June 25, 1963 C. L. HELBLE ETAL **3,095,083**

METHOD OF AND APPARATUS FOR CORRECTING TUBING
ECCENTRICITY BY DRAWING

Filed Nov. 3, 1958

6 Sheets-Sheet 1

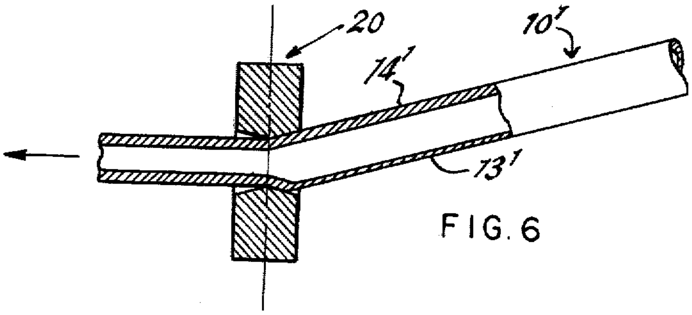

FIG. 6

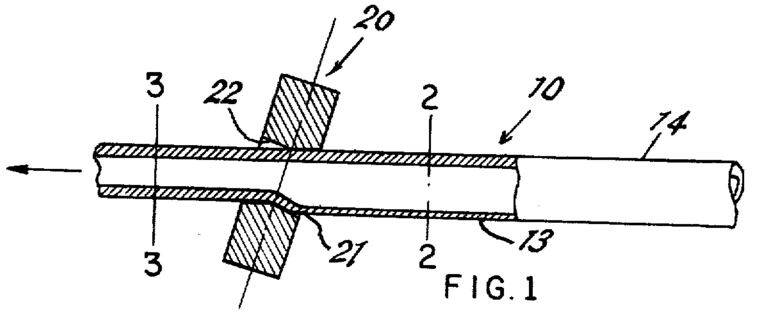

FIG. 1

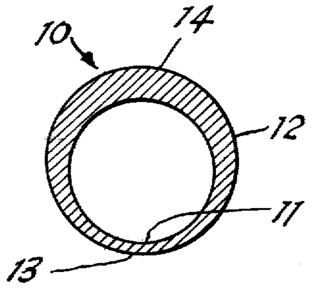

FIG. 2

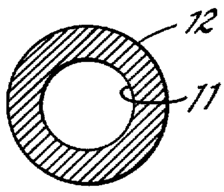

FIG. 3

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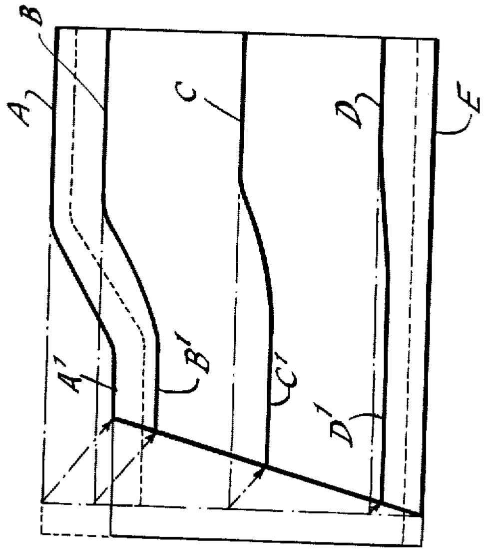

FIG. 4

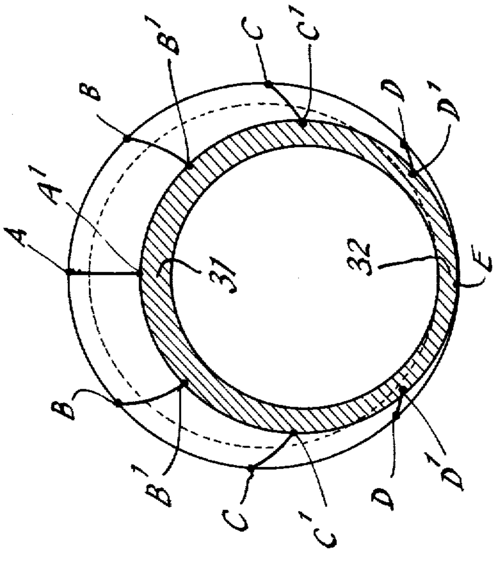

FIG. 5

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6 Sheets-Sheet 3

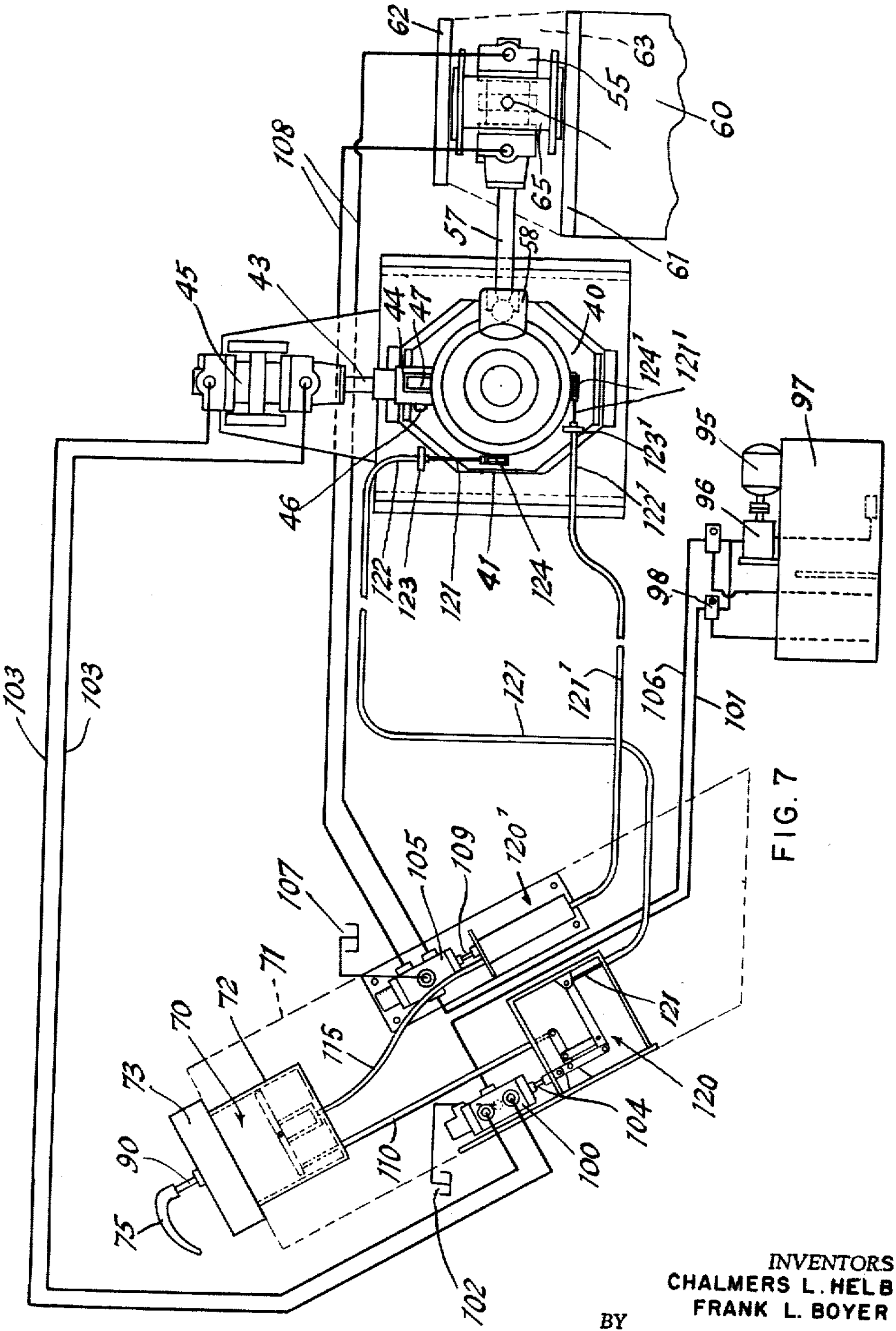

FIG. 7

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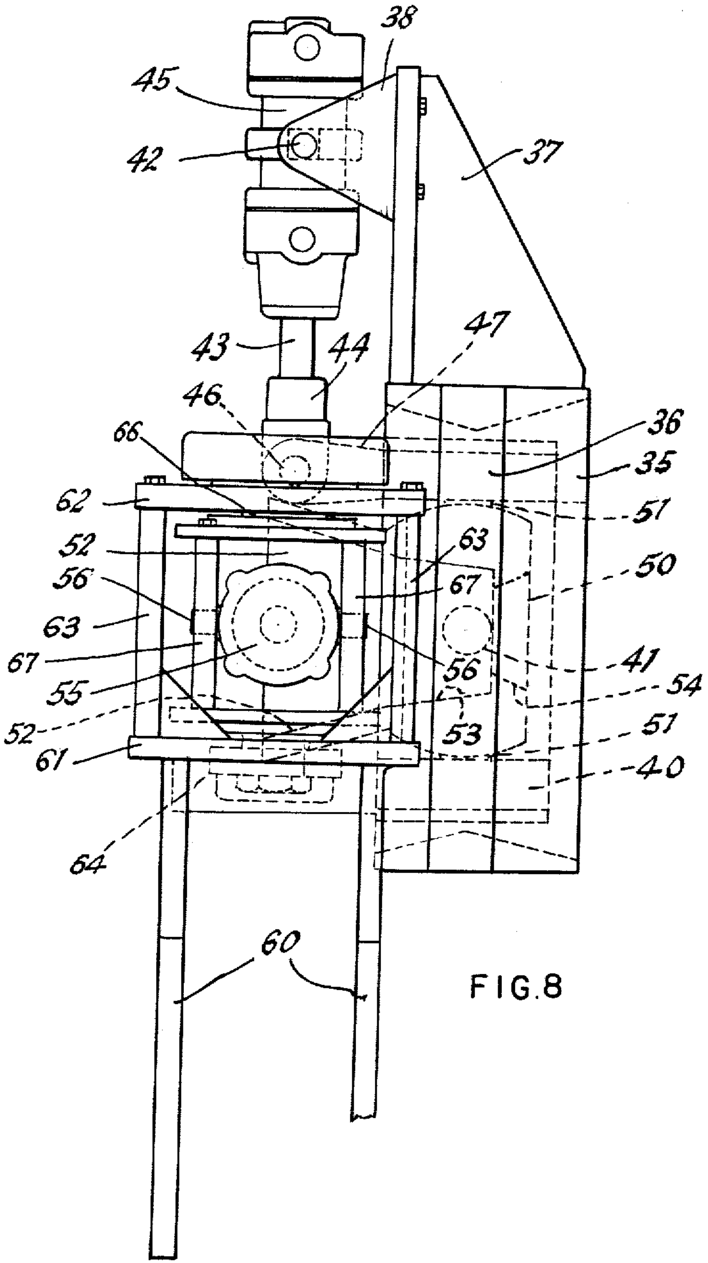

FIG.8

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METHOD OF AND APPARATUS FOR CORRECTING TUBING ECCENTRICITY BY DRAWING

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6 Sheets-Sheet 5

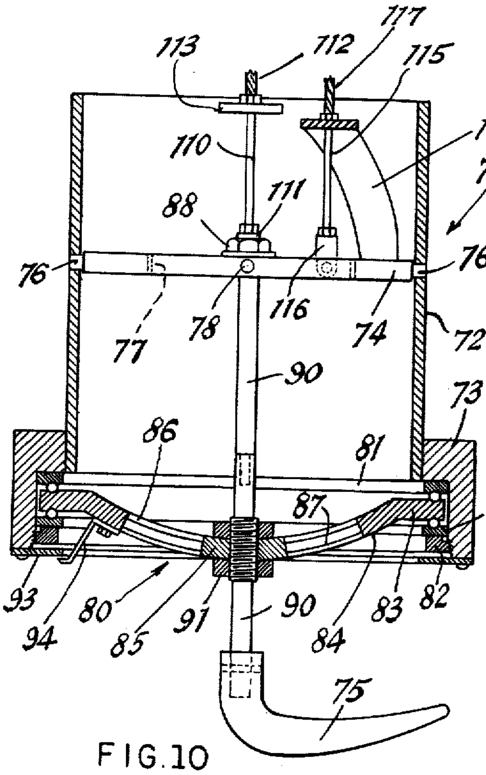

FIG.10

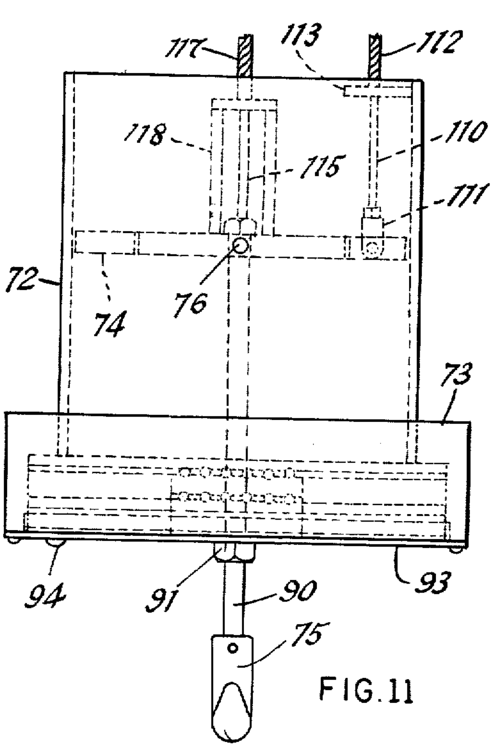

FIG.11

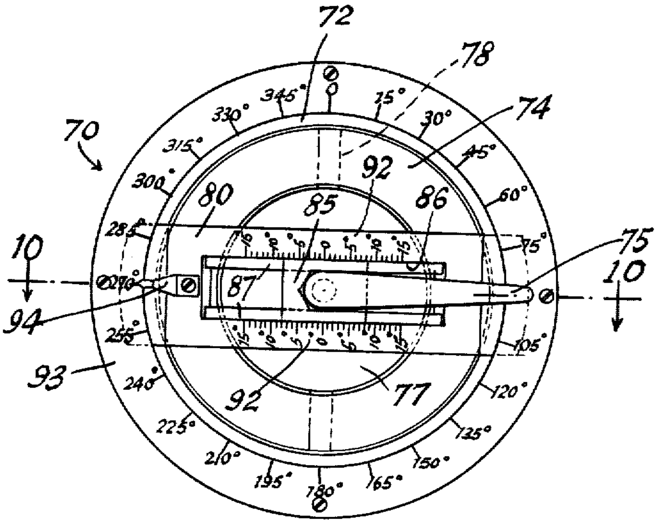

FIG.9

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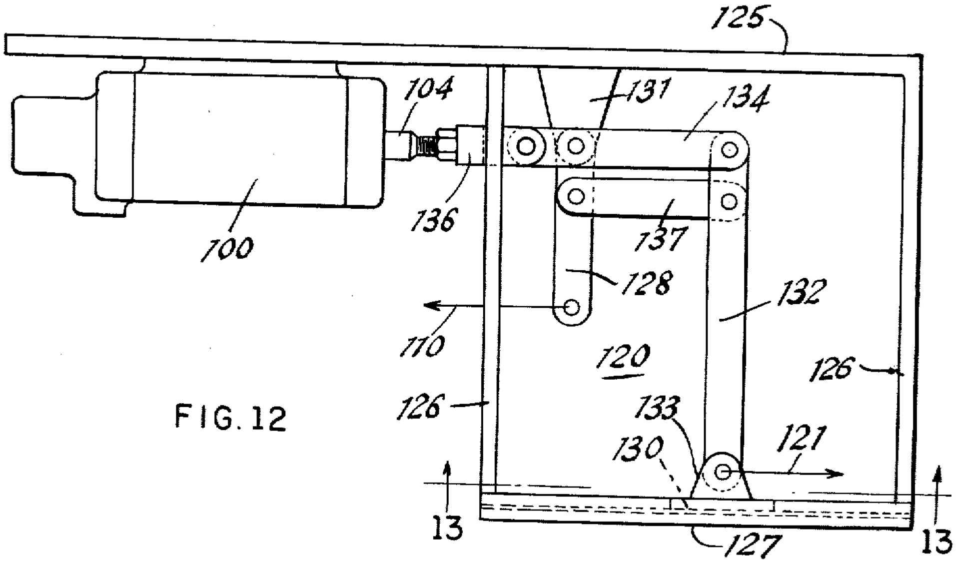

FIG. 12

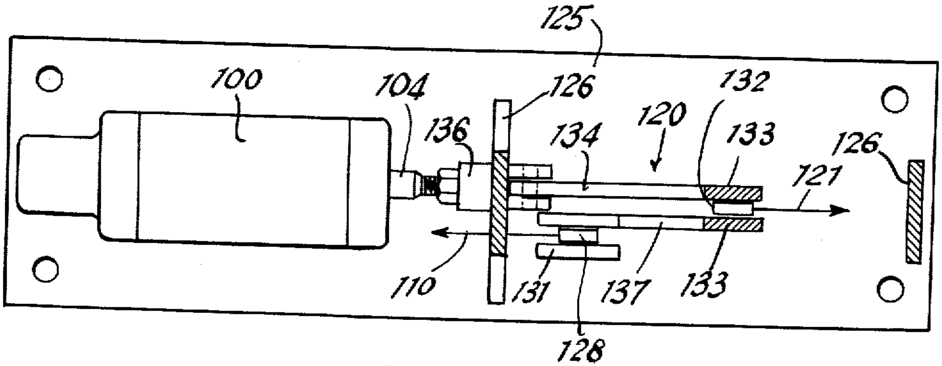

FIG. 13

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United States Patent Office

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Patented June 25, 1963

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METHOD OF AND APPARATUS FOR CORRECTING TUBING ECCENTRICITY BY DRAWING

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Filed Nov. 3, 1958, Ser. No. 771,642
7 Claims. (Cl. 205—4)

This invention relates to the manufacture of metal tubing and, more particularly, to a novel method of and apparatus for correcting eccentricity of the outer and inner surfaces or diameters of metal tubing so as to produce tubing of uniform wall thickness.

In the manufacture of metal tubing, particularly seamless tubing, manufactured by the rotary piercing or extrusion processes, for example, there is usually a lack of concentricity between the inner and outer circular peripheries of the tubing resulting in a variation in the wall thickness of the tubing circumferentially thereof. The zones of maximum and minimum wall thickness are substantially diametrically opposite each other. In the case of eccentric extruded tubing, the zone of maximum wall thickness generally extends substantially longitudinally of the tubing whereas, while in the case of rotary pierced tubing, such zone tends to follow a spiral path along the tubing.

For many applications of tubing, such variation in wall thickness is not an important factor. However, certain applications require tubing having not less than a pre-set minimum wall thickness. When the inner and outer peripheries are not concentric, resulting in wall thickness varying from a maximum to a minimum, the minimum wall thickness must equal the required minimum thickness. In turn, the maximum wall thickness will be in excess of the required minimum wall thickness. Consequently, the weight of metal in the tube will be in excess of that required were the wall thickness substantially uniform circumferentially of the tube.

Stated succinctly, to obtain a pre-set minimum wall thickness in a tube whose wall thickness varies circumferentially requires a greater amount of metal than is needed to obtain the same pre-set minimum wall thickness in a tube whose wall thickness is uniform circumferentially. As a result, the material cost of such a tube having a variable wall thickness exceeds that of a tube having a uniform wall thickness. This is an excess metal cost which can run into a large sum in mass production of tubing. Consequently, there is a substantial saving in metal cost available in producing tubes with a pre-set minimum wall thickness if the tube can be produced with a uniform wall thickness, as less weight of metal would be required for each such tube.

In accordance with the present invention, it has been found that eccentricity between the inner and outer circumferential peripheries of a tube can be corrected by drawing the tube through a tube drawing die or rolls in such a manner as to exert on the tube wall, over an arc centered on the line of minimum wall thickness, greater radial unit pressures than those exerted over the remaining major portion of the tube wall circumference. This technique causes the metal of the tube wall within such arc to be "crowded" circumferentially of the tube, the thus displaced metal increasing the wall thickness within the selected arc. By proper control of the degree of crowding within such selected arc, the wall thickness therewithin can be increased to a value of the order of the maximum wall thickness of the tube so that the wall thickness of the drawn tube is substantially uniform around its circumferential periphery.

One form of apparatus for performing this operation comprises an annular size reducing die having a frusto-conical entrance throat and mounted for tilting about a diameter of the die. By varying the degree of tilting relative to the line of movement of the tube through the die, the amount of increase in radial unit pressure on the metal within such selected arc may be varied, thus varying the amount of metal displacement circumferentially of such arc. However, the method may be performed using a die having its axis parallel to the line of draw but having an inlet angle varying from a maximum, such as 30 degrees, at one end of a diameter, to a minimum, such as 15 degrees at the opposite end of such diameter. The invention method may also be performed using appropriately disposed and correlated sets of rollers.

The line of heaviest wall or of thinnest wall may shift circumferentially along the length of the tube, and in many cases spirals along such length. Accordingly, when a tilting die is used to perform the invention method, such die, in addition to being mounted for a controlled degree of tilting about one axis, is also mounted for controlled adjustment about a second axis perpendicular to the first-mentioned axis. This is effected by a gimbal mounting, similar to that of a gyroscope mounting, so that the arc of application of increased radial unit pressure may be kept centered on the line of thinnest wall.

Preferably, the adjustments of the tilting die are effected by power actuators remotely controlled by an operator at a control station for the drawing operation. The operator controls the die position and degree of tilt in accordance with measurements of wall thickness previously made along the length of the tube. Such measurements may be made by any suitable means, such as ultrasonic or radiation devices, for example.

For an understanding of the invention principles, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings. In the drawings:

FIG. 1 is a somewhat schematic cross-sectional view illustrating a tube having its eccentricity corrected by a reduction draw through the annular die;

FIGS. 2 and 3 are diametric sectional views on the correspondingly numbered lines of FIG. 1;

FIG. 4 is a partial elevation view of an initially uniform wall thickness tube marked at circumferentially spaced lines to illustrate the metal displacement during drawing through the die, the figure representing an actual tube processed in accordance with the invention;

FIG. 5 is an end elevation view of FIG. 4;

FIG. 6 is a view similar to FIG. 1 illustrating a variation of the invention method;

FIG. 7 is a part elevation and part schematic view of the mounting and adjusting means for a tilting die and the control therefor;

FIG. 8 is a side elevation view of the die mounting and adjusting means;

FIG. 9 is a front elevation view of the control unit for the die adjusting means;

FIG. 10 is a sectional view on the line **10—10** of FIG. 9;

FIG. 11 is a plan view of the control unit;

FIG. 12 is a side elevation view of a follow up mechanism for the adjusting means and control unit; and

FIG. 13 is a sectional view on the line **13—13** of FIG. 12.

Referring to FIGS. 1, 2 and 3, a metal tube **10** is illustrated as drawn through a reducing or sinking die **20** in accordance with the procedure of the present invention. The inner and outer substantially circular peripheries **11** and **12** of tube **10** are eccentric, resulting in a relatively thin wall portion **13** substantially diametrically opposite a relatively thick wall portion **14**. FIG. 2 illustrates the eccentricity of the inner and outer surfaces in an exaggerated manner.

The annular sinking die **20** has an outwardly flaring frusto-conical entrance throat **21** and a similar exit throat **22**, which intersect substantially midway of the axis of die **20**. Preferably, the included angle of throat **21** is of the order of 30 degrees.

In a manner described more fully hereinafter, die **20** is mounted for tilting about one of its diameters as an axis, and the tilting may be varied through an angle of the order of 15 degrees. Furthermore, die **20** is arranged for rotational adjustment of its point of maximum tilt about the die axis through 360 degrees. Thus, the die may be tilted an amount determined by the degree of metal displacement required in tube **10** and its point or arc of maximum tilt may be rotated to remain "in line" with the line of minimum wall thickness. As stated, this line may run rectilinearly of tube **10** or may spiral therealong.

Die **20**, being a sinking die, reduces the outer diameter of tube **10**. By virtue of the tilting of die **20** relative to the axis of tube **10**, the reducing action of die **20** can be selectively applied to a selected arc of the periphery of tube **10**, with the remaining portion of the periphery being reduced more lightly or not at all. At the extreme tilt position of die **20** as shown in FIG. 1, the surface of entrance throat **21** is substantially parallel to the outer surface **12** of tube **10** along the arc of the thicker wall portion **14**.

However, over the arc including the thinner wall portion **13**, greater radial unit pressures are exerted on the metal of the tube wall, so that the metal is crowded circumferentially of tube **10** by virtue of the reducing action of die **20**. This displaced metal, flowing circumferentially of tube **10**, increases the thickness of the tube wall along the arc including thin wall section **13**. By proper selection of the degree of tilt with reference to the difference between the thickest and thinnest wall portions, the thickness of the thinnest wall section can be made equal to that of the thickest wall section, thus producing a drawn tube having substantially uniform wall thickness, as best shown in the large scale section of FIG. 3.

The circumferential displacement of metal as a result of such selective exertion of greater radial unit pressures over a selected arc as tube **10** is drawn through die **20** is graphically illustrated in FIGS. 4 and 5. These figures depict the actual metal displacement which occurred when a tube of initially substantially uniform wall thickness was drawn through a reducing or sinking die tilted in accordance with the invention method.

In the test, the results of which are shown graphically in FIGS. 4 and 5, an electrical resistance welded (ERW) tube **30**, made in the usual manner from a strip of metal of substantially uniform wall thickness, was scribed with longitudinally extending lines A, B, C, etc. at uniformly spaced intervals around its outer circumference. This tube was then drawn through a sinking die, such as die **20**, tilted at an angle of 15 degrees to the axis of tube **30** and arranged to exert greater radial unit pressures on the metal of the upper half of the tube. As will be noted from FIGS. 4 and 5, this thickened the wall of the upper part of tube **30** along a selected arc. The scribed lines B, C and D were displaced circumferentially to the positions B′, C′, D′, with substantially no circumferential displacement taking place at lines A and E. Lines B were shifted the greatest amount, line C a lesser amount, and lines D the least amount. This provided a graduated variation in thickness between thickened wall portion **31**, at the top of tube **30**, and unaffected wall portion **32** at the bottom of the tube.

The test graphically depicted demonstrates the circumferential displacement of the metal which has greater radial unit pressures exerted thereon by tilted die **20**. Applying the same technique to the thinner wall portion of a tube of non-uniform wall thickness, with selective control of the degree of die tilting, results in circumferential displacement of the crowded metal of the thinner wall portion to thicken this wall portion in a graduated manner so that a tube of substantially uniform wall thickness is provided.

In the modified technique of FIG. 6, die **20** is maintained with its axis parallel to the axis of the tube portion on the exit side of the tube, and tube **10′** is fed at a controlled angle to die **20**. This again crowds the metal of thinner wall portion **13′** circumferentially to displace the metal in the selected arc and thus thicken wall portion **13′** to a thickness substantially equal to that of wall portion **14′**. While adequate results can be obtained by this technique, the tilted die technique of FIGS. 1, 2 and 3 is presently preferred.

FIGS. 7–13 illustrate apparatus for controllably varying the degree of tilt and angular orientation of a tiltable sinking die **20**. Referring to FIGS. 7 and 8, a gimbal support **35** is provided with keys **36** for positioning of the support in a draw bench. Support **35** has diametrically opposite bearings which are horizontally coaxial and receive horizontal trunnions **41** on an outer ring **40**. A bracket **37** on the upper surface of support **35** has projecting spaced and apertured ears **38** which receive trunnions **42** on a hydraulic actuator **45** having a piston rod **43** carrying a fork **44** connected by a pin **46** to an arm **47** projecting forwardly from outer gimbal ring **40**. Operation of actuator **45** will thus tilt outer ring **40** about a horizontal axis.

Ring **40** has diametrically opposite coaxial bearings whose common axis perpendicularly intersects the common axis of trunnions **41**. The bearings of ring **40** receive coaxial diametrically opposite trunnions **51** on an inner gimbal ring **50**. Ring **50** is thus angularly displaceable about an axis perpendicular to the axis of displacement of outer ring **40**, and rings **40** and **50** conjointly provide a universal mounting for die **20**. A pair of upright plates **60**, at one side of support **35**, have their upper ends interconnected by a shelf **61** connected to an upper shelf **62** by side plates **63**. Shelves **61**, **62** carry bearing caps **64** containing vertically coaxial bearings **66** receiving trunnions on a bracket **65** having side plates **67** receiving horizontally coaxial trunnions **56** on a hydraulic actuator **55** having a piston rod **57**. Actuator **55** thus has freedom of movement about a pair of mutually perpendicular axes.

Inner gimbal ring **50** has convex upper and lower outer edges and has a forwardly extending frusto-conical lead-in section **52** merging with a frusto-conical and shouldered seating recess **53** for die **20**. A flared exit passage **54** extends from the inner or trailing end of recess **53** and may merge with exit section **22** of die **20**. Ring **50** is operably connected to actuator **55** by means of an arm **58** on the outer edge of section **52** having a hemispherical recess receiving a spherical outer end of piston rod **57**. A spherically concave nut holds such end in the recess. By this connecting means, ring **50** may be pivoted about an axis perpendicular to the pivot axis of ring **40**.

Adjustment of the degree and direction of tilt of die **20** in its gimbal mounting **35—40—50** is effected by a gimbal controller **70** mounted on a base or column **71** and including a control handle **75**. Referring to FIGS. 9 to 11, controller **70** includes a generally tubular housing body **72** to the outer end of whiuh is secured an L-shaped ring **73**. About midway of the length of body **72**, is disposed an annular ring **74** having diametrically opposite trunnions **76** engaged in apertures in the body **72**. A circular plate **77** is concentric and, in the neutral position coplanar, with ring **74** and has diametrically opposite trunnions **78** engaged in the latter. The axis of trunnions **78** is perpendicular to that of trunnions **76**.

Ring **73** seats axially spaced antifriction bearing races **81** held in position by a lock ring **82** threaded into ring **73**. These races rotatably support a slide guide **80** having a flat annular rim **83** seated between the bearing races. A convex guide element **84** extends diametrically of rim **83** and its arc is concentric with the axis of trunnions **78**. Element **80** has a rectangular slot **86** formed with guide rails **87**, along its longer edges, on which is mounted an arcuate slide **85**. Slide **85** has a central aperture through which extends a control rod **90** which also extends centrally through plate **77** and is secured thereto by a nut **88**. Nut and washer assemblies **91** secure rod **90** to slide **85**, and control handle **75** is pinned to the outer end of the rod.

Scales **92** are marked along element **84** on each side of slot **86** and extending through 15 degrees, for example, to each side of the midpoint of the element. A dial ring **93**, graduated through 360 degrees, is secured to the outer end of ring **73** and cooperates with a pointer **94** on guide **80**. Handle **75** extends longitudinally of element **84** and is aligned with pointer **94**.

With the rigid connection of rod **90** to handle **94**, slide **85**, and plate **77**, the latter may be tilted through 15 degrees, for example, in either direction and at any angular position around ring **93**. At the 90 degree and 270 degree position shown in FIG. 9, if handle **75** is moved in either direction, plate **77** will be tilted about its trunnions **78** and ring **74** will remain stationary. At the zero and 180 degree positions of handle **75**, both ring **74** and plate **77** will be tilted in coplanar relation about the trunnions **76** of ring **74**. In any other position of handle **75**, ring **74** will be titled about trunnions **76** and plate **77** will be simultaneously tilted about trunnions **78**, so that the effective tilting direction of plate **77** will correspond to the angular direction indicated on ring **93** by pointer **94**.

Motion of handle **75** is communicated to die **20** by servo mechanism interconnecting ring **74**, plate **77**, gimbal rings **40** and **50**, and actuators **45** and **55**. Referring to FIG. 7, a motor **95** drives a pump **96** having an inlet connected to tank **97** and delivering fluid under pressure to hydraulic fluid supply lines **101** and **106** connected to four-way control valves **100** and **105**, respectively. Relief valves **98** are interposed in lines **101**, **106** and have overflows leading to tank **97**. Valves **100**, **105** are also provided with return lines to tank **97** as schematically indicated at **102**, **107**. Lines **103** connect valve **100** to actuator **45**, and lines **108** connect valve **105** to actuator **55**.

Valve **100** is arranged to be controlled by tilting movement of ring **74**. Referring to FIGS. 7, 10 and 11, a flexible cable **110** has one end connected by a yoke **111** to ring **74**, and sheath **112** of cable **110** is anchored to a bracket **113** secured to the inside of housing body **72**. The other end of cable **110** is connected through linkage **120**, described more fully hereinafter, to the stem **104** of valve **100**.

In a similar manner, valve **105** is controlled by tilting movement of circular plate **77**. Referring again to FIGS. 7, 10 and 11, a flexible cable **115** has one end connected by a yoke **116** to circular plate **77** near the periphery of the latter and on a diameter of plate **77** perpendicular to the axis of trunnions **78**. Sheath **117** of cable **115** is anchored to an arched bracket **118** secured at each end to ring **74** and extending over plate **77**. The other end of cable **115** is connected through linkage **120'**, identical to linkage **120**, to stem **109** of valve **105**.

The linkages **120**, **120'** are connected to outer and inner gimbal rings **40** and **50**, respectively, by flexible cables **121**, **121'** respectively. Sheath **122** of cable **121** is anchored to a bracket **123** on gimbal mounting **35**, and cable **121** is connected to a forwardly projecting arm **124** on outer ring **40**. Similarly, sheath **122'** of cable **121'** is anchored to a bracket **123'** on outer gimbal ring **40**, and cable **121'** is connected to a forwardly projecting arm **124'** on inner gimbal ring **50**. These arrangements constitute follow-up connections whereby valves **100**, **105** are restored to the neutral position whenever the degrees of tilt of rings **40** or **50** coincide with those of ring **74** and plate **77**.

Linkage **120**, which is identical with linkage **120'**, is best illustrated in FIGS. 7, 12 and 13. Valve **100** and linkage **120** are supported on a mounting plate **125** positioned in control column **71**. A pair of spaced arms **126** extending normal to plate **125** support a guide **127** for a slide **130**. Control cable **110** is connected to the outer end of a link **128** having its inner end pivoted on ears **131** on plate **125**. A longer link **132** has its inner end pivoted on ears **133** on slide **130**, and its outer end is pivotally connected by link **134** and yoke **136** to the end of valve stem **104**. A short link **137**, parallel and relatively close to link **134**, interconnects links **128** and **132**. Cable **121** is secured at the pivotal connection of link **132** to ears **133** and thus acts directly on slide **130**.

In the described linkage, movement of cable **110**, responsive to turning of handle **75** to a set position on dial **93** and movement along guide **80**, which latter movement then results in tilting of ring **74**, swings link or lever **128** about its pivot on ears **131**, and thus moves valve stem **104**. Valve **100** thereupon supplies hydraulic fluid under pressure to actuator **45** to tilt outer gimbal ring **40** in the same direction as ring **74** has been tilted. As ring **40** moves toward the pre-set position, cable **121** moves slide **130**. With link **128** fixed, thus fixing link **137**, link **132** is pivoted about its connection with link **137**. This movement draws stem **104** toward the neutral position so that, as gimbal ring **40** reaches the position set on dial **93** by pointer **94**, actuator **45** is deenergized. Linkage **120'** acts in the same manner upon tilting of plate **77** by movement of control handle **75** along guide **80**.

From the foregoing description, it will be seen that turning and "tilting" of control handle **75** results in a corresponding tilting of rings **40** and **50** to tilt die **20** the required degree in the required direction. Thus, the operator at control handle **75** can continuously control the direction and degree of tilt of die **20** to effect the circumferential crowding of the tube wall metal in line with the line of thinnest wall section of the tube.

It will thus be seen that a method has been provided for controllably displacing tube wall metal, during a sinking or reducing draw operation, in such a manner as to thicken the thinner parts of the tube wall so as to provide a tube having a substantially uniform wall thickness. Novel apparatus for performing this method has also been provided, and it includes novel means for varying the degree and direction of tilt of the drawing die in a controlled manner to insure application of the metal displacement forces along the center of the arc of minimum tube wall thickness.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the invention principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A method of increasing by a pre-selected maximum amount the wall thickness of a metal tube through a selected arc of the tube circumference, comprising the steps of drawing the tube through an annular reducing die, having a flared entry throat, to reduce the tube diameter; and, during such drawing, selectively tilting the die so that the die axis intersects the axis of the tube entering the die at an angle proportional to such pre-selected amount to exert on the tube wall within said selected arc a radial unit pressure greater than that exerted on the remaining portion of the tube circumference, by virtue of the angular relation of the flared entry throat and entering tube axes, to crowd metal of the tube wall, within such selected arc, circumferentially of the tube to increase the tube wall thickness within said selected arc.

2. A method of increasing by a pre-selected maximum amount the wall thickness of a metal tube through a selected arc of the tube circumference, comprising the steps of drawing the tube through an annular reducing die, having a flared entry throat, to reduce the tube diameter; and, during such drawing, selectively tilting the die so that the die axis intersects the axis of the tube enter-

ing the die at an angle proportional to such pre-selected amount to exert on the tube wall within said selected arc a radial unit pressure greater than that exerted on the remaining portion oft he tube circumference by virtue of the angular relation of the die and entering tube axes, to crowd metal of the tube wall, within such selected arc, circumferentially of the tube to increase the tube wall thickness within said selected arc; the radial unit pressure decreasing from a maximum at the midpoint of the arc to substantially zero at the ends of the arc, and the increase in wall thickness decreasing from a maximum at the midpoint of the arc to substantially zero at the ends of the arc.

3. A method of processing a metal tube having a wall thickness varying circumferentially from a maximum to a minimum, comprising the steps of drawing the tube through an annular reducing die to reduce the tube diameter; and while so drawing the tube, maintaining the die oriented with its axis at an angle to the axis of the tube portion entering the die to exert on the tube wall within a selected arc, substantially centered relative to the zone of minimum wall thickness, a radial unit pressure greater than that exerted on the remaining portion of the tube circumference by virtue of the angular relation of the die and entering tube portion axes, to crowd metal of the tube wall circumferentially of the tube to increase the tube wall thickness within said selected arc.

4. A method of processing a metal tube having a wall thickness varying circumferentially from a maximum to a minimum, comprising the steps of drawing the tube through an annular reducing die to reduce the tube diameter; while so drawing the tube, maintaining the die oriented with its axis at an angle to the axis of the tube entering the die to exert on the tube wall within a selected arc, substantially centered relative to the zone of minimum wall thickness, a radial unit pressure greater than that exerted on the remaining portion of the tube circumference by virtue of the angular relation of the die and entering tube axes, to crowd metal of the tube wall, within such selected arc, to flow circumferentially of the tube to increase the tube wall thickness within said selected arc; and maintaining the angle between the die and entering tube axis at a value coordinated with the maximum wall thicknesses to increase the wall thickness within such selected arc to substantially such maximum thickness.

5. Apparatus for processing a metal tube having a wall thickness varying circumferentially from a maximum to a minimum; said apparatus comprising, in combination, a draw bench including a gimbal support; an outer gimbal ring mounted in said support for oscillation about a first axis; an inner gimbal ring mounted in said outer gimbal ring for oscillation about a second axis perpendicular to said first axis; an annular die having a flared entry throat mounted in said inner gimbal ring for adjustment, by oscillation of said gimbal rings about their respective axes, of the angle between the axis of said die and the axis of a tube drawn therethrough to exert on the tube wall within a selected arc substantially centered relative to the zone of minimum wall thickness a radial unit pressure greater than that exerted on the remaining portion of the tube circumference, by virtue of the angular relation of the die and entering tube axes to increase the tube wall thickness within said selected arc and of the position of such selected arc circumferentially of the tube wall to maintain the selected arc centered on the zone of minimum wall thickness; a control stand having a control handle movable about a pair of mutually perpendicular axes; and servo means interconnecting said handle and said gimbal rings to maintain the orientation of said die in correspondence with the orientation of said handle and comprising a pair of fluid pressure actuators each operatively interconnected to one of said gimbal rings, and valve selectively operable to supply pressure fluid to said actuators, said valves being operatively connected to said control handle.

6. Apparatus for processing a metal tube having a wall thickness varying circumferentially from a maximum to a minimum; said apparatus comprising, in combination, a draw bench including a gimbal support; an outer gimbal ring mounted in said support for oscillation about a first axis; an inner gimbal ring mounted in said gimbal ring for oscillation about a second axis perpendicular to said first axis; an annular die having a flared entry throat mounted in said inner gimbal ring for adjustment, by oscillation of said gimbal rings about their respective axes, of the angle between the axis of said die and the axis of a tube drawn therethrough to exert on the tube wall within a selected arc substantially centered relative to the zone of minimum wall thickness a radial unit pressure greater than that exerted on the remaining portion of the tube circumference, by virtue of the angular relation of the die and entering tube axes to increase the tube wall thickness within said selected arc, and of the position of such selected arc circumferentially of the tube wall to maintain the selected arc centered on the zone of minimum wall thickness; a control stand having a control handle movable about a pair of mutually perpendicular axes; servo means interconnecting said handle and said gimbal rings to maintain the orientation of said die in correspondence with the orientation of said handle and comprising a pair of fluid pressure actuators each operatively interconnected to one of said gimbal rings, valves selectively operable to supply pressure fluid to said actuators, said valves being operatively connected to said control handle and normally having a neutral position locking said actuators against movement; and feedback linkage interconnecting said gimbal rings and said valves and operable to restore said valves to said neutral position when the orientation of said die corresponds with the orientation of said handle.

7. A method of correcting the eccentricity of a metal tube of circular cross-section having a wall thickness varying circumferentially from a maximum to a minimum, comprising the steps of drawing said tube through a die having a die orifice smaller than the diameter of the entering tube portion to reduce the outside diameter of the tube by effecting flow of the tube metal longitudinally of the tube; and mechanically subjecting the tube portion as it enters and passes through said die orifice to an inward radial unit pressure on a selected arc centered relative to the zone of minimum wall thickness greater than the inward radial unit pressure exerted on the remaining portion of the tube circumference to effect a flow of tube metal circumferentially of the tube to thereby increase the tube wall thickness within the selected arc.

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