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(54) IMPROVEMENTS IN OR RELATING TO APPARATUS FOR, AND A METHOD OF, SHAPING TUBES

(71) We, OCEANIC CONTRACTORS INCORPORATED, of Via Espana 120, Apartado Postale 1450, Panama City, Panama, a Corporation registered in accordance with the laws of Panama, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to tubes and is particularly concerned with apparatus for, and a method of, shaping an end of a tube as may be required to facilitate the joining of that tube end to the surface of another body. More particularly the invention was developed to facilitate the shaping of a tube end for joining that end to a further body by welding and as such is primarily concerned with metal or plastics tubes.

It is conventional practice when welding an end of a tube to a non-flat surface, which may conveniently be regarded as the convex surface of a second tube, to profile the end of the tube, for example to provide an arcuate or saddle shape, so that that end can be positioned adjacent to or mounted to sit on the surface in substantially complementary relationship. If the tube has negligible wall thickness then by appropriate profiling its end may be regarded as making face-to-face contact with the curved surface of the second tube. However, if the tube has a substantial wall thickness, such as heavy duty tubes as are used, for example, in the construction of a framework or jacket in the assembly of off-shore drilling rigs (where it is not unusual for the tube to have a length in the order of 4 metres, an external diameter of 180 cms and a wall thickness of 12 cms) then, depending upon the positioning of the end of the tube on the curved surface and/or the angular relationship between the two tubes a condition may be obtained on the profiled end of the tube whereby, at one

position the edge of the tube profiled end face on the inside surface of the tube will contact the curved surface while at a second position (peripherally spaced from the first position) the edge of the tube profiled end face on the outside surface of the tube will contact the curved surface. This particular configuration may result in an effective line of contact between the profiled end face of the tube and the curved surface, which line progresses at least in part radially across the wall thickness of the tube end face between its inner surface and its outer surface. With thick walled tubes such as those aforementioned it has hitherto been proposed to provide a continuous bevel or chamfer around the radially outermost peripheral edge of the profiled end face so removing the corner portion of the tube between its outer peripheral surface and the end face and thereby reducing the thickness of the wall around the end of the tube. By so chamfering or bevelling the tube wall an effective peripheral channel may be formed when the tube is mated with the curved surface to which it is to be welded within which channel weld filler material may be applied to secure the bodies together. While such form of preparation of the tube end may be regarded as acceptable in conditions where the surface of the tube subtends an angle with the curved surface or tangent to that curved surface which is greater than, say, 55° it is found that if the aforementioned subtended angle is less than 55° the portion of the channel and adjacent part length of the tube in the region of the minimum subtended acute angle becomes extremely deep with the result that a considerable amount of welding time and filler material may be required to fill the channel and form an efficient weld. In an attempt to alleviate this difficulty of inefficient usage of weld material it has been proposed to provide so called transition bevelling whereby bevel portions

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are cut manually at discrete regions along the periphery of the profiled end face of the tube so that such bevel portions are located primarily at positions required to facilitate welding of the tube end to the further body and it is an object of the present invention to provide apparatus and a method which may facilitate such shaping and bevelling of the tube end.

According to the present invention there is provided apparatus for shaping an end of a tube of substantial wall thickness having a longitudinal axis and comprising a cutter having a centre line along which it is intended to cut the tube wall, said centre line being directed at or towards the longitudinal axis and intersecting a secondary axis which is substantially perpendicular to the axis of the tube; means for mounting the tube with its end adjacent to the cutter; means for imparting relative axial rotation between the cutter and tube for cutting around the tube wall; means for imparting predetermined relative axial displacement between the tube and cutter during said relative rotation for substantially maintaining the cutter on a predetermined peripheral path at the end of the tube; cutter control means by which the cutter and the secondary axis are displaced radially relative to the axis of the tube so that, during said relative rotation and axial displacement between the tube and cutter, the secondary axis is displaced at least part way across the wall thickness of the tube to the outer peripheral surface thereof, and means for synchronising the said radial displacement of the cutter and the secondary axis with the relative axial rotation between the cutter and the tube so that, with the cutter disposed at an acute angle with respect to the tube axis, the position of intersection between the centre line of the cutter and the secondary axis follows a continuous and predetermined path which extends across at least part of the wall thickness of the tube to the outer peripheral surface thereof and the arrangement is such that by maintaining the said position of intersection in an end face of the tube a bevel surface can be cut at the end of the tube wall, said bevel surface extending from the end face of the tube across at least part of the wall thickness to the outer peripheral surface of the tube and forming a junction line with the end face of the tube which junction line progresses at least part way across the tube end face from the outer peripheral surface of the tube.

Further according to the present invention there is provided apparatus for forming a profiled end face of a tube having a substantial wall thickness and a longitudinal axis to enable the tube to be joined along an endless predetermined notional line of contact which includes inner and outer peripheral edges of the tube and which

apparatus comprises: a cutter which is to be disposed in cutting position relative to the wall of the tube and which has a centre line along which it is intended to cut the wall; drive means for providing relative rotational movement between the cutter and the tube; means for moving the cutter axially along the wall of the tube to follow a predetermined profile during relative rotation between the cutter and the tube; means for pivoting the cutter about a secondary axis for disposing the cutter with its centre line at a desired angular position relative to the axis of the tube, said secondary axis being substantially perpendicular to the axis of the tube and being intersected by the centre line of the cutter; cutter control means comprising a displaceable mounting for displacing said secondary axis radially across the thickness of the end face of the tube; and means for synchronising the radial displacement of said secondary axis with the relative rotational movement between the cutter and tube to move the intersection of said secondary axis and the centre line of the cutter along the notional line of contact for producing an edge which corresponds to the predetermined line of contact between said tube and said surface.

Still further according to the present invention there is provided a method of shaping an end of a tube of substantial wall thickness which is to be welded to a curved surface of a further body which method comprises profiling that end of the tube to provide a profiled end face on which is located a notional line that corresponds to a theoretical line of contact between the end face and said curved surface for fitting the end of the tube to the curved surface in substantially complementary relationship and which notional line follows a continuous and predetermined path which extends across at least part of the wall thickness of the tube to the outer peripheral surface thereof; cutting the tube wall at the profiled end thereof to provide a bevel surface which extends across at least part of the profiled end face of the tube to the outer peripheral surface of the tube and controlling said cutting so that the bevel surface formed thereby progresses inwardly through the tube wall thickness to form a transition line with the profiled end face which transition line substantially follows the notional line of contact where that notional line deviates from the innermost and the outermost peripheral edges of the profiled end face as initially formed.

The cutter control means preferably comprises a displaceable mounting on which the cutter is carried. This mounting is arranged to be displaceable radially relative to the tube axis in response to a predetermined pattern which is followed by a follower device that moves relative to the pattern. The

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pattern is selected to determine the path followed by the position of intersection as aforementioned between the cutter centre line and the secondary axis of the tube. Conveniently the follower device is in the form of a cam follower and the pattern is in the form of a rotatable cam having a cam surface with which the cam follower engages; the predetermined radial displacement of the mounting and thereby of the cutter being a result of the cam follower moving over the cam surface during rotation of the cam. Desirably relative movement between the pattern and its follower is synchronised with a drive arrangement for imparting relative axial rotation between the cutter and tube so that the movement between the pattern and its follower imparts radial displacement to the mounting through a predetermined cycle which cycle can, for example, be repetitive after each 360° relative axial rotation between the cutter and tube.

Although it is possible to rotate the cutter around the periphery of the tube end while the latter is stationary it is considered to be more convenient and it is preferred that the tube is mounted to exhibit rotation about its longitudinal axis and relative to the cutter so that the tube is intended to revolve past the cutter; in such an arrangement it is desirable that the cutter is mounted with its centre line substantially in a stationary plane which includes the longitudinal axis of the tube. Bearing in mind the desired synchronisation as abovementioned between the rotation of the tube and relative movement between the pattern and its follower, a first drive arrangement for axially rotating the tube is preferably synchronised with a second drive arrangement for rotating the cam as aforementioned so that the angular velocity at which the cam is rotated will substantially equal that at which the tube will be rotated.

It is preferred that the cutter is adjustably mounted or tiltable so that the angle which its centre line subtends with the longitudinal axis of the tube can be changed. Heavy duty metallic tubes are generally cut using an oxygen or other gas mixture flame while heavy duty plastics tubes may be cut by use of a laser beam or plasma stream; for convenience such flame, beam or stream cutters which cut along a centre line are intended to be included in the term "flame" or "cutter" as referred to herein. The cutter when tiltable mounted should be so mounted for rotational movement about the secondary axis for changing the angle of the bevel surface and it may be controlled manually in so far as this rotational movement is concerned. Alternatively, such rotational movement of the cutter may be controlled automatically by use of the Morgan system as is discussed in Morgan's U.K. Patent Specification No. 1013738. By the Morgan system the cutter is

connected through a linkage to a pivot point the position of which is intended to be fixed relative to the longitudinal axis of the tube so that, during axial displacement between the cutter and the tube, the linkage automatically imparts rotational movement to the cutter about the secondary axis, the extent of which movement is related to axial displacement between the cutter and the tube from a predetermined condition; consequently the angle subtended by the centre line of the cutter relative to the axis of the tube will be varied automatically to an extent predetermined by the linkage.

Conveniently the cutter is situated on a carriage which is intended for movement along a path parallel to the longitudinal axis of the tube, the carriage being movable relative to the tube axis by a drive arrangement which is responsive to line follower means. The line follower means serves to control the drive arrangement to automatically adjust the axial position of the carriage and thereby of the cutter to follow the predetermined path for the end of the tube during relative rotation between the tube and cutter. Suitable line followers for automatically adjusting the position of the carriage and thereby of the cutter axially to follow a predetermined path relative to the periphery of a tube are well known in the cutting and welding art and as such will not be discussed in detail herein. However, it is envisaged that in practice a guide line will be marked on the tube to correspond with and be parallel to (but spaced from) the predetermined path for the end of the tube so that the guide line will be followed by an optical detector during relative rotation between the tube and the detector. The detector emits signals to the drive arrangement for the carriage so that the latter moves axially in either sense of direction to ensure that the cutter moves relatively along a path which is parallel to the guide line and follows the desired profile for the tube end. This particular arrangement is most convenient for initial cutting of the tube to provide a profiled end on which the bevel is to be formed. An example of a suitable line follower device is that sold by The British Oxygen Company Limited under the Trade Mark "FALCON 23". By the present invention the tube may be rotated about its longitudinal axis and relative to the cutter and axial displacement of the cutter controlled in a first cut to cut the tube and provide a profiled end face in which is located the predetermined notional line of contact for that tube end with a further body. Furthermore the cutter may then provide a second cut whereby it is radially displaced relative to the longitudinal axis of the tube and to the profiled end face to cut the tube wall and form the bevel surface; such radial displacement of the cutter is synchro-

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nised with rotation of the tube so that the cutter substantially follows the notional line of contact to form the transition line. With this in mind the present invention also provides apparatus for forming in two cuts a junction line on the end face of a tube having a substantial wall thickness and which junction line follows a predetermined notional line of contact between the tube and a surface with which the tube may be joined, said junction line extending across the end face of the tube from a first position on the inner surface of the tube wall to a second position on the outer surface of the tube wall across the end face of the tube, the apparatus comprising a cutter disposed in cutting position relative to the wall of the tube; drive means to produce relative rotational movement between the cutter and the wall of the tube; means for moving the cutter axially along the wall of the tube during said relative rotation to profile the end of the tube on a first cut to form an end face which includes on its surface the notional line corresponding to said junction line and to follow said profile on the second cut; and control means which is synchronised with said relative rotation and controls radial displacement of the cutter during said relative rotation and axial movement on the second cut to partially bevel the end face along said notional line to form said junction line.

In the majority of cases the profiled end face of the tube will be formed to correspond to the notional line of contact in such profiled end face passing through a first position on the outer peripheral edge of the profiled end face and through a second position peripherally remote from the first position on the inner peripheral edge of the profiled end face. In such cases the bevel surface will be cut to form a transition line which progresses radially inwardly relative to the longitudinal axis of the tube substantially through the wall thickness of the tube from the first position on the external peripheral surface of the tube wall to the second position on the internal peripheral surface of the tube wall. Preferably the end of the tube is cut initially so that the profiled end face formed thereon is maintained at substantially 90° to the longitudinal axis of the tube throughout the peripheral extent of that end face. By such initial formation of the profiled end face the profiled end of the tube can then be shaped by cutting the bevel surface so that when the tube is positioned adjacent to the curved surface to which it is to be welded, the aforementioned first position of the tube wall can be located on the outer peripheral surface of the tube to correspond to a position in which a minimum acute angle or right angle is subtended between that peripheral surface and the curved surface or tangent thereto of the

body to which the tube is to be welded while the aforementioned second position of the tube wall is located to correspond with the position at which the outer peripheral surface of the tube subtends an obtuse angle with the curved surface or tangent to such surface of the body to which the tube is to be welded. The effect of this arrangement is to provide a channel wholly or partly around the periphery of the tube between the profiled end of the tube and the curved surface which channel progressively deepens and possibly broadens as it approaches the said second position from the first position - thereby permitting efficient usage of the weld material to fill the channel while any peripheral region of the tube having no such channel may be welded within the angle subtended between the peripheral surface of the tube and the curved surface on the body with which the tube is mated.

More particularly the present invention provides a method of shaping an end of a tube of substantial wall thickness which is to be welded to a curved surface of a further body so that the axis of the tube is disposed in a predetermined angular relationship with the curved surface of the further body which method comprises profiling the end of the tube to provide a profiled end face having a shape by which the tube is intended to be positioned adjacent to the curved surface of the further body with said tube substantially contacting the further body at a first position on the outer peripheral edge of the end face and at a second position on the inner peripheral edge of the end face peripherally remote from the first position and so that a notional line in said profiled end face includes said first and second positions and corresponds to a theoretical continuous line of contact for fitting the end face to said curved surface in substantially complementary relationship and at the predetermined angular relationship; cutting the profiled end of the tube wall to provide a bevel surface thereon which extends across at least part of the profiled end face of the tube to its outer peripheral surface, and controlling the cutting of the bevel surface so that the junction between the profiled end face and the bevel surface forms a transition line which line substantially follows said notional line where that line deviates from the outer and the inner peripheral edges of the profiled end face as initially formed and progresses across the wall thickness of the tube so that the profiled end face can be mounted adjacent to the curved surface at the predetermined angular relationship with substantially line contact along said notional line and the curved surface. This particular method is convenient for shaping an end of a substantially cylindrical tube which is to be mounted on a cylindrical surface of a further

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body so that the axis of the tube is disposed at a predetermined acute angle relative to and in a common plane with the axis of the cylindrical surface of the further body. The cylindrical tube may therefore have its end profiled to provide the profiled end face with a shape by which the tube is intended to be mounted adjacent to the cylindrical surface of the further body and with said tube substantially contacting the further body at the first position on the outer peripheral edge of the profiled end face in which the cylindrical outer surface of the tube subtends an acute angle in said common plane with the cylindrical surface of the further body and at the second position on the inner peripheral edge of its profiled end face in which the cylindrical outer surface of the tube subtends an obtuse angle in said common plane with the cylindrical surface of the further body and so that the notional line in the profiled end face includes said first and second positions and corresponds to the theoretical continuous line of contact for fitting the profiled end face to the curved surface in substantially complementary relationship with the respective axes disposed at the predetermined acute angle. The profiled end of the tube wall may then be cut to provide the bevel surface which extends across at least part of the profiled end face of the tube to its outer cylindrical surface. Such bevel cutting is controlled so that the transition line formed between the end face and the bevel surface progresses inwardly to substantially follow the notional line across the wall thickness of the tube from the outer to the inner cylindrical surface of the tube.

As aforementioned the cutting of the bevel surface may be controlled so that the bevel angle subtended by the bevel surface with the longitudinal axis of the tube varies along the peripheral extent of the bevel surface, these variations in the bevel angle being controlled by changing the angle of the cutter relative to the axis of the tube. Usually the angle of the cutter will be changed during cutting of the bevel surface solely during relative axial displacement between the cutter and tube.

Preferably, when cutting a cylindrical tube, the flame of the cutter is arranged to pass at 90° through the or a secondary axis which secondary axis is maintained substantially perpendicular to a plane which includes the longitudinal axis of the tube and is also maintained in a plane tangential to the tube wall; during cutting of the bevel surface, the intersection of cutter flame and the aforementioned secondary axis should be controlled so that such intersection is maintained on the notional line of contact. Further, when it is intended that the angle subtended by the bevel surface with the axis of the tube should be changed along the

periphery of the profiled end face, then such bevel angle should be varied by rotating the cutter about the aforementioned secondary and in that plane which includes the longitudinal axis of the tube.

The present invention will usually be applied to the shaping of an end of a tube which is to be welded to a convex curved surface although the possibility is envisaged of applying the invention to tube ends which are to be welded to concave surfaces. Although the tube to be shaped will usually be cylindrical as aforementioned the invention may be used for shaping tubes of other section, for example of elliptical or polygonal section. Furthermore, the curved surface to which the tube is to be welded will not necessarily be of cylindrical form and may, for example, be of spherical or elliptical configuration.

It is envisaged that the invention will mainly be applied to the preparation of a cylindrical tube end for welding to the cylindrical surface of a further tube, for example as above mentioned in the construction of tubular steel jackets for off-shore drilling rigs and in such a combination, although convenient, it is not considered essential for the axes of the two tubes to intersect each other. For example, on this latter point the tube having the profiled end may be welded to a further tube having a considerably larger diameter so that the two tubes extend at an acute or right angle with respect to each other with the profiled tube positioned partially or wholly to one side of a plane which is parallel to the axis of the profiled tube and includes the axis of the larger diameter tube. Furthermore, the tube having the profiled end may be welded into a junction of two or more further tubes (which together may be regarded as constituting the surface of the further body) so that the profiled end would eventually be welded partially to each of the further tubes; such an arrangement may necessitate complex geometrical profiling for the end face but nevertheless appropriate transition bevelling may be provided in accordance with the invention, particularly by appropriate design of the cam or other pattern which may determine the radial displacement of the cutter. Also in accordance with the present invention therefore, there is provided tube bevelling apparatus for profiling the end of a tube having a longitudinal axis to provide an end face which may be joined to an intersecting surface by a continuous joint, and comprising a cutter which has a centre line along which it is intended to cut the tube wall and which is to be moved relative to the periphery of the tube and is disposable at a variable angle relative to the axis of the tube about a secondary axis which is intersected by the centre line of the cutter to cut a predetermined bevel in

the end face of the tube, and wherein there is provided a displaceable mounting for the cutter for moving said secondary axis radially with respect to the tube; and means to move said secondary axis radially with respect to the tube axis in synchronous relation with the relative movement of the cutter and the tube to cause the point of intersection of the cutter centre line and the secondary axis to follow a notional continuous line in the end face of the tube which line substantially corresponds to a continuous line of contact for the tube end face in forming the continuous joint and includes part lengths of each of the inner and outer peripheral surfaces of the tube connected by a transition line extending across the thickness of the tube end face and cause the cutter to cut said end face to provide a bevelled end face surface which is bounded by and follows the continuous line of contact as it proceeds across the thickness of the tube between the inner surface and outer surface of the tube.

Embodiments of the present invention will now be described by way of example only with reference to the accompanying illustrative drawings in which:-

Figure 1 is a side elevation showing two cylindrical tubes in a position in which they are intended to be joined together with a branch tube of substantial wall thickness having an end profile for mating with the cylindrical surface of the other main tube;

Figure 2 is an axial view of the profiled end of the branch tube in Figure 1;

Figure 3 is a similar view to that shown in Figure 1 and illustrates the manner in which the profiled end of the branch tube is to be shaped with a bevel surface and mounted on the main tube in substantially complementary relationship;

Figure 4 is an axial end view of the branch tube shown in Figure 3 and illustrates transition lines formed between the bevel surface and an end face of the tube;

Figure 5 is a perspective view of the profiled end of the branch tube and illustrates the bevel surface and end face as seen from the direction of arrow X in Figure 4;

Figure 6 is a side elevation of one embodiment of tube cutting apparatus constructed in accordance with the present invention and by which the end of the branch tube shown in Figures 1 to 5 may be profiled and shaped while said branch tube is disposed with its axis vertical;

Figure 7 is an end elevation of the apparatus shown in Figure 6;

Figure 8 is a plan view of the apparatus shown in Figure 6;

Figure 9 is an enlarged part of the apparatus shown in Figures 6 to 8 and illustrates a plan view of a carriage and associated devices for controlling displacement of the cutter radially relative to the tube and tilting

movement of the cutter;

Figure 10 is a side elevation of the arrangement shown in Figure 9;

Figure 11 is a side elevation of a modified form of pattern which may be incorporated in the arrangement of Figures 9 and 10 and which pattern may be adjusted to provide a cam surface that the cutter is to follow to provide a predetermined transition line;

Figure 12 is an end elevation of the adjustable pattern as shown in Figure 11;

Figure 13 (A and B) is a side elevation of a further embodiment of tube cutting apparatus constructed in accordance with the present invention and by which the end of the branch tube shown in Figures 1 to 5 may be profiled and shaped while said branch tube is disposed with its axis horizontal;

Figure 14 is an end elevation of the apparatus shown in Figure 13 as seen from the position of arrows XIV in Figure 13, and

Figure 15 is an end view of the apparatus shown in Figure 13 as seen from the position of arrows XV in Figure 13.

In the construction of a steel framework or jacket as used in the assembly of an offshore drilling rig it is often necessary for a cylindrical tube 1 to have an end welded to a further cylindrical main tube 2 to branch therefrom with the respective axes in a common plane Y and inclined at an acute angle α (which could be, say 45°) to each other (see Figure 1). The branch tube 1 which is usually formed of high tensile steel may have an external diameter in the order of 2 metres and a substantial wall thickness of, for example, 12 cms while the main tube 2 has an external diameter somewhat larger than that of the branch tube. To achieve an effective join the end of the tube 1 is profiled to provide an end face 3 which straddles the cylindrical surface of the tube 2 so that the tube 2 is intended to be received in complementary relationship within the saddle surface of the profiled end and with the end face 3 adjacent to the cylindrical surface of the tube 2.

If the end face 3 is considered as being disposed at 90° to the axis of the tube 1 throughout its peripheral extent, and bearing in mind that the tube 1 has a relatively thick wall, it will be seen from Figure 1 that for the tubes to be mated in complementary relationship the external cylindrical surface of the tube 1 will substantially abut the cylindrical surface of the tube 2 at a first position A where the external surface of the tube 1 subtends the acute angle α with the cylindrical surface of the tube 2 in the aforementioned common plane Y while the inner cylindrical surface of the tube 1 will substantially abut the cylindrical surface of the tube 2 at a second position B where the external surface of the tube 1 subtends an obtuse angle β with the cylindrical surface of

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the tube 2 in the common plane Y. This being the case, a notional endless line may be regarded as being located in the plane of the profiled end face 3 and which line is symmetrical about the common plane Y, will pass through the positions A and B and is capable of providing substantially line contact in complementary relationship with the cylindrical surface of the tube 2. This notional line of contact will move radially inwardly over the end face 3 as it progresses around the periphery of the profiled end from the position A towards the position B. With the end of tube 1 appropriately profiled a notional line of contact as shown in Figures 3 and 4 can be identified; this notional line (as seen axially of the tube) follows a predetermined path which is constituted by a first part 5a that passes through the position A on the tube and terminates at D at the inner cylindrical surface of the tube, and a second part 5b which substantially coincides with the inner cylindrical surface of the profiled tube end and extends between the terminals D of the first part 5a to pass through the position B. Once the path of this notional line 5a, 5b has been determined it will be apparent that by shaping the profiled tube end to provide a bevel surface 4 (see Figure 5) which extends between the end face 3 and the external cylindrical surface of the tube 1 and forms with the end face 3 a transition line 5 which substantially corresponds to the part lengths of the notional line 5a, which extend from the outer to the inner peripheral edges of the end face 3 (that is between the points C and D in Figure 5), the tube end so shaped may be mounted on the main pipe 2 in substantially complementary relationship with the transition line 5 closely adjacent to or in contact with the cylindrical surface of tube 2. With the tubes mounted in this complementary relationship they may then be welded together with the weld filler material following a track constituted by the channel formed around the profiled end of tube 1 between the bevel surface 4 and the cylindrical surface of tube 2. Where necessary the weld filler material will extend between the external cylindrical surface of tube 1 and the cylindrical surface of tube 2; this may be especially so in the peripheral tube end region of position A where the radial depth and axial width of the channel formed by the bevel surface may be insufficient to accommodate the necessary volume of weld material.

The profiled end face 3 (see Figure 5) of the tube 1 may initially be cut so that it contains the predetermined path of the notional line and always extends at 90° to the axis of the tube 1; by such initial cutting a clearance may be provided (when seen in a section taken radially of the tube 1) between the

cylindrical surface of the tube 2 and the majority of the peripheral length of the end face 3 which is radially inward of the notional line of contact and that any such end face 3 will usually diverge from the surface of tube 2 as the end face 3 progresses radially inwardly of the tube 1. The effect of this diverging clearance should alleviate the difficulty of void detection between the tube end face 3 and the tube 2 during ultrasonic testing of the weld. If necessary the radially inner part of the end face 3 may be chamfered to provide additional diverging clearance.

Alternatively the profiled end face 3 of the tube 1 may initially be cut so that it contains the notional line of contact and extends at a constant predetermined acute or obtuse angle to the axis of the tube 1 (in effect so that the profiled end face 3 is in the form of a positive or a negative bevel or chamfer partially or wholly around the end of the tube). Initial preparation of the end face 3 in this way and with a positive bevel to the end face 3 may be desirable in circumstances where, for example, the angle α between the tubes 1 and 2 is greater than say 50° and, at position B in Figure 3; there would be insufficient angular clearance for efficient welding if the end face 3 was formed at 90° to the axis of its tube.

We will now consider with reference to Figures 6 to 12 a first embodiment of apparatus by which the end of the branch tube 1 can be appropriately shaped by profiling and bevelling as above described.

The tube 1 is mounted with its axis vertical so that its lower end stands on a horizontal turntable 6. The turntable 6 is mounted on a bogie 7 and is rotatable on the bogie about a vertical axis by an electric motion 7a. The bogie permits horizontal adjustment in the positioning of the tube 1 relatively towards and from a vertical column 8 carried by a tubular support frame 8a. With the tube 1 centrally disposed on the turntable 6, the correct positioning of the bogie 7 (and thereby of the tube) is achieved when the external cylindrical wall of the tube abuts a roller 6a mounted for rotation about a vertical axis on a frame part 6b fixed relative to the column 8. Mounted on the column 8 for controlled vertical movement up and down the column is a carriage 9 which carries a flame cutter 10 fuelled by an oxygen mixture gas through pipes 10' and the frame from which is directed for cutting along a centre line of the cutter. The position of the carriage 9 along the column 8 may be controlled through a rack and pinion mechanism (not shown) from an appropriate drive unit. The carriage 9 is counterbalanced through an interconnecting chain 8b by a weight 8b' slidably housed in the support frame 8a.

The tube 1 is mounted on the turntable 6 in an uncut condition (save for the lower-

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most end of the tube being cut to lie in a radial plane so that it will stand vertical on the turntable) and thereafter the tube is initially cut to provide the end face 3 which conforms to the appropriate profile and which has in its plane the aforementioned notional line of contact 5a, 5b which follows the continuous and predetermined path for mating with the cylindrical surface of the tube 2 in complementary relationship. In the present example the end face 3 will, for convenience, be considered as extending at 90° to the axis of the tube 1 throughout the peripheral extent of the face 3. To achieve this initial profiling the cutter 10 is positioned and maintained on the carriage 9 so that its centre line and flame project radially into the wall of the tube while the latter is axially rotated with the turntable 6 and the carriage 9 is displaced vertically on the column 8 to cut a predetermined shape (shown at 3' in Figure 6) around the periphery of the tube which corresponds to the end face 3. In this way the end face 3 which is exposed on the lower portion of the tube (after removal of the upper severed portion of the tube) is always at right angles to the axis of the tube irrespective of the axial positioning of the end face over the length of the tube. Vertical displacement of the carriage and cutter 10 is automatically controlled by a line follower device, known in the art, so that the carriage 9 is adjusted in its vertical positioning on the column 8 as a result of control signals derived from an optical scanning unit 11 positioned vertically below the cutter 10 on the carriage 9. The unit 11 follows a line 12 previously drawn around the periphery of the tube 1 to correspond with the desired path of line 3' but axially spaced therefrom by a vertical distance corresponding to the vertical spacing between the cutter 10 and optical scanner 11. In this way as the scanner 11 is adjusted vertically to follow the line 12 the carriage 9 and thereby the cutter 10 automatically moves to cut the appropriately shaped end profile. If required either or both the cutter 10 and scanning unit 11 can be axially adjustable on the carriage 9 to facilitate setting in determining the axial length of the cut pipe (especially if the axial positioning of the line 12 on the tube is inaccurate).

After cutting of the end face 3 the apparatus is prepared for cutting the bevel surface 4 and we will now describe with particular reference to Figures 9 and 10 the manner in which the cutter 10 is carried on the carriage 9 in order to achieve cutting of the bevel surface 4. For convenience the optical scanning unit 11 has been omitted from the carriage 9 in Figures 9 and 10.

The carriage 9 includes a sub-frame 13 which is movable vertically with the carriage but is displaceable horizontally thereon in a

direction parallel to, but not including, a radial line of the tube 1 and it is this sub-frame 13 which actually carries the cutter 10. The sub-frame 13 comprises a pair of parallel rods 13a which are horizontally slidable in linear bearings through tubes 9a on the part of the carriage 9 which is capable only of vertical displacement and which rods 13a are interconnected by cross members 13b and 13b' of the sub-frame. The part lengths of the rods which extend from the tubes 9a are enclosed within bellows 13c which protect the rods and may retain lubrication for the linear bearings. The cutter 10 is mounted at the end of an arm 14 which lies in a radial plane of the tube 1 and which is rigidly carried by a block 15. The block 15 is mounted on a shaft 16 extending from the cross member 13b so that it can rotate with the shaft and in bearings 16a in the cross member 13b about a secondary axis 17 (see Figure 9) which extends tangentially to the cylindrical profile of the tube 1. The secondary axis 17 is located in a plane which is perpendicular to the axis of the tube 1 and extends at right angles to a plane which includes both the axis of tube 1 and the centre line (or flame) of cutter 10. The cutter 10 is positioned on the arm 14 so that the flame along its centre line intersects the secondary axis 17 at 90° and consequently if that intersection is maintained in the end face 3 it will be apparent that by appropriate rotational adjustment of the block 15 about the axis 17, the flame from the cutter 10 may either be directed parallel to the end face 3 or at progressively increasing angles relative to the plane of the end face 3 to cut a bevel surface at the outer periphery of the profiled end of the tube 1. For example, by rotating the cutter 10 about the axis 17 and securing it at a predetermined angle relative to the axis of the tube, and thereafter axially rotating the tube while the axis 17 is located and maintained at a tangent to the internal cylindrical surface of the tube 1 (as drawn in Figure 9), a bevel surface will be cut around the full external periphery of the profiled end of the tube which bevel is of constant radial depth corresponding to the wall thickness of the tube. Following from this if it is now envisaged, as an alternative to the above described constant bevel cutting, that the sub-frame 13 is adjusted while the tube 1 is rotating to move the aforementioned intersection of the cutting flame and the secondary axis 17 radially outwardly through the wall thickness of the tube 1 from the position shown in Figure 9 (whilst retaining the axis 17 substantially tangential with the cylindrical profile of the tube wall and the aforementioned intersection in the plane of the end face 3) it will be found that during cutting of the bevel surface that surface forms a junction or edge with the pro-

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filed end face 3 which junction or edge moves progressively radially outwardly through the wall thickness of the tube 1 as the tube progressively rotates; this is the basis on which the bevel surface 4 is to be cut to follow the transition lines 5.

As previously discussed, the desired transition lines 5 for the profiled end of tube 1 should substantially correspond to the part lengths C to D of the notional line part 5a (Figure 5) and consequently the radial positioning of the secondary axis 17 relative to the tube 1 has to be controlled so that during relative rotation between the cutter 10 and the tube the bevel surface 4 is cut to form a junction line with the end face 3 which follows the transition line 5. To provide this control for the positioning of the secondary axis 17 radially relative to the wall thickness of the tube 1, the cross member 13b' (see Figure 9) of the sub-frame 13 carries a cam follower in the form of a roller 18. This roller 18 is mounted to run over a pattern constituted by the peripheral surface of a cam plate 19. The cam plate is conveniently formed by a circular disc 20 and a kidney shaped plate 21. The disc and plate 20, 21 are coupled together and mounted for unified rotation about, and are driven by, a shaft 22 of an electric motor 23. The shaft 22 is concentric with the disc 20 and this shaft together with its motor are carried by the carriage 9 to be vertically displaceable therewith. If required, spring means such as that shown at 24 (Figure 9) can be provided between the fixed tubes 9a of the carriage 9 and the sub-frame 13 to bias the roller 18 into engagement with the periphery of the cam plate 19.

When the cam plate is rotated by the shaft 22 it will be apparent that there will be no displacement of the sub-frame 13 relative to the tubes 9a for so long as the roller 18 follows the cylindrical surface of the disc 20. However, immediately the roller 18 moves on to the peripheral surface of the kidney plate 21 there will be displacement of the sub-frame 13 radially relative to the tube 1 and this displacement progressively moves the sub-frame 13 to a maximum radial distance outwardly of the tube 1 thereafter progressively permitting the sub-frame 13 to return to the minimum radial distance from the tube 1 as the roller 18 moves from the periphery of plate 21 to return to the circumferential surface of the disc 20.

The drive to the shaft 22 by the motor 23 is synchronised with rotation of the turntable 6 and thereby the tube 1 so that the tube 1 and cam plate 19 are rotated at the same angular velocity whereby one revolution of the tube corresponds to one revolution of the cam plate.

The shape of the cam surface presented by the cam plate 19 to the roller 18 is pre-

termined in accordance with the geometrical configuration of the notional line of contact which is located on the tube end face 3 and bearing in mind that while the roller runs over the surface of disc 20, the intersection of the flame along the centre line of the cutter 10 and the secondary axis 17 is not radially displaced relative to the tube 1 from the Figure 9 position and that as the roller engages with the kidney plate 21 such intersection may be radially displaced through the pipe wall thickness. Consequently, in the present example, the cam surface part presented by the plate 21 is intended to determine the shape of the notional line (which corresponds to a theoretical line of contact between the end of tube 1 and the tube 2) where this deviates from the cylindrical inner edge of the profiled end face 3 (as viewed axially of the tube 1). Since the intersection of the cutter flame with the axis 17 is intended to be displaced through the wall thickness of the tube 1 during rotation of the latter, then the maximum radial distance from the peripheral surface of the kidney plate 21 to the axis of shaft 22 less the radius of the circular disc 20 should substantially equal the wall thickness of the tube 1 (that is in Figures 9 and 10 the distance x is equal to the radial wall thickness of the tube 1). The shape of the periphery of the plate 21 with which the roller 18 engages will therefore substantially correspond to the shape of the notional line (as viewed axially of the tube) where this line extends remote from the inner peripheral edge of the profiled end face 3 (that is the notional line part 5a in Figures 4 and 5).

To form the transition line 5 the cam plate 19 is first rotated through 180° relative to the roller 18 from the position shown in Figures 9 and 10 (so that the secondary axis 17 extends tangentially to the outer cylindrical surface of the tube wall) and the tube 1 is positioned relative to the cutter 10 so that the cutter is located adjacent to the first position A on the profiled end of the tube. The assembly of the cutter 10, arm 14 and block 15 is rotated about the secondary axis 17 to provide a required angle at which, for example, the cutting flame subtends an angle of 15° with the axis of the tube while the cutting flame will lie in a plane which includes the tube axis and will intersect the axis 17 in the end face 3. Flame cutting is now initiated simultaneously with axial rotation of the tube 1 (which is synchronised with rotation of the cam plate 19 about shaft 22) and vertical displacement of the carriage 9 over the column 8 under control of the optical follower 11 to maintain the intersection of the cutter flame with the secondary axis 17 in the plane of the end face 3.

During movement of the roller 18 over the periphery of plate 21 the sub-frame 13 is

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progressively displaced downwardly in Figure 9 and thereby progressively displaces the intersection of the cutting flame and secondary axis 17 in the end face 3 radially inwardly from the outer cylindrical surface towards the inner cylindrical surface of the tube 1 so that the transition line 5 follows a part length C to D of the notional line part 5a. When both the cam plate and tube have rotated through 180° the intersection of the cutting flame and axis 17 will be positioned at the inner peripheral edge of the tube at the second position B (corresponding to where the angle β is to be formed between the welded tubes). Continued rotation of the pattern beyond the aforementioned 180° position eventually progressively moves the sub-frame 13 upwardly in Figure 9 and causes the intersection of the cutting flame with the secondary axis 17 to move radially outwardly through the wall thickness of the tube in the plane of the end face 3 from the inner cylindrical surface towards the outer cylindrical surface of the tube so that the transition line 5 follows the other part length D to C of the notional line part 5a (thereby progressively decrease the radial depth of the bevel surface 4) until the roller 18 eventually moves back to the centre point of its maximum displacement on the peripheral surface of plate 21 where no bevel surface is formed and one revolution is simultaneously completed for the cam plate 19 and the tube 1. As an alternative to the aforementioned 360° continuous rotation of the tube 1 relative to the cutter, cutting of the bevel surface may be achieved by initially setting up the cutter at the position A as above described and then rotationally reciprocating the turntable and tube so that first one transition line side C to D of the tube is cut with the turntable 6 rotating in one direction and thereafter the turntable is reversed so that the cutter passes through position A and cuts the opposite transition line side C to D of the tube (during such reciprocal rotation of the tube it is ensured that rotation of the cam plate 19 is reciprocated in synchronisation therewith).

Since the correct positioning of the tube 1 in the apparatus is determined by the correct location of the external cylindrical surface of the tube (that is when this surface abuts the roller 6a) by movement of the bogie 7, it should be ensured prior to initial bevel cutting for tubes of different wall thicknesses that the radial position, relative to the tube, of the secondary axis 17 in Figure 9 is correctly adjusted so that that axis lies tangentially to the inner or the outer circumferential surface of the tube end as appropriate. To facilitate such adjustment, the roller 18 is carried on a bar 25 of the sub-frame 13 which bar is adjustable relative to the remaining part of the sub-frame so

that the cross member 13b and thereby the axis 17 can be raised and lowered (see Figures 9 and 10) relative to the roller 18 in accordance with the tube wall thickness. Conveniently the strut 25 is calibrated as shown in Figure 9 for various tube wall thicknesses.

If the angle subtended by the centre line of the flame cutter 10 with the axis of the tube 1 is maintained constant during the formation of the bevel surface, the bevel surface as a whole so formed may be unsuitable since the bevel angle formed between a particular region of the bevel surface and a plane which is tangential to the cylindrical surface of the tube 2 at that region will vary around the peripheral extent of the bevel surface as a result of axial displacement between the tube and cutter as the latter follows the profiled end shape. For example, if the tube 1 is rotated to a very small extent while the cutter 10 undergoes a considerable vertical displacement, there will be negligible bevel on the part of the profiled end surface corresponding to such vertical displacement of the cutter since this part of the profiled end face may be considered as lying in a plane which includes the axis of the tube 2. Desirably the angle subtended by the bevel surface and the plane which is tangential to the cylindrical surface of the tube 2 should be constant (preferably in the range 45° to 60°) for all regions around the periphery of the bevel surface. To achieve such a constant subtended angle it is necessary that the angle subtended between the centre line of the cutter 10 and the axis of tube 1 during formation of the bevel surface is changed progressively as the cutter moves around the periphery of the profiled end from a subtended angle of, say, 15° between the cutter 10 and the axis of tube 1 in the positions C progressively increasing to 90° in the peripheral region of position B. The angle of the cutter 10 relative to the axis of the tube 1 is changed by rotating the block 15 and thereby the centre line of the cutter 10 about the secondary axis 17 (so ensuring that the intersection of the cutting flame and the axis 17 is maintained in the plane of the profiled end face 3). Adjustment of the angle of the cutter 10 by rotation about the axis 17 as appropriate may be controlled manually. Alternatively, however, automatic adjustment of the cutter angle may conveniently be provided by use of the control system disclosed by Morgan in British Patent Specification No. 1,013,738. By the Morgan system a rod 26 is fixed at one end for rotation with the shaft 16 and is coupled at its other end for rotation about a pin 27 which is secured to a vertical secondary column 8c. The rod 26 extends radially relative to both the shaft 16 and pin 27 while the axis of centre line of the latter intersects the axis

of the tube 1. Further, the axis or centre line of the pin 27 lies in a plane which includes the axis of the tube 1 and which is at 90° to the plane which includes the axis of the tube 1 and the cutter 10. The coupling between the rod 26 and pin 27 permits a lost motion effect between these components and conveniently is formed by the end of the rod 26 being received within a bifurcated part of the pin 27 so that the distance between the shaft 18 and pin 27 may be increased or decreased.

The pin 27 is adjusted on the secondary column 8c to a position in which it is located approximately mid-way between the vertical spacing of positions A and B of the profiled end of the tube. With the cutter 10 positioned on the carriage 9 to correspond with the first position A on the profiled tube end, the cutter is arranged on the arm 14 to provide the required bevel angle (of say 15°) subtended between the bevel surface and the axis of the tube 1. As cutting of the bevel surface commences from the position A and the tube rotates beneath the cutter 10, the carriage 9 is moved vertically over the support 8 to follow the profile of the tube end and thereby the relative movement between the carriage 9 and pin 27 causes the rod 26 to progressively rotate the shaft 16. This results in the angle subtended between the bevel surface 4 and the axis of the tube 1 progressively increasing to a maximum when the tube has rotated for the cutter to be located at a region 4a (Figure 5). Further rotation of the tube beyond the region 4a, through the position B and beyond the second region 4a causes the angle subtended by the bevel surface to be progressively decreased until the position A is again reached by the cutter. The regions 4a indicate where the cutter has rotated under control of the Morgan system sufficiently for the flame to move out of the wall of the tube so that no bevel cutting is effected for the peripheral extent of the profiled end face from one region 4a, through position B, to the other region 4a. The lost motion connections between the rod 26 and pin 27 ensures that the carriage 9 is free to move relative to the pin 27 as the carriage is displaced vertically over the column 8 and also as the sub-frame 13 is displaced in the carriage 9. For convenience the rod 26 is shown as being straight in Figures 9 and 10 whereas in practice it is likely to be of dog-legged form as shown in Figure 8.

During rotational movement of the cutter 10 about the secondary axis 17 and also during radial displacement of the axis 17 through the wall thickness of the tube 1 it will be apparent that the cutter, particularly the nozzle 28 thereof will be displaced radially relative to the tube 1 and as a result there may be variations in cutting efficiency. To alleviate this possibility the nozzle 28 is

motor controlled to be capable of controlled movement radially of the tube 1 and relative to the arm 14. As shown in Figure 9 the cutter 10 comprises a housing 29 secured to the arm 14 and within which housing is maintained the nozzle 28. The nozzle 28 is capable of sliding movement in its housing in the radial direction of the tube 1 and has fixedly attached thereto a fixed nut 30 which engages with a lead screw 31. The lead screw is rotationally mounted in bearings in the housing and is driven by an electric motor 32 through gearing 33. Upon rotation of the lead screw 31 the nozzle 28 will be driven towards or from the outer face of the tube 1 so that optimum flame cutting conditions can be maintained irrespective of variations in radial spacing between the housing 29 and the tube 1. Energization of the motor 32 to effect displacement of the nozzle 28 is manually controlled by an operator supervising the cutting operation. The apparatus includes an operator's platform 34 from which the cutting operation is eventually supervised and which carries a control unit 35 for the equipment. The platform 34 is mounted on a vertical column 36 to be capable of vertical displacement thereon so that the operator can follow vertical movement of the carriage 9 and thereby remain in the vicinity of cutting. Vertical displacement of the platform 34 may be achieved through a rack and pinion drive mechanism provided between the platform and the column 36. If required, the drive system for displacing the platform 34 may be automatically controlled simultaneously with the drive system for displacing the carriage 9 so that the platform automatically follows the carriage.

If the cutter 10 is to be used for forming an initial profiled end face 3 which is maintained at right angles to the axis of the tube 1 then the cutter 10 is appropriately orientated and secured about the secondary axis 17 and the shaft 18 uncoupled from the rod 26 and the pin 27.

While it is convenient to form the profiled end face 3 so that such end face is always maintained at right angles to the axis of the tube 1 it is not essential and, if required, the profiled end face may subtend an acute angle with the axis of the tube wholly or partially around its peripheral extent provided that the transition line is located in such end face. To form such a profiled end face which is effectively an internal or external bevel surface on the profiled end of the tube, the cutter 10 is pivoted on the shaft 16 about the secondary axis 17 to form the required acute angle with the axis of the tube 1 and thereafter cutting is commenced. During such cutting the aforementioned Morgan system 26, 27 for automatically controlling rotational or pivotal movement of the cutter 10 is disconnected, however, the control system for

radial displacement of the cutter 10 relative to the axis of the tube 1 by engagement of the cam plate 19 with the roller 18 is maintained to ensure that throughout the formation of the profiled end face such face will be cut in a manner whereby the transition lines 5 will be located somewhere on the resulting profiled end face. After cutting of the profiled end face so that, in the present example part of the peripheral length of such end face will be inclined relative to the axis of the tube 1, the Morgan system is reconnected and transition line cutting effected to provide the appropriate bevelling of the profiled end face. During bevel cutting with the Morgan control system operative it is possible that the bevel which is formed at the end of the tube will run-out into the profiled end face (as previously discussed and shown at regions 4a in Figure 5).

It will be realised that by appropriate selection of the pattern or cam surface which is presented to displace the roller 18 of the sub-frame 13, the cutter 10 can be controlled in its radial displacement relative to the tube 1 to cut a bevel surface at the end of the tube which forms any predetermined transition line with the end face of the tube irrespective of the cross-sectional shape of the tube provided that the intersection of the secondary axis 17 with the centre line or cutting flame of the cutter is substantially maintained in the plane of the end face.

In the form of cam plate 19 as shown in Figures 9 and 10 the plate 21 is releasably secured by bolts to the plate 20 so that the plate 21 may easily be replaced by another plate comprising a different cam surface for changing the characteristics of the transition line which is to be formed at the profiled end of the tube. A modified form of pattern which may replace the cam plate 19 shown in Figures 9 and 10 is illustrated in Figures 11 and 12. This modified pattern is constituted by the peripheral surface presented by a pair of overlying circular discs 37, 38 of equal diameters. These discs are coupled together for unified rotation with the shaft 22. The disc 37 is provided with a radially extending slot 39 through which the shaft 22 extends and this disc is secured to the shaft 22 and to the disc 38 by a lock nut 40. By release of the lock nut 40 and sliding the slot 39 over the shaft 22 the disc 37 may be radially displaced to a predetermined extent relative to the disc 38, the latter being secured concentrically with the shaft 22. By displacing the discs 37, 38 eccentrically in this manner and thereafter tightening the lock nut 40 a figure eight profile is presented by the outermost peripheries of the combined discs and which profile is followed by the roller 18 as the unified discs rotate with the shaft 22. With the discs 37, 38 in overlying concentric relationship there will be no

displacement of the sub-frame 13 radially relative to the tube 1 as the pattern is rotated and therefore the axis 17 will be maintained at a predetermined radial position relative to the cylindrical surfaces of the tube 1. To provide predetermined cutting along a transition line in the profiled end face of the tube 1 the disc 37 is displaced eccentrically relative to the disc 38 to an extent which corresponds to the wall thickness of the tube 1; for example with a tube wall thickness of 5 inches the disc 37 is positioned so that its lowermost peripheral edge is 5 inches below the lowermost peripheral edge of the disc 38. To facilitate adjustment of the discs 37 and 38 in determining an appropriate figure eight cam profile, the disc 38 is provided with a radially extending scale 38a from which the amount of radial displacement of disc 37 relative thereto can easily be determined to correspond to the wall thickness of the tube which is to be bevelled.

If the end face 3 is profiled so that it includes a generally circular notional line of contact when viewed axially of the tube and if such a notional line of contact has a diameter equal to that of the outer diameter of the tube 1 less the wall thickness of the tube, is eccentric with the axis of the tube so that it lies on the outer diameter of the end face 3 in the first position A and on the inner diameter of the end face 3 in the second position B, then the pattern followed by the roller 18 may be in the form of a single circular disc which is radially displaceable to an eccentric position on the shaft 22. This single disc pattern is displaced and secured eccentrically to the shaft 22 to an extent which is equal to one half of the wall thickness of the tube 1 and is appropriately orientated so that the roller 18 displaces the cutter 10 to substantially cut along the notional line.

The apparatus as above described and illustrated with reference to Figures 6 to 12 refers to the profiled tube end being shaped while the tube is being rotated with its axis vertical and there will now be described with reference to Figures 13 to 15 a further embodiment of the apparatus in which the profiled end of the tube is formed and may be bevelled while the tube is rotatably supported with its axis horizontal. For convenience similar parts or members in Figures 13 to 15 to those in Figures 6 to 10 have been accorded the same references.

In Figures 13 to 15 the tube 1 is mounted with its axis horizontal on two sets of horizontally spaced rollers 41 and 42. Rollers in each of the two sets straddle the tube whilst those in set 41 are idler rollers and the rollers in set 42 are rotatably driven by an electric motor 43. By energisation of the motor 43 the rollers 42 impart drive to the tube 1 so that the latter is rotated about its horizontal

axis. The sets of rollers are mounted on fixed bases 44 between a pair of parallel ground rails 45 which extend parallel to the axis of tube 1. Mounted through wheels 46 on the rails 45 is a box-like framework 47 which is movable along the rails to straddle the tube 1 after the latter has been mounted on the rollers 41 and 42. One of the wheels 46 is rotatably driven by an electric motor 48 to move the framework 47 as required. One side of the framework 47 includes a spaced array of three vertical columns 49. These columns 49 provide location through guide plates 51 for a horizontal beam 50 which is vertically slidable with the plates 51 along the respective columns 49 so that the height of the beam relative to the rollers 41 is adjustable. Vertical displacement of the beam 50 is controlled by an electric motor 52 which actuates winch systems 53 having cables 54 connected at longitudinally spaced positions to the guide plates 51. As shown in Figure 13, three winch systems are provided which are driven by a common shaft 55 rotated by the motor 52; the shaft 55 is mounted in bearings 56 on the framework.

The beam 50 serves a similar purpose to the column 8 in Figure 6 in that there is mounted on the beam 50 for controlled horizontal movement along the beam a carriage 9 on which is situated or coupled thereto a flame cutter 10, optical scanning unit 11, displaceable sub-frame 13, cam plate 19 and associated components (including the Morgan linkage system 26, 27) for controlling displacement of the cutter 10 radially relative to the axis of the tube 1 and rotation of the cutter in a similar manner to that described with reference to Figures 9 and 10. Consequently the scanning unit 11 follows a line 12 (shown at the right hand end of the tube in Figure 13) previously drawn around the periphery of the tube 1 to correspond with the desired path of the profiled end 3 of the tube but axially spaced therefrom by a horizontal distance correspond to the horizontal spacing between the cutter 10 and optical scanner 11. In this way as the scanner 11 is adjusted horizontally to follow the line 12 which rotates beneath it, the carriage 9 and thereby the cutter 10 automatically move to cut appropriately shaped end profiles.

The cam plate 19 is driven by its motor 23 at the same angular velocity as that at which the tube 1 is axially rotated as previously described. To ensure that the speed at which the cam plate 19 rotates is synchronised to the speed at which the tube 1 rotates so that both these components complete one revolution in the same time, the rate at which the motor 23 is actuated to drive its cam plate is synchronised with the speed at which the tube is rotated. To provide such synchronisation the apparatus includes an

end carriage unit 57 which is horizontally displaceable on rollers 58 along the rails 45 until an arm 59 on the end carriage unit adjacent to the end of the tube 1 remote from that end 3 which is to be profiled can be coupled at 60 to the wall of the tube 1. The arm 59 is rotatable with a shaft 61 and the axis of this shaft is located to lie in the same vertical plane as the axis of the tube 1. In addition, the shaft 61 is vertically adjustable on the carriage 57 by a screw mechanism 62 so that the axis of the shaft can be brought into line with the axis of the tube 1. When the shaft 61 has been adjusted to be concentric with the tube 1 and the arm 59 connected to the wall of the tube it will be seen that the arm 59 will rotate the shaft 61 as a result of rotation of the tube 1. The rotating shaft 61 provides an output by way of a gear system 63 and master synchro motor 63' which output serves as a controlling input signal to the motor 23 driving the cam plate 19, which input signal controls the drive to the cam plate 19 so that the latter is rotated at an angular velocity equal to that at which the tube 1 is rotated.

The cutting of the profiled end face 3 of the tube and transition line bevelling of that end face are carried out in a similar manner to that previously described in the earlier embodiment except that the carriage 9 is displaced horizontally while its sub-frame 13 is displaceable vertically during transition line bevelling.

It will be apparent that the vertical positioning of the cutter 10 will have to be altered for tubes of different external diameters and this is achieved by appropriate vertical displacement of the beam 50 as aforementioned.

The immense size and weight of tubes which may be used in the construction of jackets for off-shore drilling rigs generally renders them unsuitable for convenient handling and it may be required to provide each end of a tube with an appropriately profiled end face and transition line bevelling. To alleviate the problem of re-orientating the horizontal tube 1 on the rollers 41, 42 after profiling and bevelling one end of the tube the apparatus is provided on its carriage 9 with a second sub-frame 13' and associated components identical to those associated with the sub-frame 13. The sub-frame 13' and its associated components are located on the carriage 9 on the side of the scanning unit 11 remote from the sub-frame 13. By such an arrangement the scanning unit 11 is common to both cutters 10 for controlling their horizontal displacement and the cutter 10 on sub-frame 13' may be moved with the carriage 9 horizontally under control of the scanning unit 11 for profile and bevel cutting of the lefthand end of the tube 1 as shown in Figure 13 whilst

the tube is rotated on the rollers 41, 42. In re-adjusting the apparatus for cutting the lefthand end of the tube 1 the arm 59 is disengaged from the tube 1 and the carriage 57 withdrawn while the box-like frame 47 is driven along the rails 45 leftwardly in Figure 13 until the optical unit 11 can scan a previously drawn line towards the lefthand end of the tube 1. The cam plate 19 associated with the sub-frame 13' is rotated by motor 23' at the same angular velocity as that at which the tube 1 is rotated. To achieve this synchronisation between rotation of the tube and rotation of the cam plate 19 which is to the left of the scanner unit 11 in Figure 13, a second carriage 64 is provided which is movable along the rails 45 in a similar manner to the carriage 57. The carriage 64 is provided with a rotatable arm 59, coupling device 60, shaft 61, gear system 63, master synchro motor 63' and a vertical adjustment mechanism 62 similar to those of carriage 57. Consequently the arm 59 of carriage 64 is manoeuvred to engage with the right-hand end of the tube 1 so that as the tube rotates the output signal derived from the motor 63' of carriage 64 provides a controlling input signal to the motor 23' of the cam plate 19 associated with the sub-frame 13' to ensure that the drive to that cam plate is synchronised with rotation of the tube 1 as aforementioned.

The main advantage which the apparatus shown in Figures 13 to 15 has over the earlier described embodiment is the facility which it provides as aforementioned for profiling and bevelling both ends of a tube without need for adjustment in the position of the tube. Alternatively however the main advantage provided by the apparatus in the embodiment shown in Figures 6 to 8 over the horizontal machine is the facility which it provides to profile and bevel the end of a short length or stub tube resulting from the fact that the whole axial length of the tube is available to be cut by the cutter (for example, since the outer surface of the tube is not engaged by chuck jaws or the like).

WHAT WE CLAIM IS:-

1. Apparatus for shaping an end of a tube of substantial wall thickness having a longitudinal axis and comprising a cutter having a centre line along which it is intended to cut the tube wall, said centre line being directed at or towards the longitudinal axis and intersecting a secondary axis which is substantially perpendicular to the axis of the tube; means for mounting the tube with its end adjacent to the cutter; means for imparting relative axial rotation between the cutter and tube for cutting around the tube wall; means for imparting predetermined relative axial displacement between the tube and cutter during said relative rotation for substantially maintaining the cutter on a

predetermined peripheral path at the end of the tube; cutter control means by which the cutter and the secondary axis are displaced radially relative to the axis of the tube so that, during said relative rotation and axial displacement between the tube and cutter, the secondary axis is displaced at least part way across the wall thickness of the tube to the outer peripheral surface thereof, and means for synchronising the said radial displacement of the cutter and the secondary axis with the relative axial rotation between the cutter and the tube so that, with the cutter disposed at an acute angle with respect to the tube axis, the position of intersection between the centre line of the cutter and the secondary axis follows a continuous and predetermined path which extends across at least part of the wall thickness of the tube to the outer peripheral surface thereof and the arrangement is such that by maintaining the said position of intersection in an end face of the tube a bevel surface can be cut at the end of the tube wall, said bevel surface extending from the end face of the tube across at least part of the wall thickness to the outer peripheral surface of the tube and forming a junction line with the end face of the tube which junction line progresses at least part way across the tube end face from the outer peripheral surface of the tube.

2. Apparatus as claimed in claim 1 wherein the cutter control means comprises a displaceable mounting on which the cutter is carried, said mounting being displaceable radially relative to the tube axis in response to a predetermined pattern which is followed by follower means which moves relative to the pattern, said pattern determining the path followed by the position of intersection between the cutter centre line and the secondary axis.

3. Apparatus as claimed in claim 2 wherein the follower means comprises a cam follower and the pattern comprises rotatable cam means having a cam surface with which the cam follower engages, the predetermined radial displacement of the mounting and thereby of the cutter being a result of the cam follower moving over the cam surface during rotation of the cam means.

4. Apparatus as claimed in claim 3 wherein the cam means comprises a cam plate rotatably driven about an axis relative to which axis the mounting is displaceable and wherein the cam follower comprises a roller on the mounting which engages with the cam surface formed by the periphery of the cam plate.

5. Apparatus as claimed in any one of claims 2 to 4 wherein relative movement between the pattern and the follower means is synchronised with drive means for imparting relative axial rotation between the cutter

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the tube is rotated on the rollers 41, 42. In re-adjusting the apparatus for cutting the lefthand end of the tube 1 the arm 59 is disengaged from the tube 1 and the carriage 57 withdrawn while the box-like frame 47 is driven along the rails 45 leftwardly in Figure 13 until the optical unit 11 can scan a previously drawn line towards the lefthand end of the tube 1. The cam plate 19 associated with the sub-frame 13' is rotated by motor 23' at the same angular velocity as that at which the tube 1 is rotated. To achieve this synchronisation between rotation of the tube and rotation of the cam plate 19 which is to the left of the scanner unit 11 in Figure 13, a second carriage 64 is provided which is movable along the rails 45 in a similar manner to the carriage 57. The carriage 64 is provided with a rotatable arm 59, coupling device 60, shaft 61, gear system 63, master synchro motor 63' and a vertical adjustment mechanism 62 similar to those of carriage 57. Consequently the arm 59 of carriage 64 is manoeuvred to engage with the righthand end of the tube 1 so that as the tube rotates the output signal derived from the motor 63' of carriage 64 provides a controlling input signal to the motor 23' of the cam plate 19 associated with the sub-frame 13' to ensure that the drive to that cam plate is synchronised with rotation of the tube 1 as aforementioned.

The main advantage which the apparatus shown in Figures 13 to 15 has over the earlier described embodiment is the facility which it provides as aforementioned for profiling and bevelling both ends of a tube without need for adjustment in the position of the tube. Alternatively however the main advantage provided by the apparatus in the embodiment shown in Figures 6 to 8 over the horizontal machine is the facility which it provides to profile and bevel the end of a short length or stub tube resulting from the fact that the whole axial length of the tube is available to be cut by the cutter (for example, since the outer surface of the tube is not engaged by chuck jaws or the like).

WHAT WE CLAIM IS:-

1. Apparatus for shaping an end of a tube of substantial wall thickness having a longitudinal axis and comprising a cutter having a centre line along which it is intended to cut the tube wall, said centre line being directed at or towards the longitudinal axis and intersecting a secondary axis which is substantially perpendicular to the axis of the tube; means for mounting the tube with its end adjacent to the cutter; means for imparting relative axial rotation between the cutter and tube for cutting around the tube wall; means for imparting predetermined relative axial displacement between the tube and cutter during said relative rotation for substantially maintaining the cutter on a

predetermined peripheral path at the end of the tube; cutter control means by which the cutter and the secondary axis are displaced radially relative to the axis of the tube so that, during said relative rotation and axial displacement between the tube and cutter, the secondary axis is displaced at least part way across the wall thickness of the tube to the outer peripheral surface thereof, and means for synchronising the said radial displacement of the cutter and the secondary axis with the relative axial rotation between the cutter and the tube so that, with the cutter disposed at an acute angle with respect to the tube axis, the position of intersection between the centre line of the cutter and the secondary axis follows a continuous and predetermined path which extends across at least part of the wall thickness of the tube to the outer peripheral surface thereof and the arrangement is such that by maintaining the said position of intersection in an end face of the tube a bevel surface can be cut at the end of the tube wall, said bevel surface extending from the end face of the tube across at least part of the wall thickness to the outer peripheral surface of the tube and forming a junction line with the end face of the tube which junction line progresses at least part way across the tube end face from the outer peripheral surface of the tube.

2. Apparatus as claimed in claim 1 wherein the cutter control means comprises a displaceable mounting on which the cutter is carried, said mounting being displaceable radially relative to the tube axis in response to a predetermined pattern which is followed by follower means which moves relative to the pattern, said pattern determining the path followed by the position of intersection between the cutter centre line and the secondary axis.

3. Apparatus as claimed in claim 2 wherein the follower means comprises a cam follower and the pattern comprises rotatable cam means having a cam surface with which the cam follower engages, the predetermined radial displacement of the mounting and thereby of the cutter being a result of the cam follower moving over the cam surface during rotation of the cam means.

4. Apparatus as claimed in claim 3 wherein the cam means comprises a cam plate rotatably driven about an axis relative to which axis the mounting is displaceable and wherein the cam follower comprises a roller on the mounting which engages with the cam surface formed by the periphery of the cam plate.

5. Apparatus as claimed in any one of claims 2 to 4 wherein relative movement between the pattern and the follower means is synchronised with drive means for imparting relative axial rotation between the cutter

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and tube so that said movement between the pattern and the follower means imparts radial displacement to the mounting through a predetermined cycle.

6. Apparatus as claimed in claim 5 wherein the predetermined cycle is repetitive after each 360° relative axial rotation between the cutter and the tube.

7. Apparatus as claimed in any one of the preceding claims including mounting means for locating the tube and rotating it about the longitudinal axis and relative to the cutter so that the tube is intended to revolve past the cutter, and wherein the cutter is mounted with its centre line substantially in a stationary plane which includes the longitudinal axis of the tube.

8. Apparatus as claimed in claim 7 wherein the mounting means includes drive means for axially rotating the tube.

9. Apparatus as claimed in claim 8 when appendant to claim 3 in which second drive means for rotating the cam means is synchronised with first drive means for rotating the tube so that the angular velocity at which the cam means is rotated will substantially equal that at which the tube will be rotated.

10. Apparatus as claimed in any one of the preceding claims wherein the cutter is adjustably mounted for pivotal movement about said secondary axis so that the angle subtended between the centre line of the cutter and the longitudinal axis of the tube is variable.

11. Apparatus as claimed in claim 10 when appendant to claim 2 wherein the displaceable mounting includes an arm on which the cutter is carried, said arm being rotatable about the secondary axis to impart pivotal movement to the cutter.

12. Apparatus as claimed in either claim 10 or claim 11 wherein the cutter is connected through a linkage to a pivot point the position of which is intended to be fixed relative to the longitudinal axis of the tube whereby, during axial displacement between the cutter and the tube, said linkage automatically imparts pivotal movement to the cutter about said secondary axis, the extent of such pivotal movement being related to axial displacement between the cutter and the tube from a predetermined condition so that the angle subtended by the centre line of the cutter relative to the axis of the tube will be varied automatically to an extent predetermined by the linkage.

13. Apparatus as claimed in claim 12 when appendant to claim 11 wherein the linkage is coupled to said rotatable arm and extends from said arm to the pivot point, said pivot point being located so that the linkage can rotate about a pivot axis to rotate the arm about the secondary axis during relative axial displacement between the cut-

ter and tube, said pivot axis being spaced from and parallel to the secondary axis and being intended to pass through the longitudinal axis of the tube.

14. Apparatus as claimed in either claim 12 or claim 13 wherein the cutter is disconnectable from the linkage so that its centre line can be maintained at a predetermined angle relative to the axis of the tube which angle is maintained constant during relative movement between the tube and the cutter.

15. Apparatus as claimed in any one of the preceding claims wherein the cutter is situated on a carriage intended for movement along a path parallel to the longitudinal axis of the tube, the carriage being movable relative to the tube axis by drive means which is responsive to line follower means, the line follower means serving to automatically control the drive means for adjusting the axial position of the carriage and thereby of the cutter to follow the said predetermined path during relative rotation between the tube and the cutter.

16. Apparatus as claimed in claim 15 wherein the line follower means is situated on the carriage for displacement axially of the tube simultaneously with the cutter, said line follower means being spaced from the cutter and being intended to follow a guide line provided on the tube.

17. Apparatus as claimed in claim 16 in which the line follower means comprises an optical scanning device.

18. Apparatus as claimed in any one of the preceding claims wherein the cutter is a flame cutting device having a nozzle for directing its flame to the tube, and wherein said nozzle is adjustable independently of said cutter control means for adjusting the distance between the nozzle and tube to achieve optimum cutting efficiency.

19. Apparatus as claimed in claim 18 wherein adjustment of the nozzle is controllable by means remote from the cutter.

20. Apparatus as claimed in claim 19 wherein the nozzle is displaceable by rotation of a screw mechanism which mechanism is rotationally controlled by actuation of a drive motor on the cutter, actuation of the drive motor being controlled from a position remote from the cutter.

21. Apparatus as claimed in any one of the preceding claims and including the or a mounting means by which the tube is intended to be located with its longitudinal axis vertical, said mounting means being intended to rotate the tube about its longitudinal axis relative to the cutter.

22. Apparatus as claimed in claim 21 wherein the mounting means comprises a horizontal turntable rotatable about a vertical axis, the tube being intended to stand on the turntable with its uppermost end



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adjacent to the cutter and to rotate with the table.

23. Apparatus as claimed in claim 22 wherein the turntable is rotatably driven to effect rotation of the tube.

24. Apparatus as claimed in either claim 22 or claim 23 in which the turntable is horizontally adjustable for locating the tube wall at a predetermined position relative to the cutter.

25. Apparatus as claimed in claim 24 wherein a roller is provided which is rotatable about a vertical axis, the location of said vertical axis of the roller being fixed at a predetermined position relative to which the turntable is horizontally adjustable and relative to the cutter, the roller being located to abut the outer surface of a tube when located on the turntable to determine the positioning of the tube relative to the cutter.

26. Apparatus as claimed in any one of claims 21 to 25 wherein the cutter is vertically displaceable along a column relative to which column the tube is rotatable.

27. Apparatus as claimed in any one of claims 21 to 26 and including an operative's platform which is vertically displaceable for location in the region of the uppermost end of the tube and from which the cutting is intended to be supervised and controlled.

28. Apparatus as claimed in claim 27 wherein means is provided for synchronising vertical displacement of the operative's platform with vertical displacement of the cutter so that the platform moves substantially simultaneously with and follows the cutter.

29. Apparatus as claimed in any one of claims 1 to 20 including the or a mounting means for mounting the tube with its longitudinal axis horizontal, said mounting means being intended to rotate the tube about its longitudinal axis relative to the cutter.

30. Apparatus as claimed in claim 29 wherein the mounting means comprises rollers rotatable about parallel horizontal axes and on which rollers the tube is intended to be seated for rotation therewith.

31. Apparatus as claimed in claim 30 wherein at least one of the rollers is rotatably driven to effect rotation of the tube.

32. Apparatus as claimed in any one of claims 29 to 31 wherein the cutter is displaceable along a horizontal beam which is intended to be parallel to the axis of the tube and relative to which beam the tube is rotatable.

33. Apparatus as claimed in claim 32 wherein the beam is carried by a framework, said framework being mounted for displacement in a direction substantially parallel to the axis of the tube for locating the cutter at an end of the tube independently of such location as may be possible by displacement of the cutter along the beam.

34. Apparatus as claimed in either claim 32 or claim 33 wherein the beam is vertically displaceable for locating the cutter at a predetermined position relative to the tube wall.

35. Apparatus as claimed in any one of claims 29 to 34 when appendant to claim 16 wherein the carriage on which is situated the cutter and line follower means is displaceable along the or a beam which is intended to be parallel to the horizontal longitudinal axis of the tube, and wherein cutter being horizontally spaced from the first cutter and from the line follower means and being on the side of the line follower means remote from the first cutter, the line follower means being common to both cutters; said carriage, cutters and line follower means being arranged so that one end of the tube can be cut by the first cutter while the line follower means controls horizontal displacement of the carriage and the second cutter is inoperative and thereafter the carriage may be displaced horizontally relative to the tube so that the other end of the tube can be cut by the second cutter while the line follower means controls horizontal displacement of the carriage and the first cutter is inoperative.

36. Apparatus as claimed in any one of claims 29 to 35 when appendant to claim 8 wherein the second drive means for rotating the cam means associated with the or a cutter is synchronised with the first drive means for rotating the tube by a system comprising a coupling member, intended for attachment to, and rotation with, the tube, rotation of the coupling member providing an output signal for controlling rotation of the cam means at the same angular velocity as that at which the tube rotates.

37. Apparatus as claimed in claim 36 wherein the coupling member is mounted as a unit to be capable of horizontal displacement axially of the tube and independently of the cutter so that the coupling member can be moved into a position in which it is connectable to the end of the tube remote from that end at which cutting is intended.

38. Apparatus as claimed in claim 37 when appendant to claim 35 in which two horizontally displaceable units are provided which are located at axially opposite ends of the tube, each unit having a coupling member and being displaceable axially of the tube, the arrangement being such that when the first cutter is operative for cutting the one end of the tube, rotation of the cam means associated with that first cutter is synchronised with rotation of the tube by connection of the coupling member on a first unit to the other end of the tube to which other end it is adjacent while the coupling member of the second unit is disengaged from the tube and when the second cutter is



operative for cutting the other end of the tube, rotation of the cam means associated with that second cutter is synchronised with rotation on the tube by connection of coupling member on the second unit to the one end of the tube to which one end it is adjacent while the coupling member on the first unit is disengaged from the tube.

39. Apparatus for shaping an end of a tube substantially as herein described with reference to Figures 6 to 12 of the accompanying illustrative drawings.

40. Apparatus for shaping an end of a tube as claimed in claim 39 and modified substantially as herein described with reference to Figures 13 to 15 of the accompanying illustrative drawings.

41. Apparatus for forming a profiled end face of a tube having a substantial wall thickness and a longitudinal axis to enable the tube to be joined along an endless predetermined notional line of contact which includes inner and outer peripheral edges of the tube and which apparatus comprises: a cutter which is to be disposed in cutting position relative to the wall of the tube and which has a centre line along which it is intended to cut the wall; drive means for providing relative rotational movement between the cutter and the tube; means for moving the cutter axially along the wall of the tube to follow a predetermined profile during relative rotation between the cutter and the tube; means for pivoting the cutter about a secondary axis for disposing the cutter about a secondary axis for disposing the cutter with its centre line at a desired angular position relative to the axis of the tube; said secondary axis being substantially perpendicular to the axis of the tube and being intersected by the centre line of the cutter; cutter control means comprising a displaceable mounting for displacing said secondary axis radially across the thickness of the end face of the tube; and means for synchronising the radial displacement of said secondary axis with the relative rotational movement between the cutter and tube to move the intersection of said secondary axis and the centre line of the cutter along the notional line of contact for producing an edge which corresponds to the predetermined line of contact between said tube and said surface.

42. Apparatus as claimed in claim 41 and having a pattern corresponding to the path of said notional line and a follower adapted to follow said pattern in a manner synchronously related to the relative movement between the cutter and the tube to control the radial movement of the secondary axis.

43. Apparatus as claimed in claim 42 wherein the pattern comprises a rotatable cam having a cam surface and the follower

comprises a cam follower which engages the cam surface to determine radial displacement of the displaceable mounting and thereby of the cutter.

44. Apparatus as claimed in claim 43 and comprising a second drive means for rotating the rotatable cam at an angular velocity which is substantially equal to the angular velocity of the relative rotational movement between the cutter and the tube.

45. Apparatus as claimed in any one of claims 41 to 44 and comprising mounting means for locating the tube and rotating it about its longitudinal axis relative to the cutter so that the tube revolves past the cutter.

46. Apparatus as claimed in claim 45 wherein the mounting means comprises a horizontal turntable rotatable about a vertical axis for supporting the tube with its longitudinal axis vertical and with the uppermost end of the tube adjacent the cutter.

47. Apparatus as claimed in claim 45 wherein the mounting means comprises rollers rotatable about parallel horizontal axes for supporting the tube with its longitudinal axis horizontal.

48. Apparatus as claimed in any one of claims 41 to 47 and comprising a carriage supporting the cutter for movement axially along the wall of the tube; and an optical scanning line follower to maintain the position of the cutter along a predetermined end profile path during said relative rotation between the cutter and the tube.

49. Apparatus as claimed in claim 47 or in claim 48 when appendant to claim 47 and comprising a second cutter horizontally spaced from the cutter disposed in a cutting position relative to the tube; and wherein the or an optical scanning line follower is disposed between the two cutters and is adapted to selectively maintain the position of each cutter along a predetermined end profile path on opposite ends of the tube during the relative rotation between the cutter and the tube.

50. Apparatus as claimed in any one of claims 41 to 49 and which comprises a linkage connectable to the cutter and having a pivot point fixed relative to the longitudinal axis of the tube so that during axial displacement between the cutter and tube the linkage imparts pivotal movement to the cutter while its centre line is maintained in a plane which is parallel to and includes the longitudinal axis of the tube and wherein the cutter is disconnectable from the linkage so that it can be maintained with its centre line at a predetermined angle relative to the longitudinal axis of the tube which is constant during relative rotational movement between the tube and the cutter.

51. Tube bevelling apparatus for profiling the end of a tube having a longitudinal axis to provide an end face which may be

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joined to an intersecting surface by a continuous joint, and comprising a cutter which has a centre line along which it is intended to cut the tube wall and which is to be moved relative to the periphery of the tube and is disposable at a variable angle relative to the axis of the tube about a secondary axis which is intersected by the centre line of the cutter to cut a predetermined bevel in the end face of the tube, and wherein there is provided a displaceable mounting for the cutter for moving said secondary axis radially with respect to the tube; and means to move said secondary axis radially with respect to the tube axis in synchronous relation with the relative movement of the cutter and the tube to cause the point of intersection of the cutter centre line and the secondary axis to follow a notional continuous line in the end face of the tube which line substantially corresponds to a continuous line of contact for the tube end face in forming the continuous joint and includes part lengths of each of the inner and outer peripheral surfaces of the tube connected by a transition line extending across the thickness of the tube end face and cause the cutter to cut said end face to provide a bevelled end face surface which is bounded by and follows the continuous line of contact as it proceeds across the thickness of the tube between the inner surface and outer surface of the tube.

52. Apparatus as claimed in claim 51 wherein the means to move the second axis radially comprises a cam corresponding in shape to said continuous line of contact, which cam rotates at substantially the same angular velocity as the relative peripheral movement between the cutter and the tube; and a cam follower which follows said cam for determining the radial displacement of the cutter with respect to the tube axis.

53. Apparatus for forming in two cuts a junction line on the end face of a tube having a substantial wall thickness and which junction line follows a predetermined notional line of contact between the tube and a surface with which the tube may be joined, said junction line extending across the end face of the tube from a first position on the inner surface of the tube wall to a second position on the outer surface of the tube wall across the end face of the tube, the apparatus comprising a cutter disposed in cutting position relative to the wall of the tube; drive means to produce relative rotational movement between the cutter and the wall of the tube; means for moving the cutter axially along the wall of the tube during said relative rotation to profile the end of the tube on a first cut to form an end face which includes on its surface the notional line corresponding to said junction line and to follow said profile on the second cut; and

control means which is synchronised with said relative rotation and controls radial displacement of the cutter during said relative rotation and axial movement on the second cut to partially bevel the end face along said notional line to form said junction line.

54. A method of shaping an end of a tube of substantial wall thickness which is to be welded to a curved surface of a further body which method comprises profiling that end of the tube to provide a profiled end face on which is located a notional line that corresponds to a theoretical line of contact between the end face and said curved surface for fitting the end of the tube to the curved surface in substantially complementary relationship and which notional line follows a continuous and predetermined path which extends across at least part of the wall thickness of the tube to the outer peripheral surface thereof; cutting the tube wall at the profiled end thereof to provide a bevel surface which extends across at least part of the profiled end face of the tube to the outer peripheral surface of the tube and controlling said cutting so that the bevel surface formed thereby progresses inwardly through the tube wall thickness to form a transition line with the profiled end face which transition line substantially follows the notional line of contact where that notional line deviates from the innermost and the outermost peripheral edges of the profiled end face as initially formed.

55. A method as claimed in claim 54 which comprises rotating the tube about its longitudinal axis and relative to a cutter and controlling axial displacement of said cutter to cut the tube and provide the profiled end face; mounting the cutter so that a centre line thereof along which it is intended to cut the tube wall is directed at or towards the longitudinal axis at an acute angle with respect thereto and intersects a secondary axis which is substantially perpendicular to the longitudinal axis; radially displacing the cutter relative to the longitudinal axis of the tube and the profiled end face to cut the tube wall and form the bevel surface and synchronising said radial displacement of the cutter with rotation of the tube so that the point of intersection of the centre line of the cutter with the secondary axis substantially follows the notional line of contact.

56. A method as claimed in either claim 54 or claim 55 which comprises forming the profiled end face to correspond with the notional line of contact in such profiled end face passing through a first position on the outer peripheral edge of the profiled end face and through a second position peripherally remote from the first position on the inner peripheral edge of the profiled end face, and cutting the bevel surface to form a transition line which progresses ra-



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5 dially inwardly relative to the longitudinal axis of the tube substantially through the wall thickness of the tube from the first position on the external peripheral surface of the tube wall to the second position on the internal peripheral surface of the tube wall.

57. A method as claimed in any one of claims 54 to 56 which comprises cutting the end of the tube so that the profiled end face is maintained at substantially 90° to the longitudinal axis of the tube throughout the peripheral extent of said end face.

58. A method of shaping an end of a tube of substantial wall thickness which is to be welded to a curved surface of a further body so that the axis of the tube is disposed in a predetermined angular relationship with the curved surface of the further body which method comprises profiling the end of the tube to provide a profiled end face having a shape by which the tube is intended to be positioned adjacent to the curved surface of the further body with said tube substantially contacting the further body at a first position on the outer peripheral edge of the end face and at a second position on the inner peripheral edge of the end face peripherally remote from the first position and so that a notional line in said profiled end face includes said first and second positions and corresponds to a theoretical continuous line of contact for fitting the end face to said curved surface in substantially complementary relationship and at the predetermined angular relationship; cutting the profiled end of the tube wall to provide a bevel surface thereon which extends across at least part of the profiled end face of the tube to its outer peripheral surface, and controlling the cutting of the bevel surface so that the junction between the profiled end face and the bevel surface forms a transition line which line substantially follows said notional line where that line deviates from the outer and the inner peripheral edges of the profiled end face as initially formed and progresses across the wall thickness of the tube so that the profiled end face can be mounted adjacent to the curved surface at the predetermined angular relationship with substantially line contact along said notional line and the curved surface.

59. A method as claimed in claim 58 and for shaping an end of a substantially cylindrical tube which is to be mounted on a cylindrical surface of a further body so that the axis of the tube is disposed at a predetermined acute angle relative to and in a common plane with the axis of the cylindrical surface of the further body which method comprises profiling the end of the tube to provide the profiled end face with a shape by which the tube is intended to be mounted adjacent to the cylindrical surface of the further body with said tube substantially

contacting the further body at the first position on the outer peripheral edge of the profiled end face in which the cylindrical outer surface of the tube subtends an acute angle in said common plane with the cylindrical surface of the further body and at the second position on the inner peripheral edge of its profiled end face in which the cylindrical outer surface of the tube subtends an obtuse angle in said common plane with the cylindrical surface of the further body and so that the notional line in the profiled end face includes said first and second positions and corresponds to the theoretical continuous line of contact for fitting the profiled end face to said curved surface in substantially complementary relationship with the respective axes disposed at the predetermined acute angle; cutting the profiled end of the tube wall to provide the bevel surface thereon which extends across at least part of the profiled end face of the tube to its outer cylindrical surface, and controlling such bevel cutting so that the transition line formed between the end face and the bevel surface progresses inwardly to substantially follow the notional line across the wall thickness of the tube from the outer to the inner cylindrical surface of the tube.

60. A method as claimed in any one of claims 54 to 59 which comprises controlling the cutting of the bevel surface so that the bevel angle subtended by said surface with the longitudinal axis of the tube varies along the peripheral extent of the bevel surface, said variations in the bevel angle being controlled by changing the angle of the cutter relative to the axis of the tube.

61. A method as claimed in claim 60 which comprises changing the angle of the cutter during cutting of the bevel surface solely during relative axial displacement between the cutter and tube.

62. A method as claimed in any one of claims 54 to 61 in which the tube is cylindrical and the cutter comprises a flame which passes at 90° through the or a secondary axis, the method comprising maintaining said secondary axis substantially perpendicular to a plane which includes the longitudinal axis of the tube and in a plane which is tangential to the tube wall, and controlling the intersection of said cutter flame and the secondary axis so that such intersection is maintained on the notional line of contact during cutting of the bevel surface.

63. A method as claimed in claim 62 when appendant to either claim 60 or claim 61 comprising varying the bevel angle by pivoting the cutter about the secondary axis and in said plane which includes the longitudinal axis of the tube.

64. A method of shaping an end of a tube substantially as herein described with reference to the accompanying illustrative

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drawings.

65. A tube having an end shaped by the method as claimed in any one of claims 54 to 64.

66. A tube having an end shaped by apparatus as claimed in any one of claims 1 to 53.

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