Aug. 22, 1967 L. E. ZERLAUT 3,336,776

TUBE-BENDING APPARATUS

Filed June 24, 1964 7 Sheets-Sheet 1

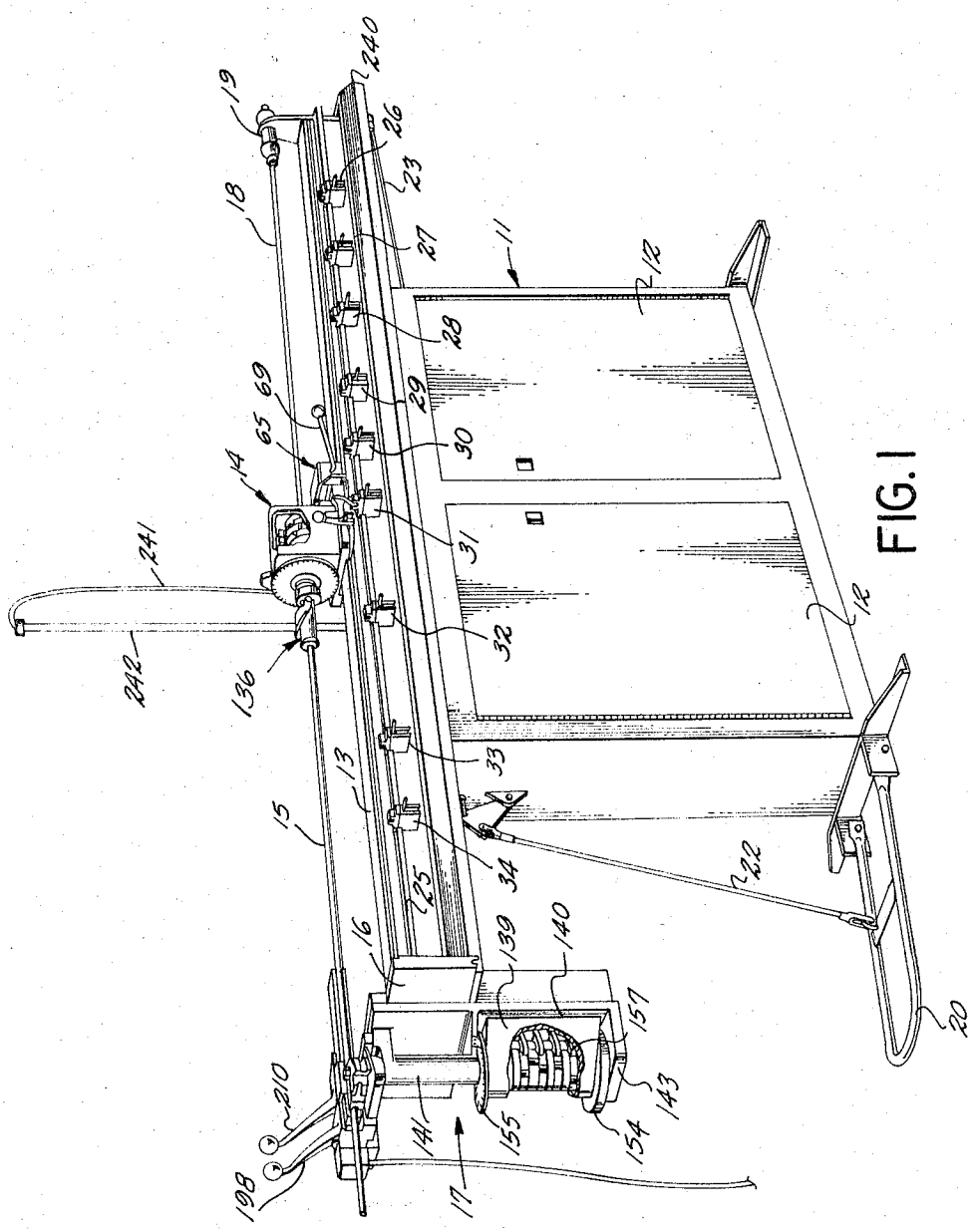


FIG. 1

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Aug. 22, 1967 L. E. ZERLAUT 3,336,776

TUBE-BENDING APPARATUS

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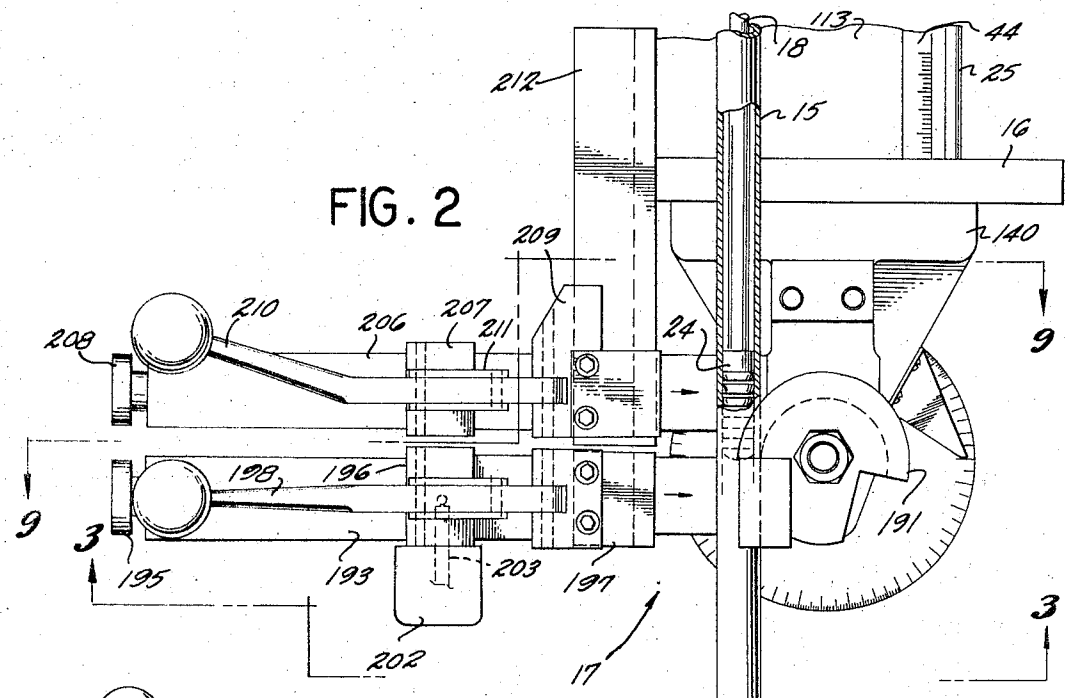


FIG. 2

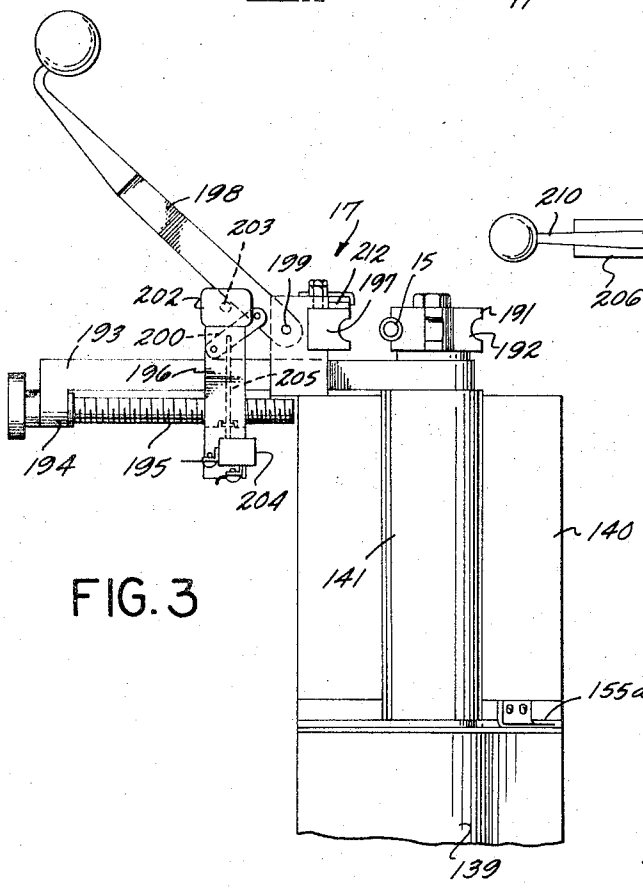


FIG. 3

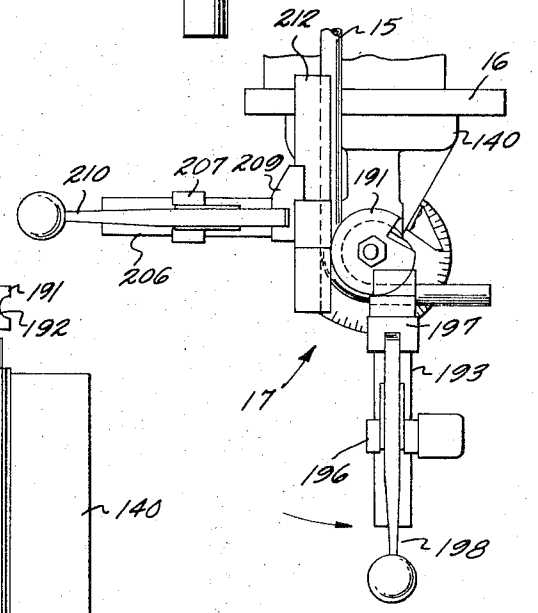


FIG. 4

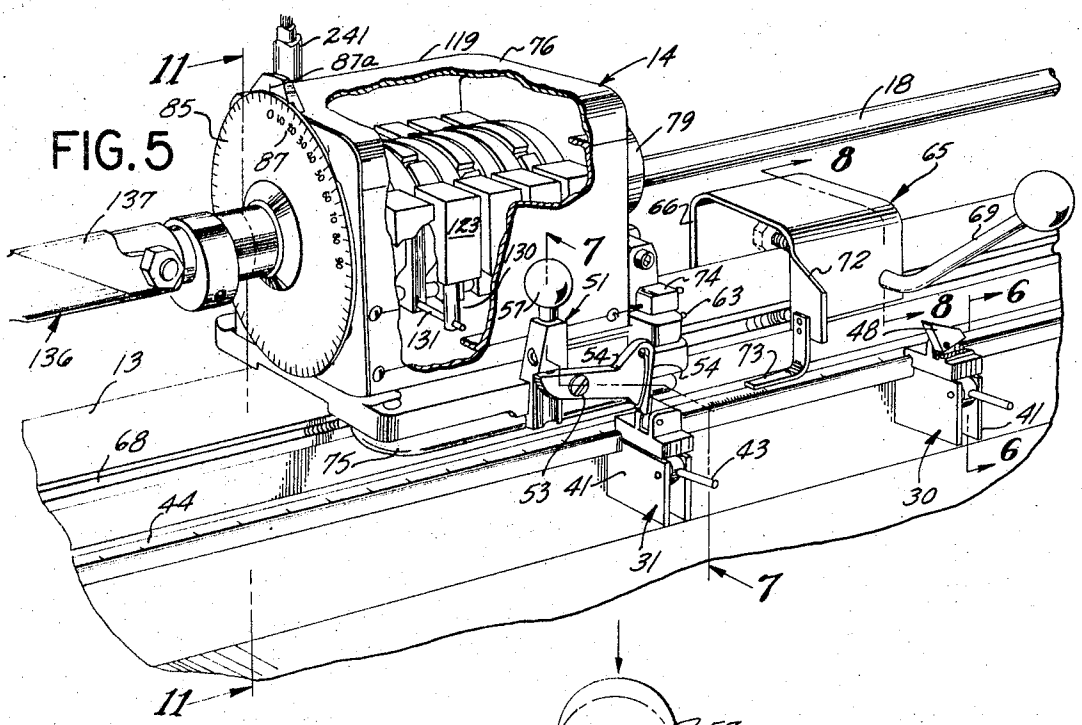
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Aug. 22, 1967 L. E. ZERLAUT 3,336,776

TUBE-BENDING APPARATUS

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FIG. 5



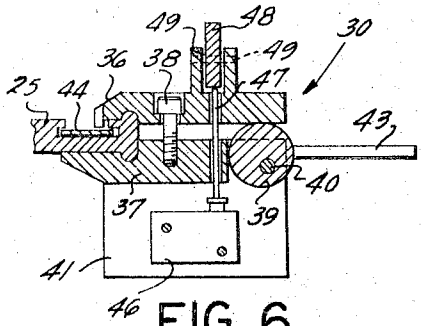


FIG. 6

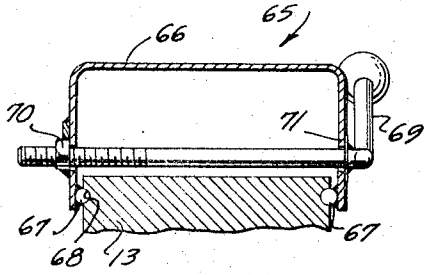


FIG. 8

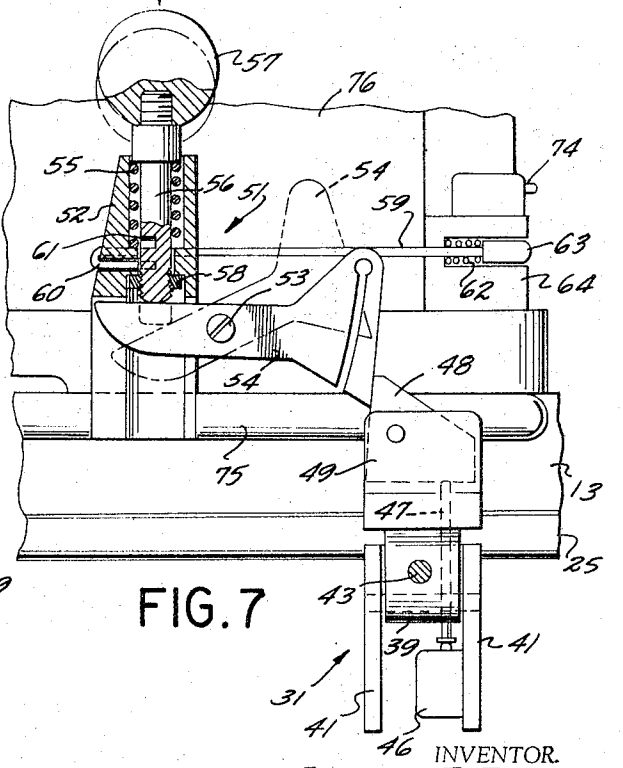


FIG. 7

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Aug. 22, 1967 L. E. ZERLAUT 3,336,776

TUBE-BENDING APPARATUS

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FIG. 9

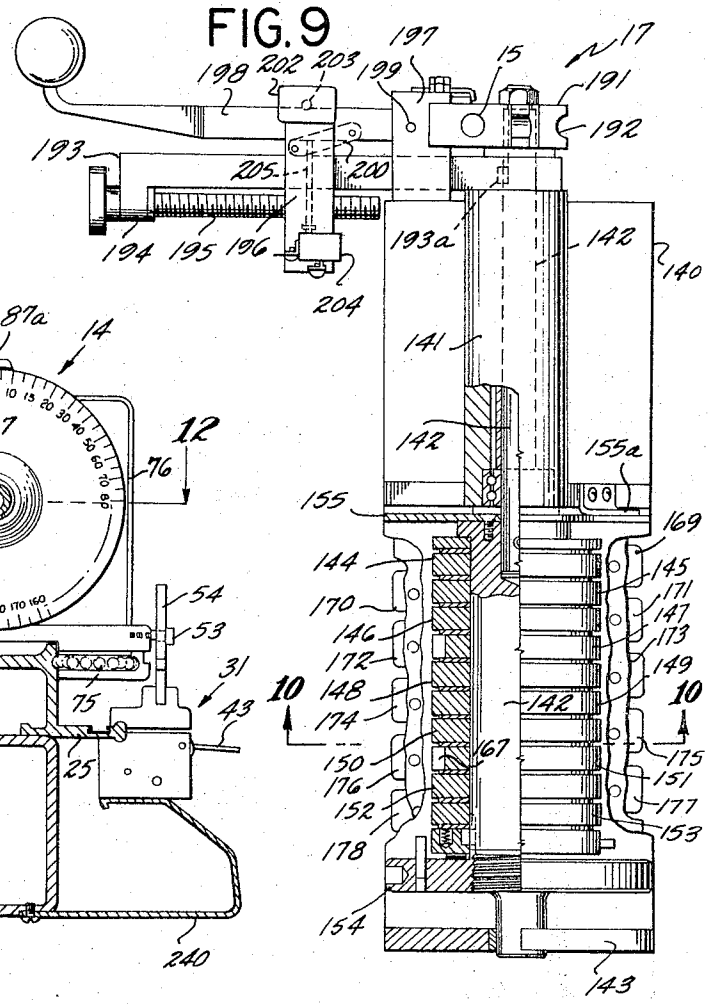
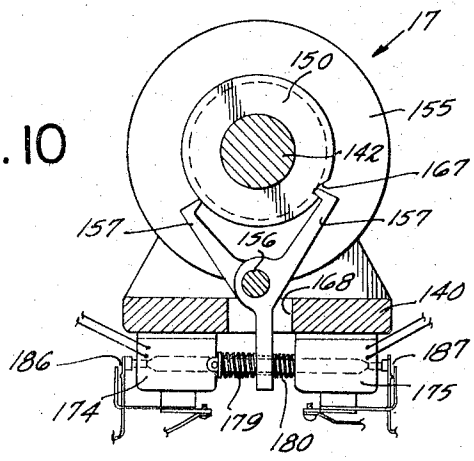


FIG. 11

FIG. 10



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TUBE-BENDING APPARATUS

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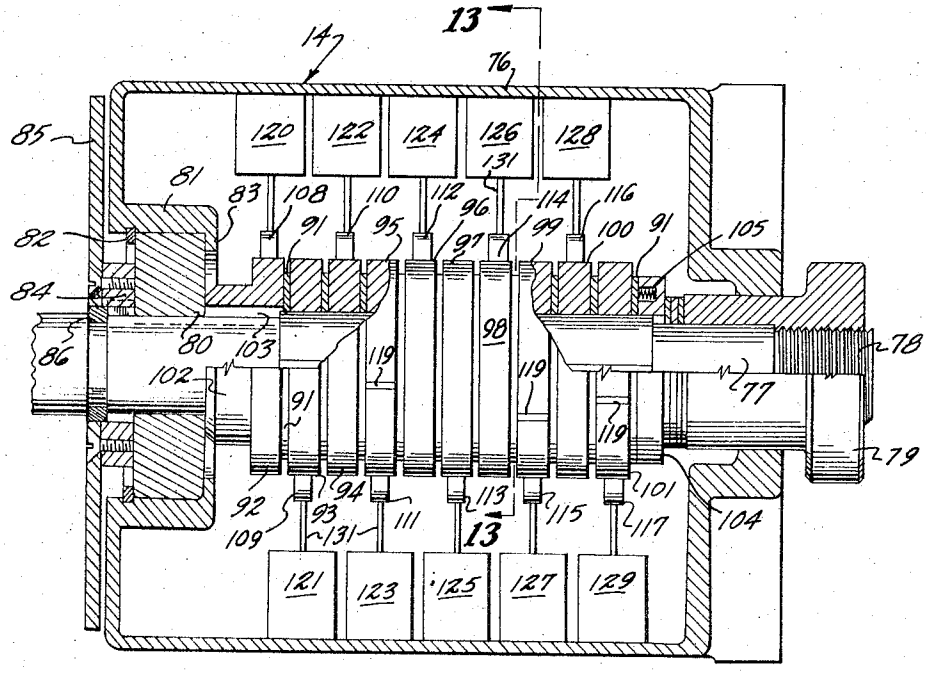


FIG. 12

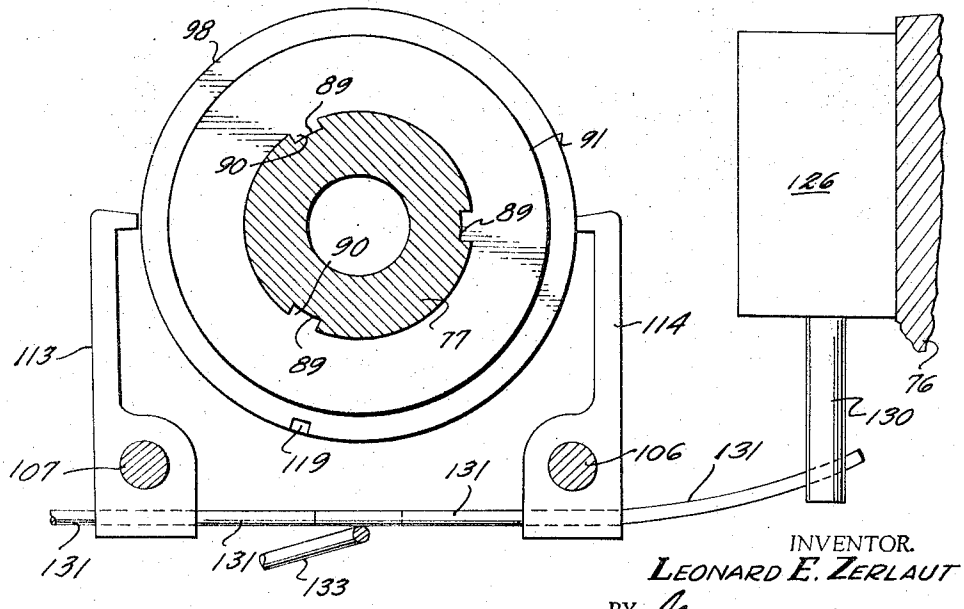


FIG. 13

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TUBE-BENDING APPARATUS

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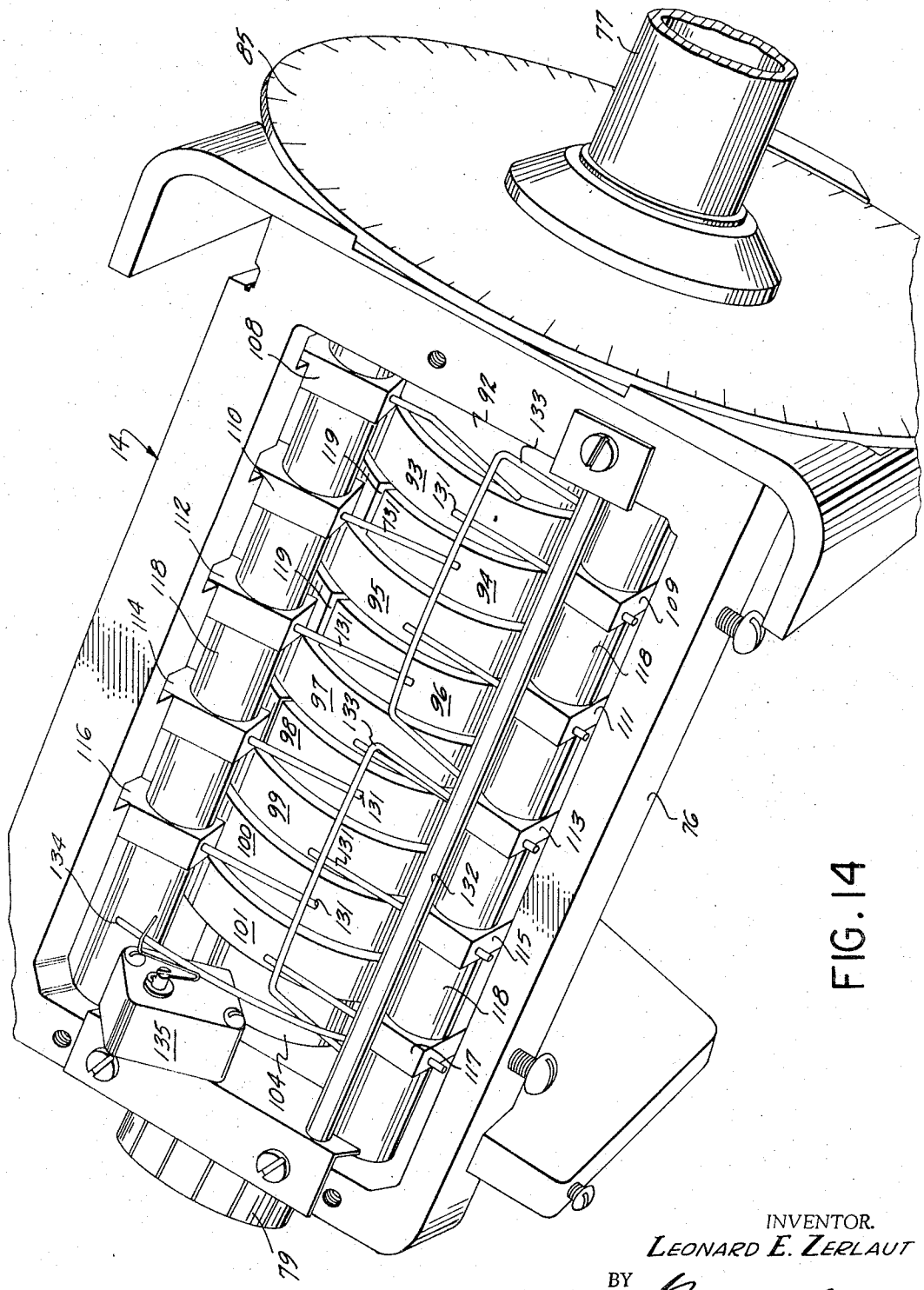


FIG. 14

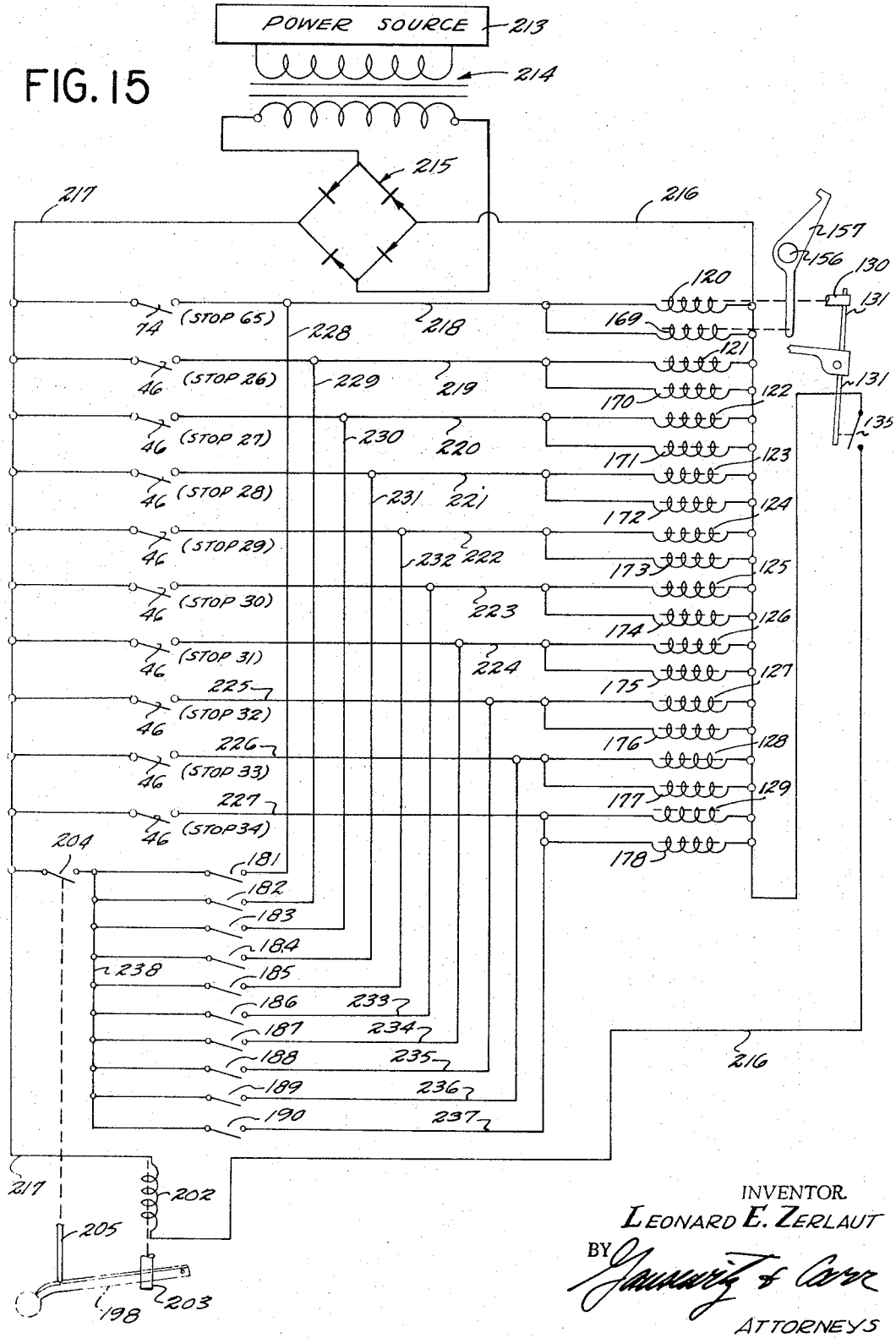
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TUBE-BENDING APPARATUS

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FIG. 15



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United States Patent Office 3,336,776
Patented Aug. 22, 1967

3,336,776

TUBE-BENDING APPARATUS

Leonard E. Zerlaut, Santa Ana, Calif., assignor to Leonard Precision Products Co., Santa Ana, Calif., a corporation of California

Filed June 24, 1964, Ser. No. 377,746
19 Claims. (Cl. 72—14)

This invention relates to a tube-bending apparatus. More specifically, the invention relates to a tube bender which, once properly set, will prevent the operator from making any bend in an incorrect plane, or at an incorrect location.

A primary object of the present invention is to provide a tube-bending apparatus incorporating novel electro-mechanical interlocks between the carriage (which determines the degree of rotation, that is to say the plane of bend) and the head (which determines the degree of bend).

A further object of the invention is to provide a tube-bending apparatus of the indicated type, wherein the initial set-up or adjustment may be performed in a highly simply manner by relatively inexperienced personnel, regardless of the types of bends to be made.

Another object of the invention is to provide a tube bender wherein an operator may, without moving from a predetermined position, mass manufacture in a simple and rapid manner large numbers of identical bent tubes or the like, without possibility that any of the tubes will contain a bend at an incorrect location or in an incorrect plane.

A further object is to provide a tube bender incorporating novel carriage and head mechanisms, such mechanisms embodying readily-adjustable stop rings and associated electrical switch elements for correlating the carriage with the head.

An additional object is to provide a tube bender of the manually operated type, in which the bend arm may not be moved to a tube-clamping position unless all factors are properly adjusted relative to both spacing of bend and plane of bend.

These and other objects will become apparent from the following detailed description taken in connection with the accompanying drawings in which:

FIGURE 1 is a perspective view of a tube-bending apparatus incorporating the present invention;

FIGURE 2 is a fragmentary top plan view illustrating the head end of the apparatus, the parts being illustrated in the positions assumed prior to clamping of the tube;

FIGURE 3 is an end view of the apparatus, taken from station 3—3 indicated in FIGURE 2;

FIGURE 4 is a fragmentary plan view corresponding generally to FIGURE 2, but illustrating the positions assumed after clamping of the tube and after the making of a bend;

FIGURE 5 is a fragmentary perspective view illustrating the carriage and associated stop and switch mechanisms, a portion of the carriage housing being broken away to illustrate stop rings and solenoids incorporated therein;

FIGURE 6 is a fragmentary transverse sectional view taken along line 6—6 of FIGURE 5, illustrating the construction of one of the bend-locating stops and the associated switch means;

FIGURE 7 is a fragmentary longitudinal sectional view taken along the broken line 7—7 of FIGURE 5, illustrating another of the bend stops and the associated self-releasing detent mechanism;

FIGURE 8 is a fragmentary transverse sectional view, on line 8—8 of FIGURE 5, illustrating the means for locking the first bend-locating stop (the tail stop) at any desired position longitudinally of the apparatus;

FIGURE 9 is an elevational view illustrating (like FIGURE 3) the head end of the apparatus, a housing or cover portion being removed to permit illustration of the various stop rings which determine the degree of bend;

FIGURE 10 is a horizontal sectional view taken on line 10—10 of FIGURE 9, and showing one of the degree-of-bend stop rings, together with associated solenoid and switch components;

FIGURE 11 is a transverse sectional view taken generally one line 11—11 of FIGURE 5;

FIGURE 12 is a fragmentary horizontal longitudinal sectional view taken on line 12—12 of FIGURE 11, showing portions of the carriage as viewed from above;

FIGURE 13 is a transverse sectional view taken on line 13—13 of FIGURE 12, illustrating a degree-of-rotation stop ring and the associated finger;

FIGURE 14 is an enlarged perspective view showing the underside of the carriage; and

FIGURE 15 is a schematic diagram of the electrical connections between the various switching and solenoid elements.

Referring to the drawings, the illustrated embodiment comprises an elongated horizontal bed **10** (FIGURE 11) which is rigidly supported upon a fixed base **11**, the latter being shown in FIGURE 1 as being adapted with doors **12** so that it may serve as a storage cabinet. An elongated rail or track **13** is mounted on the upper surface of the base **11** in order to slidably support the carriage **14** which forms an important part of the present invention. The carriage **14** determines the rotated position of a tube **15** which it is desired to bend (that is to say determines the "plane of bend").

Rigidly mounted in laterally-adjustable relationship on a cross-slide **16**, at one end of the bed **10**, is a head **17** which determines the degree of bending of the tube **15** (that is to say determines the arc through which the tube is bent). The head **17** also forms an important part of the present invention, and is correlated electrically with the carriage **14** as will be described in detail hereinafter.

A mandrel rod **18** is mounted parallel to and above the rail **13**, extending slidably through the axis of carriage **14** and through the tube **15**. One end of mandrel **18** is connected to a movable tail member **19** which is adapted to be shifted in response to depression of a foot pedal **20** (FIGURE 1) disposed at the head end of the apparatus. The foot pedal is connected to tail member **19** by means of a suitable linkage including rods **22** and **23**, the relationship being such that depression of the foot pedal shifts the mandrel **18** to the right (as viewed in FIGURE 1) and thereby releases from the bend in tube **15** a ball mandrel element **24** shown in FIGURE 2.

Description of the bend-locating stops, and associated actuating and switch means

Extending laterally from a lower edge of rail **13** is a flange **25** (FIGURES 6 and 11) adapted to provide a track and support for a plurality of adjustable bend-locating stops **26–34**, inclusive (FIGURE 1). The stops **26–34**, which are so located that they regulate the distances between the bends in tube **15**, are adjustably supported on flange **25** in the manner shown in FIGURE 6.

Each bend stop comprises a pair of horizontal jaws **36** and **37** which are pivotally associated with each other by means of a cap screw **38**. An eccentric element **39** is rotatably mounted beneath the upper jaw **36**, being supported upon a shaft **40** which extends between two plates **41** associated with lower jaw **37**. A lock crank **43** may be manually rotated to cause eccentric **39** to be tightened against the upper jaw, thus effectively clamping the bend stop at the desired point longitudinally of the rail. A tape

measure 44 is supported on the rail flange 25 in order to assist in the precise location of each bend stop.

Each of the bend stops 26–34 incorporates a switch means, for example comprising the normally-open switch indicated at 46 in FIGURES 6 and 7. The switch means includes a pin 47 which extends upwardly through the jaws 36 and 37 for operation by a pivotally mounted switch lever 48. Switch lever 48, which is pivoted between two ears 49 formed on upper jaw 36, has a beveled or inclined surface facing the tail end of the apparatus. The surface of switch lever 48 facing the head end of the apparatus is generally vertical. The relationship is therefore such that the lever 48 will pivot and depress pin 47 to close switch 46 in response to pressure aaginst such generally vertical surface by the mechanism next to be described.

The mechanism for operating the switch means 46–48 is shown to comprise a self-releasing detent and actuating mechanism 51, such mechanism being suitably mounted on carriage 14. More specifically, each mechanism 51 includes a base 52 which is fixedly attached to carriage 14 at one side thereof, and which pivotally supports at 53 an actuating member 54 adapted to engage and move the above-indicated generally vertical surface of switch lever 48.

A helical compression spring 55 is mounted within base 52 around a pin 56, the latter having a knob 57 at the upper end thereof. The relationship is such that the spring 55 normally urges the pin upwardly to a position at which a collar 58 at the lower pin end engages a shoulder formed at the lower portion of base 52. When the pin 56 is in this normal position, the actuating element 54 is in the illustrated solid-line position (FIGURE 7) adapted to engage the switch-operating lever 48. Depressing of knob 57 causes the pin 56 to effect upward pivoting of actuating element 54 to the phantom-line position shown in FIGURE 7, at which such element is disposed at a higher elevation than is the switch-operating lever 48. The carriage 14 may then be moved toward the tail end of the apparatus, without engaging the bend stops.

Pin 56 may be held in its lower position by means of a detent rod 59 having a hooked end 60 adapted to be inserted into a recess 61 in one side of the pin. A helical compression spring 62 bears against a plunger 63 in order to urge the rod 59 toward the right as viewed in FIGURE 7, so that the hooked end 60 will automatically enter the recess 61 in response to depression of knob 57.

Plunger 63, which is slidably mounted in a suitable housing 64 on carriage 14, is adapted to engage a tail stop ("No. 1" bend-locating stop) 65 the construction of which will be described below. When the tail stop 65 is thus engaged, the plunger 63 is actuated inwardly to effect shifting of the hooked end 60 out of the recess in pin 56, thereby permitting spring 55 to shift the pin 56 upwardly. The pivotally-mounted actuating element 54 then drops to its solid-line position (FIGURE 7) at which it may engage one of the switch-operating levers 48.

As best shown in FIGURES 5 and 8, the tail stop or "No. 1" bend-locating stop 65 may comprise a channel element 66 having elongated bearing elements 67 welded to the flange portions thereof. Bearing elements 67 are adapted to be clamped into horizontal grooves 68 which are formed on opposite sides of track 13. A clamping or locking crank 69 having a threaded end is inserted through openings in the flanges of element 66, being threaded through a nut 70 which is welded to one of such flanges. Rotation of crank 69 causes a fixed washer 71 on crank 69 to apply compression between the washer 71 and the nut 70, thus locking stop 65 at the desired position along grooves 68.

Formed at one edge of the channel element 66 is a flange or wing 72 (FIGURE 5) against which the plunger 63 of detent and actuating mechanism 51 is adapted to abut. Such flange 72 carries a member 73 which extends downwardly to the tape measure 44, thereby facilitating adjustment of the tail stop element 65 to the proper position longitudinally of the apparatus.

The wing 72 is also disposed to be engaged by a switch 74 which is mounted on the carriage 14, for example above housing 64 as shown in FIGURES 5 and 7. Switch 74 is of the normally-open variety, and functions conjointly with the switches 46 of bend stops 26–34.

The initial or starting point of any bending operation is achieved when the carriage 14 abuts the tail stop 65, switch 74 and detent plunger 63 then engaging and being operated by the wing 72. The carriage 14 is then moved progressively away from the tail stop 65, a bend being made after the pivotally-mounted actuating means 54 rides over a switch lever 48 and is then pushed back toward the tail end of the apparatus to operate the associated switch 46. Thus, for example, in the arrangement shown in FIGURES 1 and 5 the bend stops 26–30 are not employed. Instead, the first bend is made when carriage 14 engages tail stop 65; the second bend is made when bend stop 31 is engaged; etc.

The above-indicated grooves 68 in rail 13 (FIGURE 8) also serve to receive the balls of a ball-return type antifriction mechanism 75. Such mechanism locks the carriage 14 against displacement off the rail 13, while reducing to a minimum the friction incident to longitudinal shifting of the carriage.

Description of the carriage 14

Referring particularly to FIGURES 5 and 12–14, the carriage 14 is illustrated to comprise a suitable housing 76 having a base portion adapted to ride on rail or track 13 longitudinally of the apparatus, as previously noted. A horizontal spindle 77 (which is tubular, so that mandrel 18 may extend therethrough) is rotatably mounted generally axially of the carriage. The spindle is provided with a threaded end 78 which receives a hand nut 79. Such nut, which is adapted with a flange to facilitate manual rotation thereof, extends inwardly through a corresponding opening in the end of housing 76, the nut thus serving as a journal element in addition to the brake or clutch function to be described below.

Keyed to the opposite end portion of spindle 77, relatively adjacent the head end of the apparatus, is a journal element or collar 80. Such collar rotates in an inwardly-extending cylindrical bearing portion 81 of the housing, and is held against axial movement by means of a snap ring 82 and a neck 83.

Rigidly associated with spindle 77 adjacent collar 80 are a spacer ring 84, an indicator disc or dial 85, and a snap ring 86 which seats in an annular groove in the spindle. Such assembly may include suitable elements, such as keys, to insure that there will be no rotational or axial movement of indicator disc 85 relative to the spindle. The face of the indicator disc 85 is provided with indicia 87 to indicate the degrees of a circle. A fixed marker 87*a* is provided on the housing, so that the rotated position of the spindle may be determined.

The central portion of spindle 77 is illustrated as being somewhat enlarged, and as having longitudinal keyways 89 (FIGURE 13) formed therein. Such keyways receive inwardly extending key portions 90 of thin washers 91 which are provided at spaced points longitudinally of the spindle.

Mounted on the enlarged spindle portion, on opposite sides of the respective washers 91, are degree-of-rotation stop rings or collars 92–101, inclusive. The first such stop ring, number 92, is provided with a neck portion 102 which engages the inner surface of the collar 80. Such first stop ring 92 is keyed to spindle 77 by means of a key 103. The remaining stop rings 93–101 are not keyed to the spindle, having no projections which extend into keyways 89, the result being that such remaining stop rings 93–101 may be rotated relative to the spindle unless frictionally locked in response to rotation of the hand nut 79.

The remaining elements associated directly with spindle

77 comprise an additional ring or collar 104 disposed relatively adjacent nut 79, being separated therefrom by means of suitable washers. Ring 104 is recessed to receive helical compression springs 105 which urge the collar 104, and thus all of the stop rings 93–101 and the associated washers, toward the fixedly mounted element 80. Thus, a light spring bias is created in order to prevent undesired rotation (but not preventing intentional rotation) of any of the rotatably-mounted stop rings 93–101 at any time, even when nut 79 is loose. When the nut 79 is rotated in a direction forcing all of the collars and washers tightly against the end or stop collar 80 and its associated snap ring 82, there is created a positive brake or clutch action which prevents rotation of any stop ring 93–101 despite the application of considerable force thereto.

It is a feature of the apparatus that the washers or clutch discs 91, being keyed to spindle 77 as stated above and as shown in FIGURE 13, prevent frictional transmission of rotational movement between the stop rings. Thus, any stop ring 93–101 may be rotatably adjusted on spindle 77 without disturbing the adjustment of any other such stop ring.

Mounted within the carriage housing 76, longitudinally adjacent opposite lower side portions thereof, are shafts 106 and 107 which pivotally support stop fingers 108–117. Suitable spacer collars 118 (FIGURE 14) are provided on the respective shafts between the fingers thereon, the relationship being such that the fingers are positioned adjacent the various stop rings 92–101. More specifically, finger 108 is adjacent stop ring 92, finger 109 is adjacent stop ring 93, etc.

Each of the fingers has a hooked end portion adapted to enter a corresponding notch 119 in the associated stop ring or collar. Thus, when any finger is inserted into the corresponding notch 119 after nut 79 is tightened, the spindle 77 is maintained against rotation. On the other hand, when the clutch or brake nut 79 is loosened, insertion of a finger end into a notch 119 serves to maintain only the single stop ring against rotation while the spindle is rotated during initial adjustment or set-up of the tube-bending apparatus.

Solenoids 120–129 are connected, respectively, to the finger members 108–117 to effect pivoting thereof into notches 119 in the stop collars or discs. As best shown in FIGURES 5 and 12–13, the solenoids are suitably supported on the side walls of carriage housing 76 and have downwardly extending cores or plungers 130. The lower end of each core 130 has extended therethrough a relatively stiff (but flexible) spring rod or wire 131, such rod or wire also penetrating the base portion of the associated finger member (relatively adjacent the shaft 106 or 107 therefor). The inner end portion of each wire 131 extends to a position beneath the axis of the spindle as shown in FIGURES 13 and 14.

The above-described relationship is such that energization of any solenoid will shift the associated core or plunger 130 upwardly and thus bias the connected finger against the periphery of the corresponding stop ring or disc. The amount of upward travel of the solenoid core 130 is sufficient, as illustrated in FIGURE 13 which shows solenoid 126 in energized condition, to flex or bend the outer spring portion 131. It follows that subsequent rotation of the stop ring (for example, number 98) until notch 119 therein is registered with the finger end will cause such end to snap into the notch.

As best shown in FIGURE 14, an additional shaft 132 is rotatably mounted longitudinally of the lower portion of housing 76. Such shaft is illustrated as having associated therewith two generaly U-shaped crank members 133, the base portions of which lie beneath the inner ends of wires 131. An additional crank 134 is provided on shaft 132, being adapted to actuate a normally-open master switch 135 which is suitably mounted on the housing wall.

The inwardly-extending end portions of the flexible rods or wires 131 are thus adapted to pivot the crank members 133 when, and only when, the end of one of the fingers 108–117 penetrates the corresponding notch 119. Such pivoting or rotation is sufficient to effect, through arm 134, closing of switch 135. Stated conversely, the relationship is such that any movement of the U-shaped cranks 133 in response to operation of any solenoid 120–129, prior to the time that the ascociated finger is registered with the notch 119 therefor, will be insufficient to effect closing of the switch 135.

The above-described relationship is extremely important in that an operator is thereby prevented from making a bend in an incorrect plane. The energized finger does not snap into a notch 119 until operator rotates the tube (about its longitudinal axis) to the correct rotated position. Master switch 135 then closes and (for the first time) makes it possible for the operator to initiate a bending operation.

A suitable tube-clamping or chuck device, indicated at 136 in FIGURE 5, is provided on the spindle end which is nearest the head. Such device incorporates a lock element 137 adapted to be pivoted to a position permitting insertion of the end of a tube 15 until it seats against a suitable stop (not shown). The lock element 137 is then pivoted back to a locking position which prevents rotation of the tube 15 relative to spindle 77.

Description of the head 17

The head 17 of the tube-bending apparatus is best illustrated in FIGURES 1–4 and 9–10, and incorporates a vertical support plate 140 and bearing housing 141 adapted to rotatably receive a vertical spindle 142 (which may comprise two parts non-rotatably pinned to each other). The lower end of the spindle is rotatably mounted in a horizontal flange element 143 which is provided at the lower end of support plate 140. A removable cover 139, shown in FIGURES 1 and 3 only, protects the various elements which are located below the bearing housing.

A plurality of degree-of-bend stop discs, collars or rings 144–153 are rotatably mounted on the spindle 142. Such discs are adapted to be clamped against rotation in response to operation of a clutch nut or disc 154 which is provided at the lower (and suitably threaded) end of the spindle, above flange element 143. An indicator disc or dial 155, having the degrees of a circle marked thereon, is fixedly associated with the spindle 142 adjacent the lower end of the bearing housing 141. A pointer or indicator means, shown at 155*a*, is mounted on support plate 140 in order to permit reading of dial 155.

The various stop rings 144–153 and associated elements are not described in great detail since they may correspond to the elements shown and described relative to carriage 14. Thus, for example, suitable spring-bias means and separator washers may be provided, the latter being disposed between the respective stop rings 144–153 and being keyed to the spindle 142.

The various actuating elements associated with the stop rings 144–153 may also correspond to the elements described in detail relative to FIGURES 12–14. Alternatively, the actuating elements best shown in FIGURES 9 and 10 may be employed as will next be described in a general manner.

Referring to FIGURE 10, a vertical shaft 156 is rigidly associated with the support plate 140 and has ten finger levers 157 pivotally mounted thereon. Similarly to the case of the finger elements 108–117 described relative to carriage 14, the finger levers 157 have hooked ends adapted to be received in notches 167 in the respective stop rings 144–153. As shown in FIGURE 10, one wall of each of the notches 167 may be inclined.

The finger levers 157 have tail portions which project through an opening 168 in support plate 140 for connection to solenoids 169–178 (FIGURES 9, 10 and 15) which are suitably mounted on the rear or inner surface

of the support plate. Solenoid **169** operates the lever **157** for disc **144**, solenoid **170** for disc **145**, etc.

Stated more specifically, the tail portion of each finger lever **157** slidably receives the plunger or core of the associated one of solenoids **169–178**, being associated with such core by means of two helical compression springs **179** and **180** which are mounted around the core or plunger on opposite sides of the finger. When a particular solenoid is energized, for example the solenoid **175** shown at the right in FIGURE 10, the core or plunger immediately snaps into the retracted position, thereby compressing the outermost compression spring **179** and biasing the end of the associated finger **157** against the cylindrical periphery of the corresponding stop ring **150**. Then, as soon as the stop ring rotates until the finger may enter the notch **167** therein, the spring **179** biases the lever until it enters the notch. The remaining spring, number **180**, serves to bias the solenoid plunger and the associated finger back to the retracted position in response to de-energization of the solenoid.

Switches **181–190** (FIGURES 10 and 15) are mounted, respectively, on solenoids **169–178** for operation in response to energization of such solenoids. The switches **181–190** are the normally-open type and are incorporated in the electrical apparatus for holding-circuit purposes to be described hereinafter.

Proceeding next to a description of those portions of the tube-bending apparatus which clamp and bend the tube **15**, a conventional bending die **191** is suitably mounted coaxially at the upper end of spindle **142**, such die having an annular groove **192** therein adapted to receive the tube **15**. A bending arm or crank **193** is connected (as by a key **193***a*, FIGURE 9) to the upper end of spindle **142** and extends radially outwardly therefrom as best shown in FIGURES 2–4 and 9. The outer end portion **194** of such arm is internally threaded to receive an adjustment screw **195** which is threaded through a slide or adjustment element **196** adapted to slide along the arm **193** radially toward or away from bending die **191**. Thus, the screw **195** may be operated in a manner determining the initial position of the slide element **196**, in accordance with the diameter of the particular tube **15** to be bent.

A clamp-block element **197** is slidably mounted on arm **193** between slide **196** and the bending die. A clamp lever **198** is pivotally connected at **199** to the clamp-block **197**, being associated through a pivot link **200** with the slide **196**. The resulting linkage operates somewhat in the manner of a toggle, so that upward pivoting of clamp lever **198** (FIGURE 3) effects retraction of the clamp-block **197** from tube **15**, whereas downward pivoting of lever **198** forces the clamp-block element **197** against tube **15** as shown in FIGURE 9.

It is a very important feature of the invention that a solenoid **202** is mounted fixedly on one side of slide element **196**, having an armature or plunger pin **203** which extends inwardly through a suitable opening in slide **196** to a position beneath clamp lever **198** when the latter is in its upper position (shown in FIGURE 3). The construction of solenoid **202** is such that the armature **203** is normally extended, being retracted in response to energization of the solenoid. It follows that the clamp lever **198** may not be depressed to clamp the tube **15** except during periods when the solenoid is energized.

The clamp lever **198** is adapted, when fully depressed to clamping position as shown in FIGURE 9, to effect closing of a normally-open switch **204**. Such switch is mounted at the lower portion of slide **196** and is adapted to be operated by a vertical pin **205** which extends upwardly through a suitable bore in slide **196** to a position at which it may be operated by the lever **198** upon depression thereof.

The illustrated bending tools are adapted to effect draw bending of the tube **15**, the bending die **191** rotating between the FIGURE 2 position and the FIGURE 4 position as the bend arm **193** is pivoted about the vertical axis. The degree of such pivoting is, as will be described subsequently, determined by the setting of the associated degree-of-bend stop ring **144–153**. Because the tube **15** is clamped tightly against the bending die **191**, which is adapted to rotate with the spindle, it follows that bending of the tube effects longitudinal shifting thereof in a direction toward the head **17**.

In accordance with another form of bending (compression bending), the die **191** does not rotate, the element **197** being instead provided with suitable rollers which roll along the tube as bending is effected. No longitudinal shifting of the tube results from such bending.

A follow means is provided adjacent the bend arm **193** to prevent lateral movement of tube **15** as bending is effected. In the illustrated embodiment, such means corresponds generally to the previously-described arm **193**, etc., except that there is no pivotal movement about the vertical axis. The illustrated mechanism comprises an arm **206** which is fixedly secured to the head, a slide or adjustment element **207** mounted on the arm **206** for adjustment by a screw **208**, a clamp-block base **209** slidably mounted on the arm, and a lever and linkage **210** and **211** pivotally associated with the elements **207** and **209** to effect the clamping action as shown in FIGURES 2 and 4.

In the illustrated draw-bending arragement, the clamp-block base **209** slidably supports a movable die **212** adapted to shift longitudinally of the apparatus as bending progresses. In a compression-bending arrangement, as indicated above, there is no such shifting but instead a mere clamping action.

Description of the remaining portions of the electric circuitry

Referring next to FIGURE 15, a suitable power source is indicated at **213** and may comprise, for example, a conventional 115-volt 60-cycle power line. Source **213** is connected through a transformer **214** to a full-wave rectifier bridge **215**. The rectifier bridge is, in turn, connected through a lead **216** to the solenoid **202** which controls armature pin **203** associated with clamp lever **198**, as described above relative to FIGURES 2–4. The remaining terminal of the solenoid **202** is connected through a lead **217** back to the rectifier bridge.

The master switch **135** is interposed in lead **216** and therefore controls the energization of solenoid **202** to retract armature pin **203**. Such switch **135** is, as described relative to FIGURES 12–14, closed in response to shifting of any of the fingers **108–117** into an associated notch **119**, such shifting occurring in response to energization of a solenoid **120–129**, but only when the corresponding stop ring is in the correct rotated position.

A plurality of leads, numbered **218–227**, are connected between leads **216** and **217** through the parallel combinations of the solenoid **120–129** and **169–178**, respectively. Thus, solenoids **120** and **169** (the latter being associated with one of the fingers **157** on head **17**) are shown as connected in parallel so that both are simultaneously energized upon closing of the switch **74** on carriage **14**. It follows that when switch **74** engages wing **72** on tail stop **65** (FIGURE 5), solenoids **120** and **169** are energized to effect, respectively, closing of switches **135** and **181**. Switch **135**, however, does not (as previously noted) close unless the corresponding notch **119** is registered therewith.

It is to be remembered that solenoid **120** is associated with the stop ring **92** which (FIGURE 12) is keyed to spindle **77** by means of the key **103**. This, therefore, is the zero position. Thus, the dial **85** is adapted (in conjunction with stationary marker **87***a*) to read zero when the finger **108** is registered with groove or notch **119** in stop ring **92**.

In like manner, solenoids **121** and **170** are connected in parallel with each other for energization in response to closing of the switch **46** which is incorporated in bend stop **26**. Such energization results in closing of switch **182** and also (if stop ring **93** is then so rotated that the

notch **119** therein registers with finger **109**) in closing of master switch **135**.

The respective leads **218–227** are connected (at points between the switches and solenoids therein) through leads **228–237** with the respective switches **181–190**. The remaining sides of such switches are connected through a terminal strip or lead **238** to the switch **204** and thus to lead **217**. Thus, for example, lead **228** connects the lead **218** through the series-related switches **181** and **204** to lead **217**. Therefore, when switches **181** and **204** are both closed, the solenoids **120** and **169** are energized independently of switch **74** and provide a holding means which maintains the solenoids energized in the event that the carriage is moved away from the tail stop **65** as bending progresses. Such movement of the carriage away from the associated tail stop normally occurs during a draw-bending operation, as previously noted.

It is to be remembered that switch **181** is associated with the solenoid **169**, switch **182** with solenoid **170**, etc., so that these switches will be closed in response to energization of the associated solenoids. Each holding circuit is not completed however, until the bend lever **198** is depressed to close switch **204**.

It is one feature of the present apparatus that the wiring represented in FIGURE 15 may be physically incorporated into the apparatus without in any manner interferring with operation thereof. Thus, for example, the various leads associated with the bend stops **26–34** are all incorporated within a suitable housing **240** which attaches to the bed **10** as shown in FIGURE 11. Furthermore, the various leads associated with the solenoids in movable carriage **14** are connected through a cable **241** which is suspended from a mast **242**.

Description of operation

Proceeding first to a description of the manner in which the machine is set up for mass-manufacture of a particular tube, the tail (first bend-locating) stop **65** is first shifted to the proper position along track **13**. This is readily accomplished by lifting on the crank **69** to thereby loosen the bearing means **67** (FIGURE 8) so that the stop may be shifted to any desired location. Thereafter, crank **69** is again depressed to lock the tail stop in place.

The various operative bend-locating stops are then set to desired positions along the track **13**, as determined by the measuring tape **44** adjacent thereto. As previously noted, the only operative bend stops are those between tail stop **65** and head **17**. Each bend stop is readily adjusted by lifting the lock crank **43** (FIGURE 6) to release the clamping action effected by jaws **36** and **37**, following which the crank is returned to a position effecting clamping of the jaws against flange **25** as described in detail above.

The self-releasing detent mechanism **51** is then operated by depressing knob **57**, against the bias of spring **55**, until the hooked end **60** (FIGURE 7) snaps into the recess **61** in response to the bias of spring **62**. This maintains the actuating means **54** in the upwardly pivoted position shown in phantom lines in FIGURE 7, and causes the plunger **63** to protrude outwardly from the housing **64** therefor.

The mechanism **54** being in its upwardly pivoted position, the carriage **14** may be shifted toward the tail portion of the apparatus until wing **72** of tail stop **65** is engaged. Engagement of the carriage with tail stop **65** causes automatic release of the mechanism **51** due to depression of plunger **63**. Furthermore, such engagement causes the switch **74** to be closed. As shown in FIGURE 15, closing of switch **74** completes an energizing circuit between leads **216** and **217** to energize both solenoids **120** and **169**.

Carriage spindle **77** is then turned until dial **85** reads zero degrees. Thereafter, the lock or clutch nut **79** on carriage **14** is turned to a releasing position at which clamping pressure is no longer brought to bear against the stop rings **92–101** (FIGURE 12). However, such stop rings (all but number **92** of which are rotatably mounted on the spindle **77**) are lightly biased by the springs **105** to prevent undesired rotation thereof relative to each other.

The carriage **14** is then shifted toward head **17**, actuating member **54** riding over the switch lever **48** of the next-adjacent bend stop, for example the bend stop **31** shown in FIGURES 5 and 7. The carriage is then pushed toward the tail portion of the machine until element **54** forceably engages and pivots the switch lever **48**, thereby depressing pin **47** and closing switch **46**.

The closing of switch **46** completes the circuit shown in FIGURE 15 and effects energization of the related solenoids **126** and **175**. When solenoid **126** becomes energized, the associated flexible spring wire **131** urges the finger **114** (FIGURE 13) against the peripheral portion of lock ring **98**. The spindle **77** is then turned until the notch **119** in lock ring **98** registers with finger **114**, so that the finger prenetrates the notch **119** and prevents further rotation of the lock ring. The operator then rotates the spindle until the indicator disc or dial **85** indicates that the desired degree of rotation (plane of bend) for the bend which it is desired to make when the carriage **14** abuts bend stop **31**. In this manner, the lock ring **98** is readily adjusted rotationally relative to spindle **77**, to a precise position indicated by dial **85**. It is to be noted that the carriage must be maintained firmly against the associated bend stop **31** during the described setting or adjustment operation.

The describe operation is then repeated for each of the three remaining operative bend stops **32**, **33** and **34**, normally with a different degree of rotation (plane of bend) relative to each of the bend stops **32–34**. The knob **57** of detent mechanism **51** is then again depressed, and carriage **14** is shifted into engagement with tail stop **65**. The lock or clutch nut **79** is then rotated to a position clamping all of the lock rings **92–101** firmly in position, so that no rotation may take place between any lock ring and the spindle **77**.

Assuming that the proper tooling is incorporated in the head **17** for compression or draw bending (the tooling illustrated in the drawing being for draw bending), the next step in the set-up operation is to loosen the clutch nut or disc **154** (FIGURE 9) at the bottom portion of the head. This operates, similarly to the operation of the nut **79**, to release all of the lock rings **144–153** incoporated in the head.

The carriage **14** is then pressed firmly against tail stop **65**, to maintain switch **74** in closed condition, following which the bend arm **193** is turned about the vertical axis until the notch **167** in the stop ring **144** (FIGURE 9) associated with solenoid **169** is registered with the corresponding finger **157**. Because the solenoid **169** is then energized, the finger **157** snaps into the recess or notch **167** in stop ring **144**, locking such stop ring against further rotational movement. The bend arm **193** is then rotated about the vertical axis until the indicator disc or dial **155** registers the desired degree of bend.

The above-described operation is then repeated sequentially, as the carriage **14** is shifted toward head **17** and then pressed against the bend stops **31**, **32**, **33** and **34**. Thus, similarly to the setting operation described relative to the degree-of-rotation lock rings in the carriage **14**, the various degree-of-bend lock rings in the head **17** are set. It is emphasized that both sets of lock rings are thus correlated to the bend-locating stops.

The carriage **14** is then shifted away from any stop, and the clutch nut or disc **154** is rotated to a locking position preventing any further rotation of lock rings **144–153** relative to spindle **142**.

The apparatus being thus initially set up for operation, it may be readily operated by an unskilled laborer without substantial possibility of error. The operator merely moves the clamp or chuck element **137** (FIGURE 5) to permit clamping of the end of tube **15** in the chuck or clamping

mechanism **136**. The tube end being thus clamped in the chuck **136**, the tube and the connected carriage **14** are slid along track **13** until tail stop **65** is engaged. This operation is possible because the knob **57** on detent mechanism **51** is first depressed as described above.

The carriage **14** being pressed against tail stop **65**. the operator rotates the tube **15** to the extent permitted by finger **108** which is associated with solenoid **120**, the latter then being energized due to closing of switch **74** when the tail stop is engaged. As previously noted, the finger **108** will enter the notch **119** of lock ring **92** (and thus stop rotation of horizontal spindle **77**) when the dial **85** reads zero degrees.

When the finger **108** enters the notch **119** of the associated lock ring **92**, the inwardly projecting portion of wire **131** (FIGURES 13 and 14) presses downwardly against the crank member **133**, thereby operating through crank **134** to close master switch **135**. Such closing of switch **135** completes (as shown in FIGURE 15) the energizing circuit through solenoid **202**, via leads **216** and **217**, so that the armature or plunger pin **203** associated with clamp lever **198** is shifted to retracted position permitting downward movement of clamp lever **198**.

Downward shifting of lever **198** causes the clamp-block element **197** to be shifted against tube **15** as shown in FIGURES 3 and 9. The operator may then, after pivoting the lever **210** of the follow mechanism to clamping position, make a bend in the tube **15** by shifting the clamp arm **193** from the FIGURE 2 position to the FIGURE 4 position.

In summary, therefore, the operator may not make a bend unless the carriage **14** is tightly forced against the associated bend stop, since if this desired condition were not present the pin **203** of solenoid **202** would prevent the tube-clamping function which is a prerequisite to the bend function. Furthermore, and very importantly, the operator may not make a bend unless tube **15** is in the correct rotated position. It is thus impossible to make a bend at an incorrect point or in an incorrect plane.

The degree of bend is determined by the lock ring **144** which is associated with solenoid **169** in the head **17**. Stated otherwise, bending can only continue until a finger **157** snaps into a notch **167** in the lock ring **144** associated with the particular solenoid **169** which was energized concurrently with energization of solenoid **120** in carriage **14**. The degree of bend is thus correlated to the plane of bend, for each position of the tube longitudinally of the apparatus.

The downward shifting of clamp lever **198** to clamping position causes the pin **205** (FIGURES 3 and 9) to close switch **204**. As previously noted, closing of switch **204** completes a holding circuit through the particular switch **181** which is closed concurrently with energization of solenoid **169**. Thus, the solenoids **120** and **169** remain energized despite the fact that the carriage **14** is drawn away from the associated bend stop as bending progresses in a draw-bending operation.

After the bend is completed, the clamp lever **198** and the follow lever **210** are lifted to release the tube **15**, the former operation effecting opening of switch **204** to break the described holding circuit. Then, assuming that the carriage is not in engagement with any of the bend stops, the solenoids **120** and **169** become deenergized so that the associated fingers shift out of the notches in the lock rings. The tube **15** is then shifted toward the operator, who normally stands adjacent the head **17** (it being unnecessary for the operator to leave his position at any time except during set up of an apparatus).

As soon as the detent mechanism **51** rides over the next adjacent bend stop, for example number **31**, the operator pushes on the tube until the carriage **14** causes the mechanism **51** (the element **54** thereof) to engage and operate the bend-stop mechanism until switch **46** is closed. The previously described steps are then repeated, as described above, except that the degree of bend and the plane of bend are determined by the stop rings associated with solenoids **126** and **175** which become energized when the switch **46** of bend stop **31** closes.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited solely by the appended claims.

I claim:

1. Apparatus for bending a tube, which comprises:
- an elongated support,
- a carriage mounted on said support for movement longitudinally thereof,
  - said carriage incorporating a rotatable chuck adapted to clamp a tube to be bent,
  - said carriage further incorporating a plurality of stop elements connected to said chuck for rotation therewith,
  - said carriage additionally incorporating a plurality of solenoids associated, respectively, with said stop elements to render the same selectively operative and inoperative,
    - each of said solenoids being adapted when in a predetermined condition of energization to render the associated stop element operative to limit the rotation of said chuck and thus of said tube,
- a plurality of bend stops mounted in spaced relationship longitudinally of said support,
  - each of said bend stops being associated with a switch means,
    - said switch means for each of said bend stops being adapted to be operated when said carriage is in a predetermined longitudinal position,
- a head mounted adjacent one end portion of said support and incorporating rotatable means to bend said tube in a plane determined by the rotated position of said tube and said chuck,
  - said head incorporating a plurality of stop elements connected to said bending means for rotation therewith during said bending of said tube,
  - said head further incorporating a plurality of solenoids associated, respectively, with said stop elements of said head to render said stop elements selectively operative and inoperative,
    - each of said solenoids of said head being adapted when in a predetermined condition of energization to render the associated stop element operative to limit the degree of rotation of said bending means and thus determine the degree of bend,
- electric circuit means to correlate each of said solenoids on said carriage with a predetermined one of said solenoids on said head,
  - said electric circuit means being controlled by said switch means and in such manner that only one of said solenoids on said carriage and the associated one of said solenoids on said head are connected to be in said predetermined condition of energization when one of said switch means is operated in response to a predetermined position of said carriage,
- disabling means associated with said bending means to render the same inoperative to bend said tube, and
- means associated with said electric circuit means and responsive to the placing of each solenoid on said carriage in said predetermined condition of energization, and also responsive to the rotation of said chucks to the full extent permitted by the associated operative stop element, to operate said disabling means in a manner permitting bending of said tube to the extent permitted by the associated operative stop element on said head.

2. The invention as claimed in claim **1**, in which said

carriage and said head incorporate means to effect individual adjustment of the stop elements thereon, to thereby permit the apparatus to be set up for bending tubes in various planes and with various degrees of bend.

3. The invention as claimed in claim 1, in which said last-named means includes a switch adapted to be operated in response to rotation of said chuck to the full extent permitted by the associated operative stop element.

4. The invention as claimed in claim 3, in which said bending means includes manually operable means to clamp said tube, and in which said disabling means comprises a solenoid-operated member adapted to prevent clamping of said tube by said manually operable means at all times except when said switch is operated.

5. In a tube bending apparatus,
bending means to bend a tubular workpiece
a plurality of mechanical bend-locating stop means each adapted to determine the location of a particular bend in said workpiece,
a plurality of mechanical degree-of-rotation determining stop means each adapted when in operative condition to determine the rotated position of said workpiece about the longitudinal axis thereof,
a plurality of mechanical degree-of-bend determining stop means each adapted when in operative condition to determine the angle through which said workpiece is bent,
electric circuit means to correlate each of said degree-of-bend stop means with a particular degree-of-rotation stop means,
said electric circuit means being associated with said bend-locating stop means in such manner that only one degree-of-bend stop means and the correlated degree-of-rotation stop means will be connected for operation when said workpiece is associated with a particular bend-locating stop means, and
means to delay initiation of operation of said bending means, when said workpiece is associated with a particular bend-locating stop means, until said workpiece is rotated about the longitudinal axis thereof to the position determined by the associated degree-of-rotation stop means.

6. The invention as claimed in claim 5, in which said bending means includes an element movable to engage said workpiece, and in which said last-named means includes means to prevent engagement of said workpiece by said element until said workpiece is rotated about the longitudinal axis thereof to the position determined by the associated degree-of-rotation determining stop means.

7. A tube-bending apparatus, which comprises:
an elongated support,
a plurality of mechanical bend-locating stops mounted in spaced relationship longitudinally of said support,
a head mounted adjacent said support and incorporating means to bend a tubular workpiece in a plane determined by the rotated position of said workpiece,
a plurality of mechanical degree-of-rotation stops operably associated with the unbent portion of said workpiece and selectively operably to determine the degree of rotation thereof about the longitudinal axis thereof,
a plurality of mechanical degree-of-bend stops operably associated with said head and selectively operable to determine the degree of bend of said workpiece,
circut means to cause one only of said degree-of-rotation stops and one only of said degree-of-bend stops to be in condition for operation when each of said bend-locating stops is associated with said workpiece, and
means to permit bending of said workpiece by said head only during periods when all of the following conditions are present: said workpiece is in a predetermined longitudinal position determined by a particular bend-locating stop; said workpiece is in a predetermined rotated position correlated by said circuit means to said particular bend-locating stop and determined by a particular degree-of-rotation stop; and a particular degree-of-bend stop associated by said circuit means with both said particular bend-locating stop and said particular degree-of-rotation stop is in condition to limit the degree of bend to a predetermined angle.

8. Apparatus for bending a tube, which comprises:
an elongated horizontal support,
a carriage mounted on said support for movement longitudinally thereof,
said carriage incorporating a rotatable horizontal spindle disposed generally longitudinally of said support,
said carriage further incorporating a plurality of degree-of-rotation stop rings rotatably mounted on said spindle and axially spaced therealong,
each of said stop rings having a cylindrical peripheral surface provided with a notch,
said carriage also incorporating a plurality of solenoid-operated fingers which are associated, respectively, with said stop rings,
each of said fingers being associated with bias means adapted to effect biasing of such finger against the periphery of the corresponding stop ring in response to energization of the solenoid associated with such finger,
whereby such finger enters the notch in such stop ring when said notch is registered with such finger,
said carriage further incorporating means to clamp said stop rings against rotation relative to said spindle,
said carriage also incorporating a chuck mounted on said spindle and adapted to fixedly clamp one end of the tube to be bent,
a plurality of bend-locating stops mounted in spaced relationship longitudinally of said support,
each of said bend stops being associated with a switch means,
said switch means for each of said bend stops being positioned to be engaged and operated by a portion of said carriage when said carriage is in a predetermined longitudinal position,
a head mounted adjacent one end portion of said support and incorporating rotatable means to bend said tube in a plane determined by the rotational position of said tube and said chuck,
said head incorporating a plurality of degree-of-bend stop elements connected to said bending means for rotation therewith during said bending of said tube,
said head further incorporating a plurality of solenoids associated, respectively, with said stop elements of said head to render the same selectively operative,
each of said solenoids of said head being adapted when energized to cause the associated stop element to limit the degree of rotation of said bending means and thus determine the degree of bend.
electric circuit means to correlate each of said solenoids on said head with a predetermined one of said solenoid-operated fingers on said carriage,
said electric circuit means being controlled by said switch means and in such manner that one of said solenoids on said head and the associated one of said solenoid-operated fingers on said carriage are in condition for energization when one of said switch means is operated by said carriage,

means to condition said bending means to render the same operative to bend said tube, and

master switch means incorporated in said electric circuit means and responsive to the insertion of any of said solenoid-operated fingers on said carriage into the associated stop-ring notch to operate said conditioning means in such manner that bending of said tube may occur,

whereby bending of said tube only occurs when said carriage is in a predetermined position permitting energization of one of said solenoids on said head and the associated solenoid-operated finger on said carriage, followed by rotation of said spindle to the position at which said associated solenoid-operated finger enters the corresponding notch, to thus insure against bending of said tube when the same is in an incorrect rotational or longitudinal position.

9. The invention as claimed in claim **8**, in which said solenoid-operated fingers are pivotally mounted in said carriage, each finger being connected to the related solenoid by means of a flexible biasing spring, said biasing spring being adapted to bend in response to energization of said solenoid and to bias the end of said finger against the cylindrical peripheral surface of an associated stop ring, whereby said finger snaps into said notch when said notch is registered therewith.

10. The invention as claimed in claim **9**, in which a portion of said spring is adapted to actuate said master switch means.

11. The invention as claimed in claim **8**, in which said stop elements on said head include a plurality of degree-of-bend stop rings rotatably mounted on a vertical spindle, and further include fingers operated by said solenoid on said head, in which said head includes means to clamp said stop rings against rotation relative to said vertical spindle, and notch means formed in said stop rings to receive the ends of said solenoid-operated fingers, and in which each of said carriage and said head incorporates a dial marked in degrees to indicate the rotated position of the associated spindle.

12. A control circuit for a tube-bending apparatus which incorporates in addition to the bending head a plurality of bend-locating stops, a plurality of selectively operable degree-of-rotation stops, and a plurality of selectively operable degree-of-bend stops, said control circuit comprising:

a plurality of sets of solenoids,

each of said sets including two solenoids one of which is adapted when energized to render operative a particular one of said degree-of-rotation stops, and the other of which is adapted when energized to render operative a particular one of said degree-of-bend stops,

a plurality of switch means associated, respectively, with said bend-locating stops,

each of said switch means being adapted when operated to energize the two solenoids in a particular set thereof,

solenoid-operated disabling means to render said bending head inoperative, and

means responsive to the conjoint energization of the solenoids of any one of said sets to operate said disabling means in such manner that said bending means is rendered operative, whereby bending of a tube may occur.

13. The invention as claimed in claim **12**, in which holding-circuit means responsive to initiation of a tube-bending operation are provided to effect energization of said solenoids in a particular set thereof despite discontinuance of operation of said switch means.

14. The invention as claimed in claim **12**, in which said bending head comprises a bend arm having a manually operated clamping element associated therewith whereby to effect first clamping of said tube and then bending thereof, and in which said disabling means comprises a solenoid-operated element adapted to prevent shifting of said clamping element to tube-clamping position except during periods when both the solenoids in a particular set thereof are energized.

15. The invention as claimed in claim **14**, in which switch means are provided in association with said degree-of-rotation stops and are adapted to prevent said operation of said solenoid-operated disabling element except during periods when said tube is rotated about the longitudinal axis thereof to the full extent permitted by the associated degree-of-rotation stop.

16. The invention as claimed in claim **14**, in which holding-circuit means are provided and comprise a switch adapted to be operated in response to shifting of said tube-clamping element to clamping position, and a plurality of switches associated, respectively, with said solenoids for said degree-of-rotation stops.

17. Apparatus for bending a tube, which comprises:

an elongated support,

a carriage mounted on said support for movement longitudinally thereof,

said carriage incorporating a rotatable spindle disposed generally longitudinally of said support,

said carriage further incorporating a plurality of degree-of-rotation stop rings mounted on said spindle and axially spaced therealong,

each of said stop rings have a cylindrical peripheral surface provided with a notch,

said carriage also incorporating a plurality of fingers operated by solenoids and associated, respectively, with said stop rings,

each of said fingers being associated with bias means adapted to effect biasing of such finger against the periphery of the corresponding stop ring in response to energization of the solenoid associated with such finger, whereby such finger enters the notch in such stop ring when said notch is registered with such finger,

said carriage also incorporating a chuck mounted on said spindle and adapted to fixedly clamp one end of the tube to be bent,

a plurality of bend-locating stops mounted in spaced relationship longitudinally of said support,

each of said bend stops being associated with a switch means,

said switch means for each of said bend stops being positioned to be engaged and operated by a portion of said carriage when said carriage is in a predetermined longitudinal position,

a head mounted adjacent one end portion of said support and incorporating rotatable means to clamp said tube and then bend the same in a plane determined by the rotational position of said tube and said chuck,

said head incorporating a plurality of degree-of-bend stop elements connected to said clamping and bending means for rotation therewith during said bending of said tube,

said head further incorporating a plurality of solenoids associated, respectively, with said stop elements of said head to render the same selectively operable,

each of said solenoids of said head being adapted when energized to cause the associated stop element to limit the degree of rotation of said clamping and bending means and thus determine the degree of bend,

electric circuit means to correlate each of said solenoids on said head with a predetermined one of said solenoids on said carriage,

said electric circuit means being controlled by said

switch means and in such manner that one of said solenoids on said head and the associated one of said solenoids on said carriage are set up for energization in response to operation of one of said switch means by said carriage,

means to condition said clamping and bending means to render the same operative to bend said tube, and master switch means incorporated in said electric circuit means and responsive to the energization of an associated one of said finger solenoids on said carriage to operate said conditioning means in such manner that bending of said tube may occur,

whereby bending of said tube may occur only when said carriage is in a predetermined position effecting energization of one of said solenoids on said head and the associated solenoid on said carriage.

18. In a tube-bending apparatus,

bending means to bend a tubular workpiece,

a mechanism adapted to render said bending means selectively operative and inoperative,

a plurality of mechanical bend-locating stop means each adapted to determine the location of a particular bend in said workpiece,

a plurality of mechanical degree-of-rotation determining stop means each adapted when in operative condition to determine the rotated position of said workpiece about the longitudinal axis thereof,

a plurality of mechanical degree-of-bend determining stop means each adapted when in operative condition to determine the angle through which said workpiece is bent,

electric circuit means to correlate each of said degree-of-bend stop means with a particular degree-of-rotation stop means,

said electric circuit means being associated with said bend-locating stop means in such manner that only one degree-of-bend stop means and the correlated degree-of-rotation stop means will be in condition for operation when said workpiece is associated with a particular bend-locating stop means, and

means to operate said mechanism to a condition rendering said bending means inoperative except during periods when said workpiece is in predetermined longitudinal positions determined by said bend-locating stop means, and correlated ones of said degree-of-bend stop means and degree-of-rotation stop means are in condition for operation.

19. The invention as claimed in claim **18**, in which said bending means includes means to clamp said workpiece, and in which said mechanism is an electromechanical device selectively adapted to prevent clamping of said workpiece by said clamping means.

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