Jan. 15, 1957 C. R. EKHOLM ET AL 2,777,500

TUBE BENDING APPARATUS AND METHOD

Filed March 4, 1955 3 Sheets-Sheet 1

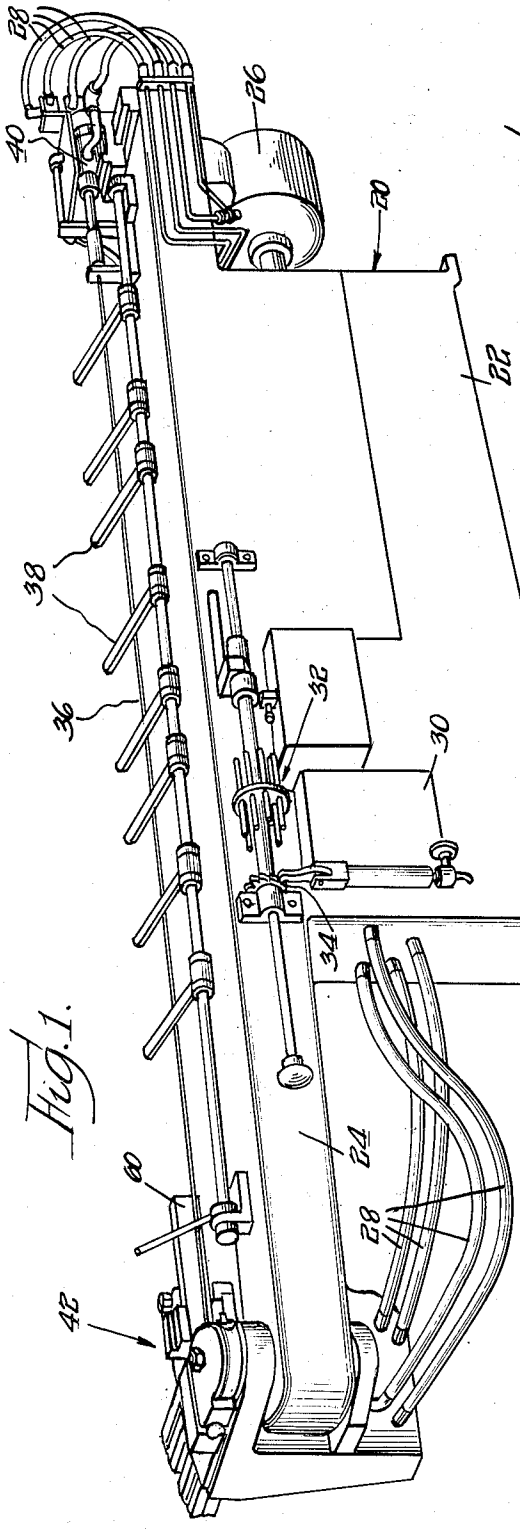


Fig. 1.

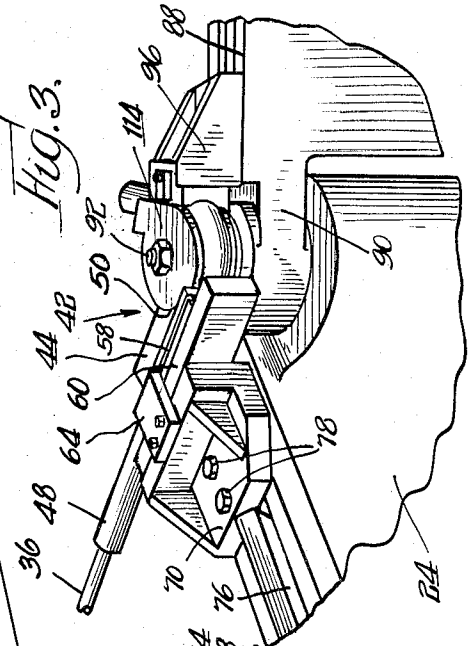


Fig. 3.

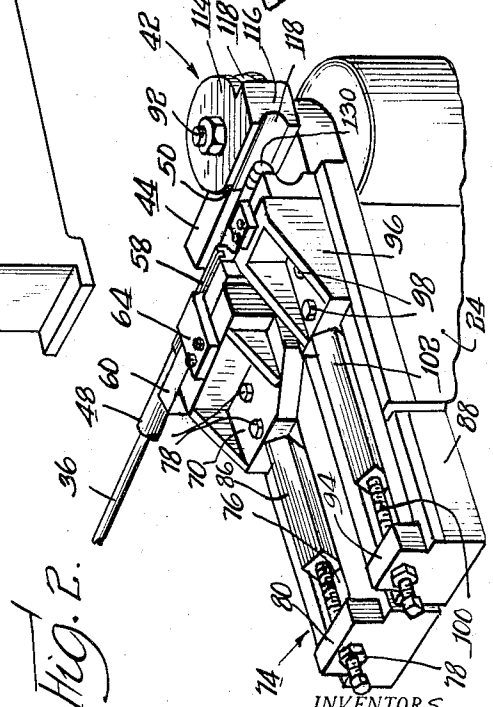


Fig. 2.

INVENTORS
Carl Roger Ekholm
Robert L. Krabbe
By: Olson & Trexler
Attys.

Jan. 15, 1957 C. R. EKHOLM ET AL 2,777,500

TUBE BENDING APPARATUS AND METHOD

Filed March 4, 1955 3 Sheets-Sheet 2

Fig. 4.

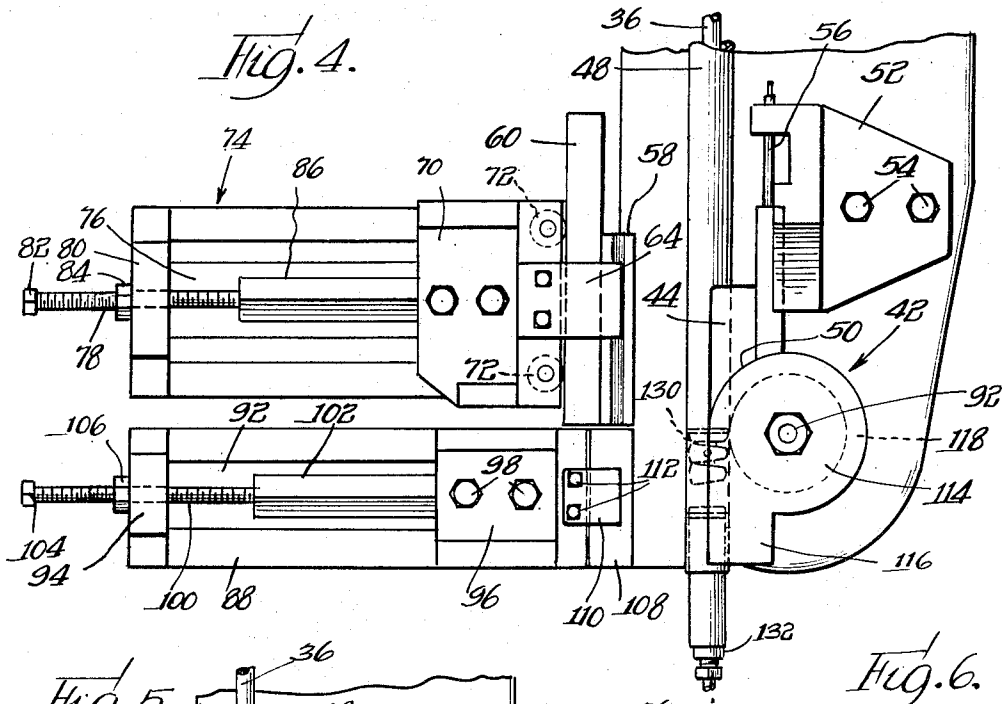


Fig. 5.

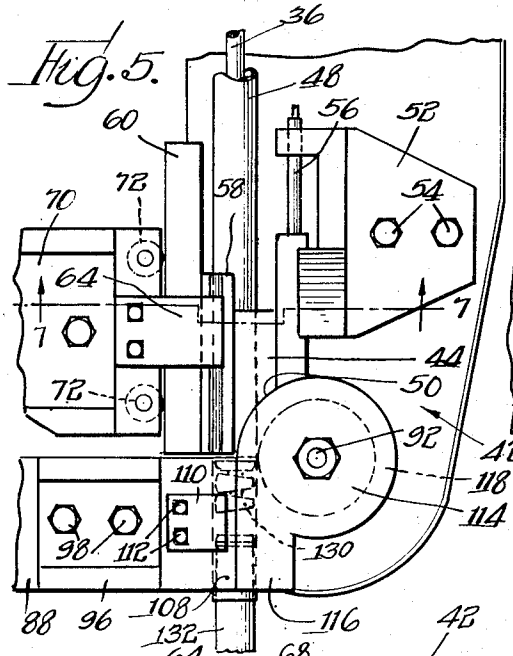


Fig. 6.

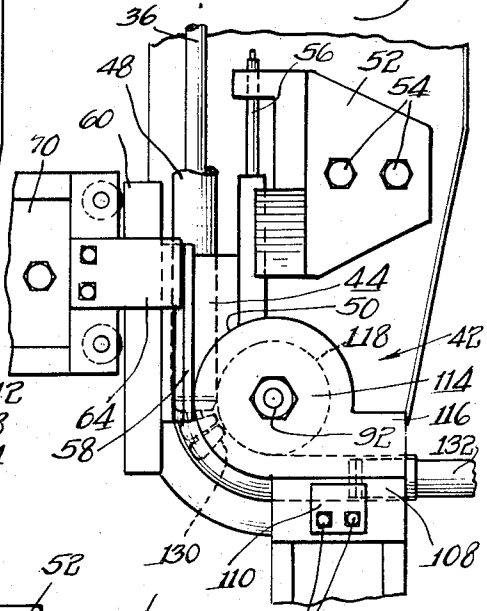
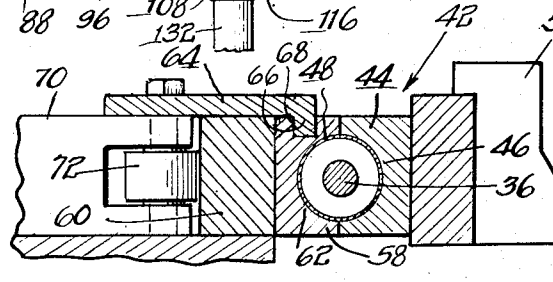


Fig. 7.



INVENTORS.
Carl Roger Ekholm
Robert L. Krabbe
By: Olson & Trueblood Attys.

Jan. 15, 1957 C. R. EKHOLM ET AL 2,777,500

TUBE BENDING APPARATUS AND METHOD

Filed March 4, 1955 3 Sheets-Sheet 3

Fig. 8.

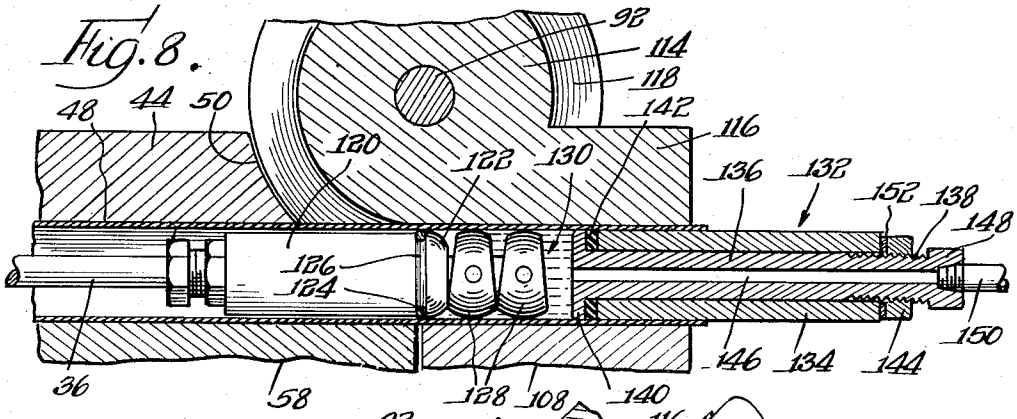


Fig. 9.

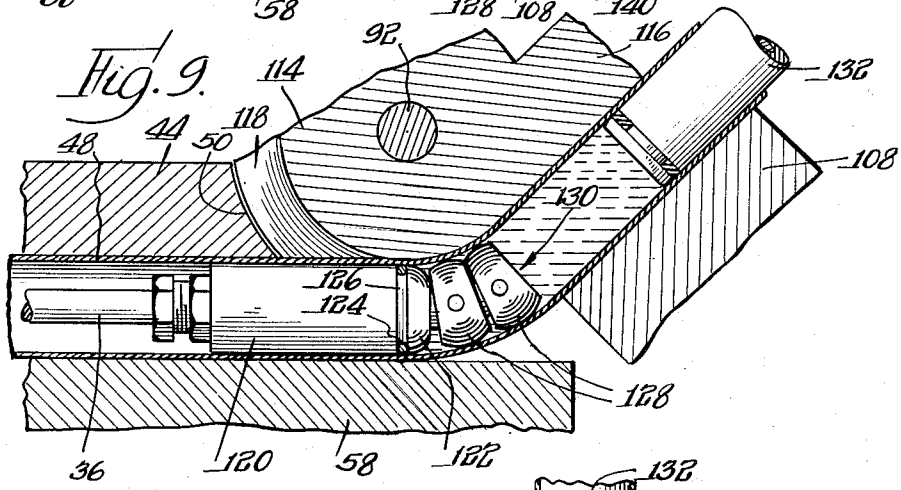
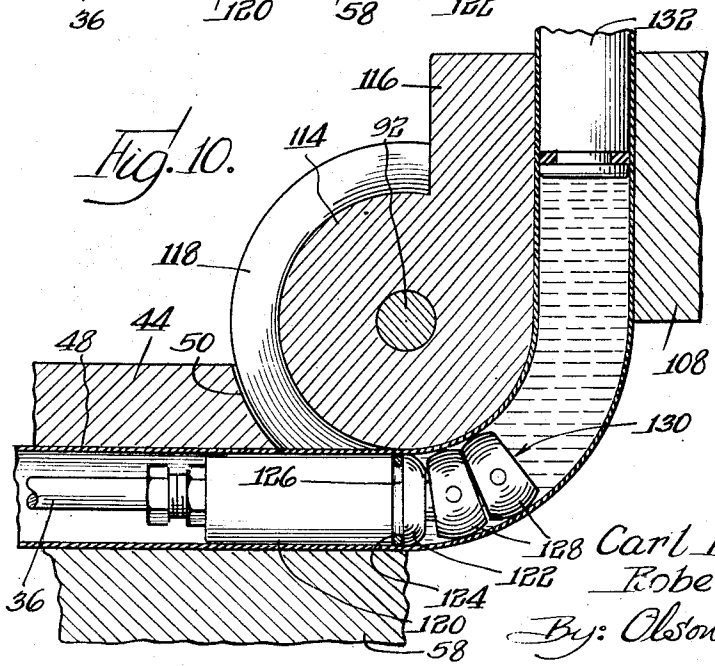


Fig. 10.



INVENTORS.
Carl Roger Ekholm
Robert L. Krabbe
By: Olson & Treyliw
attys.

United States Patent Office 2,777,500 Patented Jan. 15, 1957

2,777,500

TUBE BENDING APPARATUS AND METHOD

Carl Roger Ekholm and Robert L. Krabbe, Elgin, Ill., assignors to Flexonics Corporation, Maywood, Ill., a corporation of Illinois

Application March 4, 1955, Serial No. 492,264

10 Claims. (Cl. 153—40)

This invention is concerned with the art of manufacturing tubing, and more particularly with the bending of hollow tubing.

It has long been recognized that bending of tubing is difficult. Solid rods can be bent without difficulty, but when hollow tubes are bent, there is a very decided tendency for a circular cross section to become oval in the curved or bent part of the tube. Specifically, the inner radius of the bent portion of the tubing will wrinkle, or else the outer radius will pull in short of a true circular arc. Both of these are undesirable inasmuch as they reduce the cross sectional area of the tube through the bend, and inasmuch as they are not as strong as a circular cross section.

Various attempts have been made heretofore to solve the problems of bending hollow tubing by the use of an external bending die and an internal flexible mandrel. Several difficulties are inherent in such bending. Flexible mandrels are expensive. Such mandrels generally consist of a number of a number of interconnected balls, and there is a tendency toward ovalling of the tube between the balls. It is true that this ovalling is at least in part counteracted by the wiping action of the balls through the tube, but this makes it extremely difficult to pull the tube over the balls. In any event, the friction of the tubing moving over the flexible mandrel is substantial. Considerable power is necessary for this purpose and surface imperfections in the tubing may result. Furthermore, a portion of the tubing must project beyond the flexible mandrel for gripping, and this section of tubing subsequently must be cut off and discarded, thereby producing a high wastage of tubing.

Accordingly, it is the broad object of this invention to provide an apparatus for and method of bending tubing more efficaciously and efficiently than has been done in the prior art, and without any ovalling of a circular cross section during bending.

More specifically, it is an object of this invention to provide an apparatus for and method of bending tubing which prevents collapse of the tubing with only a very short mandrel.

Furthermore, it is an object of this invention to provide an apparatus for and method of bending hollow tubing utilizing a short mandrel wherein the mandrel is lubricated and presents little frictional drag on the tubing.

A further object of this invention is to provide an apparatus for and method of bending tubing with the aid of a flexible mandrel wherein stretching of the mandrel which tends to destroy tangency is substantially eliminated.

Yet another object of this invention is to provide an apparatus for and method of bending tubing wherein a reaction base within the tubing is presented for the clamping die.

Another object of this invention is to provide an apparatus for and method of bending tubing wherein less pressure is required on a clamping die thereby causing less distortion on the bending die.

Yet another object of this invention is to provide an apparatus for and method of bending tubing wherein stretching of the tube along the maximum arc is uniform.

Yet another object of this invention is to utilize a flexible mandrel and hydraulic pressure in combination for bending tubing without distortion, and also to make critical bends not possible with the mandrel alone.

Other and further objects and advantages of the present invention will be apparent from the following description when taken in connection with the accompanying drawings, wherein:

Fig. 1 is a perspective view of a tube bending machine or apparatus constructed in accordance with the principles of our invention;

Figs. 2 and 3 are perspective views on an enlarged scale of the various dies for effecting bending in two different positions of operation;

Fig. 4 is a top view of the dies shown in Fig. 2;

Fig. 5 is a fragmentary top view similar to a portion of Fig. 4 with the dies moved into clamping engagement with the tube;

Fig. 6 is a view similar to Fig. 5 with the parts moved into a different position of operation in bending a tube;

Fig. 7 is a vertical cross sectional view through the tube and dies taken substantially along the line 7—7 in Fig. 5;

Fig. 8 is an enlarged horizontal sectional view through a tube and the dies before bending of the tube;

Fig. 9 is a horizontal sectional view similar to Fig. 8 with the parts moved to bend the tube through an obtuse angle; and

Fig. 10 is a view similar to Figs. 8 and 9 with the parts moved to effect a right angle bend in the tube.

Referring now in greater particularity to the drawings, and first to Fig. 1 for a general understanding of the machine, there will be seen a base identified generally by the numeral **20** and comprising a pedestal **22** and a bed **24**. An electric motor **26** is supported beneath the bed exteriorly of the base. The exterior mounting of the motor provides for air cooling thereof, and for ready accessibility for servicing. The drive shaft of the motor extends into the base and drives a hydraulic pump, said base being provided interiorly with a sump or reservoir for hydraulic fluid. Various hydraulic hoses or lines extend from the pump in the base through suitable valves to various controls or operated parts, as will be brought out hereinafter, and as shown at **28**.

A panel box **30** is mounted on the side of the base and additional electrical controls for automatic operation preferably are mounted within the base. The various controls, as well as the specific hydraulic connections are not critical insofar as our invention is concerned, and it is thought that description thereof in detail would render this specification needlessly prolix.

A stop control unit **32** comprising a rotatably movable rod having a plurality of stop pins or dowels is mounted on the side of the base. The rod is automatically rotatable by means of a pawl and ratchet mechanism **34**. This mechanism also is incidental to the invention and need not be discussed in detail.

A mandrel rod **36** extends substantially from end to end of the bed and is spaced thereabove. Various mandrel rod stops **38** are positioned for engagement with a tube on the mandrel rod to position the tube. A hydraulic operating system **40** including a cylinder and piston is connected to the end of the mandrel rod **36** for effecting controlled movement thereof. Control can be effected by manual manipulation of valves, but preferably is effected by automatic sequence controls mounted within the base as heretofore has been indicated.

The parts heretofore described form the base or set-

ting for the invention herein disclosed and claimed, and as such form a part of the invention. However, the parts heretofore described can vary within wide limits without affecting the principles of the invention or the specific structure hereinafter set forth. Detailed consideration thereof accordingly is believed to be superfluous.

At the end of the bed **24** there is mounted the bending mechanism **42**. As will be seen more particularly in Figs. 2–7, the bending mechanism **42** comprises a wiper die **44** having a semicircular groove **46** for clamping a tube **48** which extends back over the mandrel rod **36**. The wiper die **44** has an arcuate trailing edge **50** for cooperation with a bending form as hereinafter will be set forth. The wiper die is mounted on the bed **24** by means of an angle bracket **52** held to the bed by means such as a pair of bolts or cap screws **54**. The wiping die is longitudinally adjustable by means of a rod **56** for movement toward and away from the bending form shortly to be described.

The bending mechanism also includes a pressure die **58** mounted generally opposite to the wiper die and fixed on a back-up block **60**. The pressure die **58** is provided in one face with a semicircular longitudinally extending recess **62** for engaging the tube **48**.

The block **60** is mounted for longitudinal movement in a fixture **64** mounted on an angle bracket **70**. The fixture is provided with a downturned flange **66** slidably received in a groove **68** in the top of the die **58** and holding the block **60** against a pair of back-up rollers **72**. The rollers hold the block firmly forwardly for causing the die **58** firmly to engage the tube **48**.

A guideway **74** is attached to the bed **24** and extends laterally therefrom away from the tube **48**. This guideway is provided with an inverted T-shaped slot **76** extending longitudinally of the guideway and receiving a T-shaped insert (not shown). The base of the bracket **70** rests on top of the guideway and a pair of bolts **78** extends down into the T-shaped slot **76** from the base of the bracket **70** and is threaded into the T-shaped insert. The bracket **70** thereby is laterally adjustable of the bed **24** toward and away from the tube **48**.

Means is provided for effecting adjustment of the bracket **70**, and hence of the pressure die **58**, toward and away from the tube, and this means includes a screw threaded rod threaded through an upstanding wall **80** at the outer end of the guideway **74**. The rod is provided on its outer end with a noncircular head **82** which conveniently may be of hexagonal configuration, and a jam nut **84** is threaded on the rod on the outside of the wall **80** for locking the rod in adjusted position. A filler block **86** is urged against the rear edge of the base of the bracket **70** by means of the threaded rod or screw **78**. The filler block eliminates a long projecting screw which would be susceptible to damage, and provides for quick withdrawal of the pressure die **58** from the tube by removal of the filler block.

A second guideway **88** generally similar to the guideway **74** is pivotally mounted on top of the base bed **24** by an extending part **90** (Fig. 3) for pivoting about an axis **92** from a position parallel to the guideway **74** to a position forming a right angle or even an obtuse angle therewith. The guideway **88** is provided with an inverted T-shaped slot **92** and with an upstanding wall **94** at the outer end of the guideway. An angle bracket **96** is adjustably mounted on top of the guideway **88** by means of bolts **98** extending through the base of the bracket and down into the inverted T-shaped slot **92** where they are threaded into an inverted T-shaped retaining member which is slidable in the slot.

A screw **100** is threaded through the wall **94** and abuts a filler block **102** for urging the bracket **96** toward the tube **98**. The rod or screw **100** is provided with a noncircular head **104** and with a jam nut **106**.

A clamp die **108** is held on the angle bracket **96** by

a retainer **110** generally similar to the retaining member **64** and having a depending flange engaging the clamp. The retainer **110** is mounted on top of the angle bracket **96** by means such as bolts **112**.

Opposite to the clamp die **108** and adjacent the wiper die there is provided a bending form **114**. This bending form is generally circular in configuration with a tangent clamping projection or bending die **116**. A circumferential groove **118** extends around the bending form and also along the bending die **116**. The bending die is arranged in alignment with the clamp die **108** so that the tube **48** can be clamped between them. The bending form is mounted for pivoting movement about the axis **92**, and as has previously been indicated, the guideway **88** and clamp die also pivot about this axis.

The end of the mandrel rod **36** is provided with an enlarged cylindrical plug **120** as best may be seen in Figs. 8–10. This plug has a rounded off nose or trailing end **122**, and a rubber or the like O-ring **124** may be seated in a groove **126** at the junction of the rounded nose with the main portion of the cylindrical plug **120**.

A pair of members **128** generally referred to as balls is pivotally connected to one another and to the plug **120**, the balls and plug forming a mandrel **130** which is flexible at least in part. The mandrel also can be seen in Figs. 2 and 4–6, although in lesser detail than in Figs. 8–10.

Specific reference now should be had to Fig. 8 which illustrates the start of a bending operation. A tube **48** is fed over the mandrel rod **36**, the mandrel rod being disconnected at its rear end for mounting of the tube, and is properly positioned by one of the mandrel stop arms **38** abutting its rear end. The front end of the tube extends over and beyond the flexible mandrel **130** and is positioned between the wiper die and the bending form on one side, and the pressure die and clamp die on the other side. It will be appreciated that for purposes of positioning the tube, the pressure die and clamp die are retracted more or less to the position shown in Fig. 4.

An end plug **132**, comprising also a hydraulic fitting, is placed in the extending end of the tube **48** to seal the end of the tube. The end plug, as is shown in detail in Fig. 8, comprises a hollow cylinder **134**. A piston rod **136** is mounted within this cylinder and is provided with a threaded outer end **138**. The piston rod **136** is provided with a flat piston or head **140** which extends beyond the left end of the cylinder **134** and into the tube **48**. A compressible rubber ring or washer **142** encircles the piston rod **136** between the piston **140** and the end of the cylinder **134**.

A nut **144** is threaded on the outer end of the piston rod, and an axial bore **146** extends completely through the piston rod and piston and communicates by means of a fitting **148** with a hydraulic hose **150**. This hose could be one of the hoses **28**, but it preferably is a separate hose carrying water under pressure. Water is preferred in this particular installation inasmuch as some of it is certain to be lost, and it is much simpler to dispose of all of it than to try to reuse it. It will be obvious that a high pressure pump would be used for supplying water under pressure to the hydraulic line or hose **150**, and that this pump could be driven from the motor **26**, or by means of a motor provided especially for this purpose.

The end plug **132** fits snugly into the end of the tube **48**, and after such fitting the nut **144** is tightened against the cylinder **134**, a washer **152** conveniently being interposed between the nut and cylinder. This pulls the piston **140** toward the cylinder **134** and compresses the rubber ring or washer **142**. Such compression of the rubber ring or washer causes it to deform outwardly to bear tightly against the inside of the tube **48**, thus sealing the end of the tube and fixing the plug **132** firmly in place. In some instances the end plug **132** may be provided with an "O" ring and groove, the parts **134** and **136** being made inte-

gral and the nut **144** being eliminated. Hydraulic pressure then is introduced through the hose **150** and axial bore **146** into the tube, leakage along the tube being prevented by the O-ring **124**, and the pressure die and clamp die are moved from the position of Fig. 4 to the position of Figs. 5, 7 and 8 to clamp the tube **48**. The internal hydraulic pressure and also the end plug **132** form a firm reaction base for gripping the end of the tube between the clamp die and the bending die.

The gripping of the tube by the clamp die and the bending die is tighter than is the gripping by the pressure die and wiper die. Accordingly, when the bending form and the guideway **88** are rotated as a unit by hydraulic means including the hoses **128** and suitable hydraulic motors (not shown), the tube is pulled over the mandrel **130** and is bent around the bending form as is illustrated in Figs. 8, 9 and 10. The balls **128** of the mandrel help to start the bending without deformation of the cross section of the tube, and the internal hydraulic pressure augments the balls in this respect.

If there were no internal hydraulic pressure, there would have to be enough balls on the mandrel plug **120** to reach entirely around the curve, thus requiring more tubing (waste) to accommodate same in the clamp area. This would be expensive, would render the mandrel more subject to failure, and would cause so much friction that tremendous forces would be needed to pull the tube over the mandrel **130**. Such forces would tend to distort the pivot of the bending form and clamp die, and thereby would cause imperfect bends. The internal hydraulic fluid in addition to eliminating several balls, and thereby decreasing friction, lubricates the few balls that are on the mandrel plug **120**, thereby substantially eliminating friction of the tube with the mandrel.

It will be appreciated that the friction between a tube being bent and a long flexible mandrel is sufficiently high that it stretches the mandrel. This destroys the tangency relation of the mandrel plug **120** to the bending form, and results in an imperfect bend and in strain on the parts. The internal hydraulic pressure acts on the mandrel plug **120** as a piston to counteract the frictional drag, and thereby substantially eliminates stretching of the mandrel.

The internal hydraulic pressure furnishes a reaction base for the clamping die, and as a result the clamping die and tangent gripping portion of the bending form can grip the tube with less pressure than heretofore has been necessary. The gripping force also can be reduced by virtue of the fact that the substantially frictionless movement of the tube over the mandrel **130** reduces the pulling force necessary on the tube. This not only produces less distortion of the bending form and its axis, but minimizes deformation and marking of the tube from gripping.

The hydraulic pressure obviously will be uniform throughout the end of the tube, and stretching of the tube along the outside diameter therefore is substantially uniform with no flattening out between the balls.

The pressure die **58** moves with the tube by virtue of the block **60** and rollers **72** and thereby prevents stretching of the outer tube wall before the bending operation, while the wiper die **44** smooths out the inner wall and helps to provide a smooth, uniform action. The O-ring **124** serves to seal the tube to the mandrel, and this is particularly true since the pulling on the tube draws down the tube slightly to reduce it in diameter.

When the bending has been completed, the internal hydraulic pressure is released. The clamp die and pressure die then are retracted, and the nut **144** is backed off to release the clamping pressure on the rubber washer **142**. The end plug **132** then can be removed, the water or other hydraulic fluid spilling out of the end of the tube. It will be appreciated that water is preferred inasmuch as no effort need be made to save it for reuse.

The mandrel **130** is retracted beyond the bend by means of the hydraulic means **40** acting on the mandrel rod **36**.

The tubing then can be cut off by any suitable agency, either automatic or manual, or it can be advanced for the formation of subsequent bends in the tube.

In some instances the O-ring **124** and groove **126** may be omitted. In bending with the application of internal hydraulic pressure as herein disclosed the tension caused by the bending and clamp dies causes the tube to draw down and hug or drag on the mandrel, thus effecting an adequate seal and causing a sudden build up of hydraulic pressure. This causes the tube to expand slightly and an infinitesimal amount of fluid passes between the mandrel and the tube, thereby allowing the tube to slip or advance slightly until the pressure drops enough for the tube again to hug the mandrel. A sort of chatter or vibration is set up as a result. This may be on the order of several hundred cycles per minute, and has proved advantageous in many applications. Water used as the hydraulic fluid flows in large quantities past the mandrel when no O-ring is provided with no pressure build up until the bending starts, and this flow immediately ceases and pressure builds up when actual bending starts.

The invention is of particular importance when applied to thin walled tubing, and although the tube to be bent may be made of substantially any deformable material, the cold working of the tube as effected by the bending and stretching is most efficacious when the tube is made of stainless steel, since such cold working increases both the tensile strength and the yield point of stainless steel.

Various changes from the specific illustrative embodiment herein shown and described will no doubt occur to those skilled in the art, and are to be understood as forming a part of our invention insofar as they fall within the spirit and scope of the appended claims.

We claim:

1. Apparatus for producing bends in tubing comprising a flexible mandrel, an O-ring on said mandrel sealing said mandrel to tubing extending over and beyond said mandrel, means for sealing the tubing spaced from said mandrel O-ring to provide a sealed length of tubing, means for introducing hydraulic fluid under pressure into the sealed length of tubing and about said mandrel, a bending form, means for bending the sealed length of tubing and part of said mandrel about said bending form while maintaining hydraulic fluid in said sealed length of tubing under pressure, and means for sliding said tubing relatively along said mandrel during such bending, the hydraulic fluid under pressure effecting uniform deformation of said sealed length of tubing and lubrication of said mandrel in said tubing.

2. Apparatus for producing bends in tubing comprising a plug for sealing an end of a section of tubing, said plug comprising a hollow cylinder, a piston having a piston rod thereon extending through said hollow cylinder, a deformable ring between said piston and cylinder and encircling said piston rod, and means relatively urging said piston rod and cylinder axially relative to one another to compress said deformable ring between said piston and said cylinder whereby said deformable ring is deformed outwardly against said tubing to seal the end of the tubing, said piston and piston rod having an axial bore therethrough for introducing hydraulic fluid under pressure into said tubing; a flexible mandrel extending into said tubing and spaced from said plug, said flexible mandrel having an O-ring sealing said mandrel to said tubing to provide a sealed length of tubing into which said hydraulic fluid under pressure is introduced; a bending form; and means for bending the sealed length of tubing about said bending form while maintaining said hydraulic fluid under pressure in said sealed length of tubing, said flexible mandrel extending part way around said bending form and said flexible mandrel and said hydraulic fluid under pressure effecting uniform deformation of said sealed length of tubing, said hydraulic fluid under pressure further serving to lubricate said flexible mandrel relative to said tubing.

3. The method of producing bends in tubing which comprises inserting a plug in an end of a section of tubing, expanding said plug to seal the end of the tubing, sealing the tubing at a location spaced from said plug to provide a sealed length of tubing, introducing hydraulic fluid under pressure into said sealed length of tubing, clamping said sealed length of tubing adjacent the end in which the plug is inserted, the plug and the hydraulic fluid under pressure serving as a reaction base for clamping, and bending the sealed length of tubing while maintaining the hydraulic fluid therein under pressure.

4. The method of producing bends in tubing as set forth in claim 3 and further including moving the second seal along the tubing while bending the same progressively to increase the length of the sealed length of tubing, additional hydraulic fluid under pressure being introduced into the sealed length of tubing during the lengthening of the sealed length of tubing.

5. Apparatus for producing bends in tubing comprising first means for sealing a length of tubing, second means for sealing said length of tubing at a position spaced along the length of tubing from said first sealing means, means for introducing fluid pressure into said tubing between said first and second sealing means, means for bending said length of tubing between the first and second sealing means, and means for pulling said length of tubing over one of said sealing means during such bending, fluid pressure being maintained in said length of tubing during said bending and pulling to effect uniform deformation of said tubing.

6. Apparatus for producing bends in tubing comprising a plug inserted in one end of said tubing, said plug including a cylinder and a piston mounted coaxial with said cylinder and having a piston rod extending through said cylinder, said piston and piston rod having a bore therethrough for introducing hydraulic fluid under pressure into said tubing, a deformable ring mounted between said piston and cylinder and encircling said piston rod, and means for urging said piston rod and cylinder in relatively opposite directions to move said piston and said cylinder relatively toward one another whereby to effect compression and outward deformation of said deformable ring for forcing said deformable ring into sealing engagement with said tubing; means for sealing said tubing spaced from said plug to provide a sealed length of tubing, a bending form, and means for bending the sealed length of tubing about said bending form while maintaining hydraulic pressure in said sealed length of tubing, said hydraulic pressure effecting uniform deformation of the sealed length of tubing.

7. The method of producing bends in tubing as set forth in claim 4 and further including inserting a flexible mandrel in the sealed length of tubing, and moving the tubing along the flexible mandrel while bending the tubing and the mandrel.

8. The method of producing bends in tubing which comprises inserting a flexible mandrel in a section of tubing, sealing said mandrel to said tubing, sealing said tubing at a location spaced from the sealing of the mandrel thereto to provide a sealed length of tubing with said mandrel at least in part in said sealed length of tubing, introducing hydraulic fluid under pressure into said sealed length of tubing, relatively moving the mandrel and the tubing axially progressively to increase the length of the sealed length of tubing, adding additional hydraulic fluid during such relative moving, and bending the sealed length of tubing and the mandrel therein during such relative moving.

9. Apparatus for producing bends in tubing as set forth in claim 5 and further including a flexible mandrel sealed within said length of tubing.

10. Apparatus for producing bends in tubing as set forth in claim 9 wherein the flexible mandrel comprises a part of the sealing means over which the length of tubing is pulled.

References Cited in the file of this patent

UNITED STATES PATENTS

203,842	Leland	May 21, 1878
533,965	Richard	Feb. 12, 1895
654,373	Wikstrom	July 24, 1900
735,307	Smith	Aug. 4, 1903
878,604	Brinkman	Feb. 11, 1908
1,007,834	Wilson	Nov. 7, 1911
1,135,875	Brinkman	Apr. 13, 1915
1,575,928	Mueller	Mar. 9, 1926
1,590,237	Geisler	June 29, 1926

FOREIGN PATENTS

567,753	Great Britain	Mar. 1, 1945
571,191	Great Britain	Aug. 10, 1945