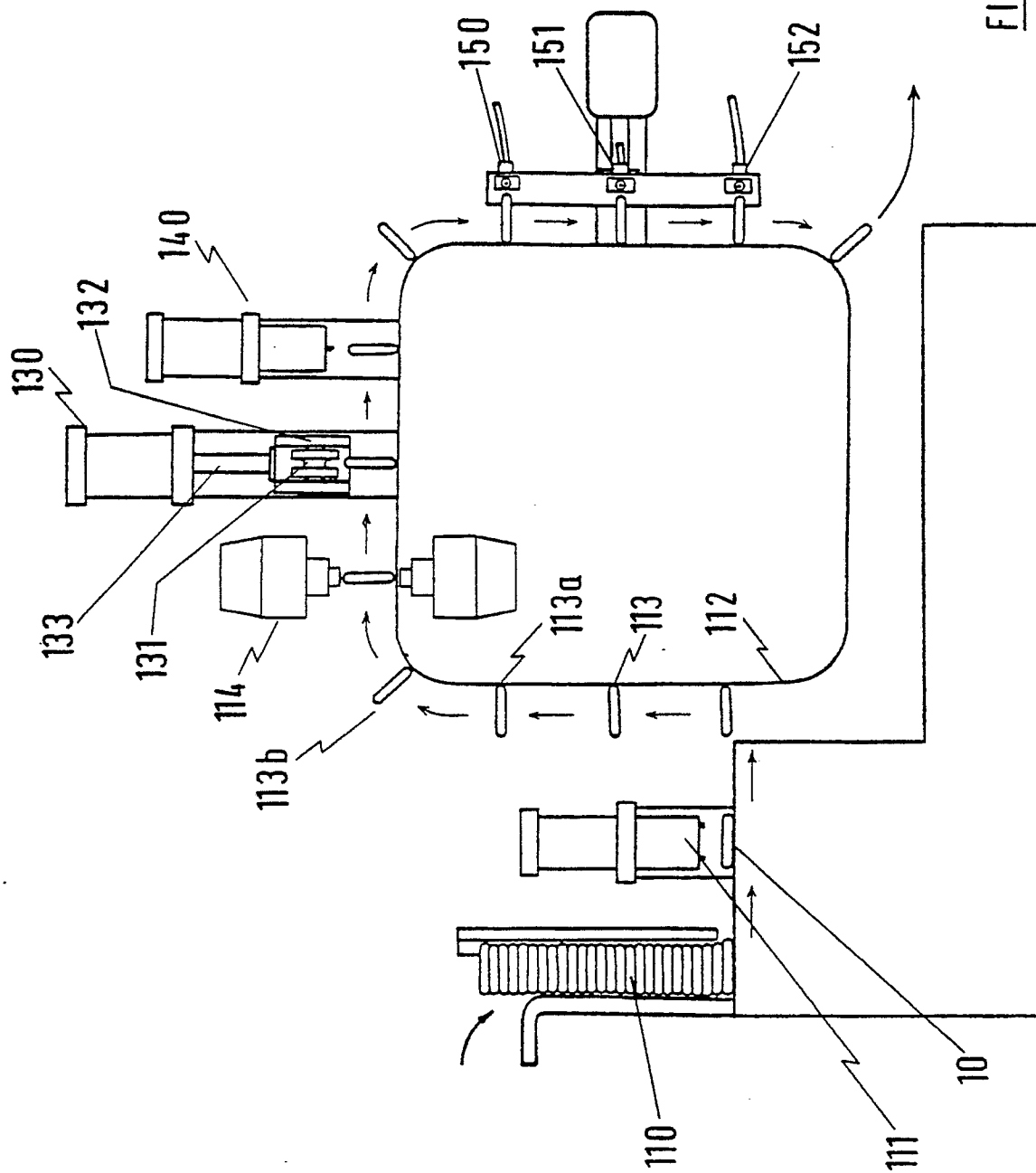


FIG 6



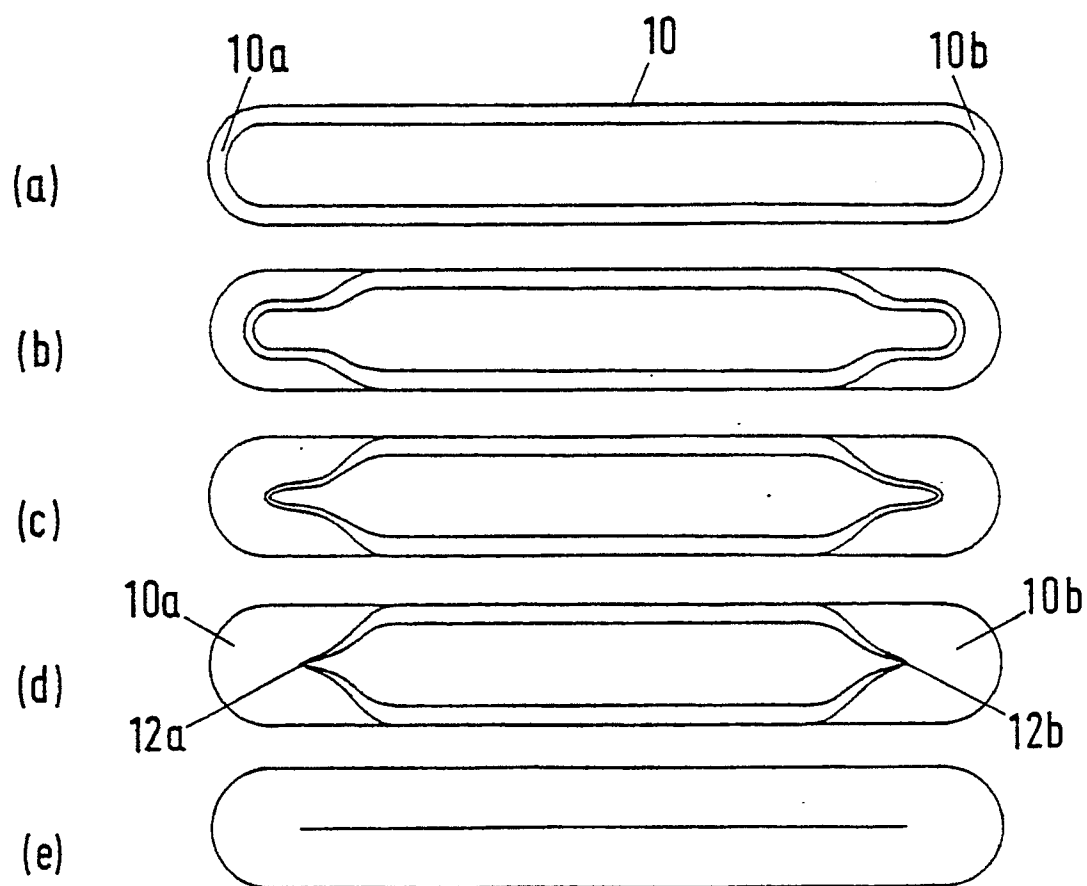


FIG 8

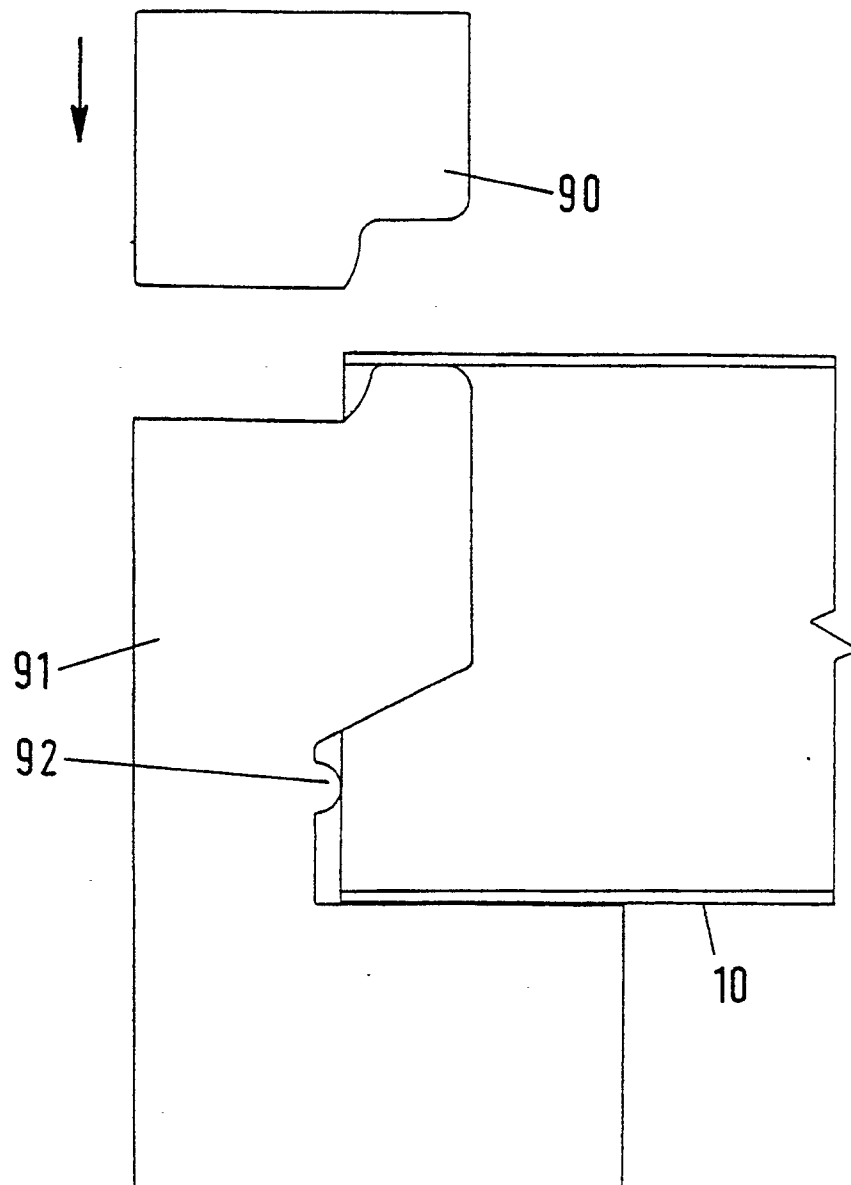


FIG 9



DOCUMENTS CONSIDERED TO BE RELEVANT			EP 90306310.5
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.')
Y	<u>GB - A - 2 151 162</u> (TUBI ITALIA SP.A) * Page 2, lines 25-51; fig. 2-4 *	1	B 21 D 41/04
Y	<u>AT - B - 283 870</u> (JUNKERS & CO) * Claim 2; page 3, lines 27-28; fig. 5 *	1	
A		2, 5, 7, 10, 11, 12, 22, 23	
A	<u>GB - A - 576 259</u> (HALL BROS LTD.) * Fig. 2 *	14, 20, 25, 27	
A	<u>DD - A - 220 520</u> (VEB ELEKTROWÄRME ALTENBURG) * Claims; fig. 1, 2 *	19	
			TECHNICAL FIELDS SEARCHED (Int. Cl.')
			B 21 D 19/00 B 21 D 21/00 B 21 D 22/00 B 21 D 41/00 B 21 D 51/00
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 18-09-1990	Examiner BISTRICH
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			