Feb. 2, 1943. F. M. KEPLER 2,310,091

MACHINE FOR AND METHOD OF BENDING TUBING

Filed Jan. 9, 1942 3 Sheets-Sheet 1

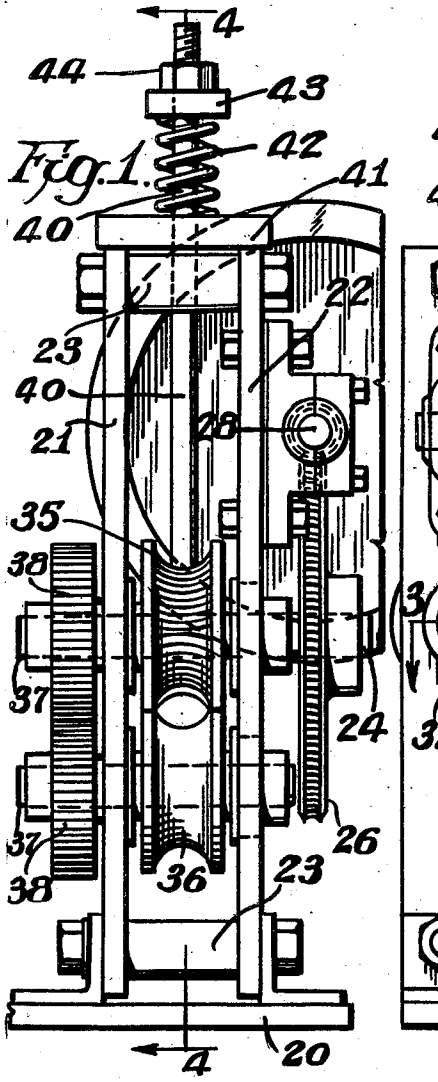


Fig. 1.

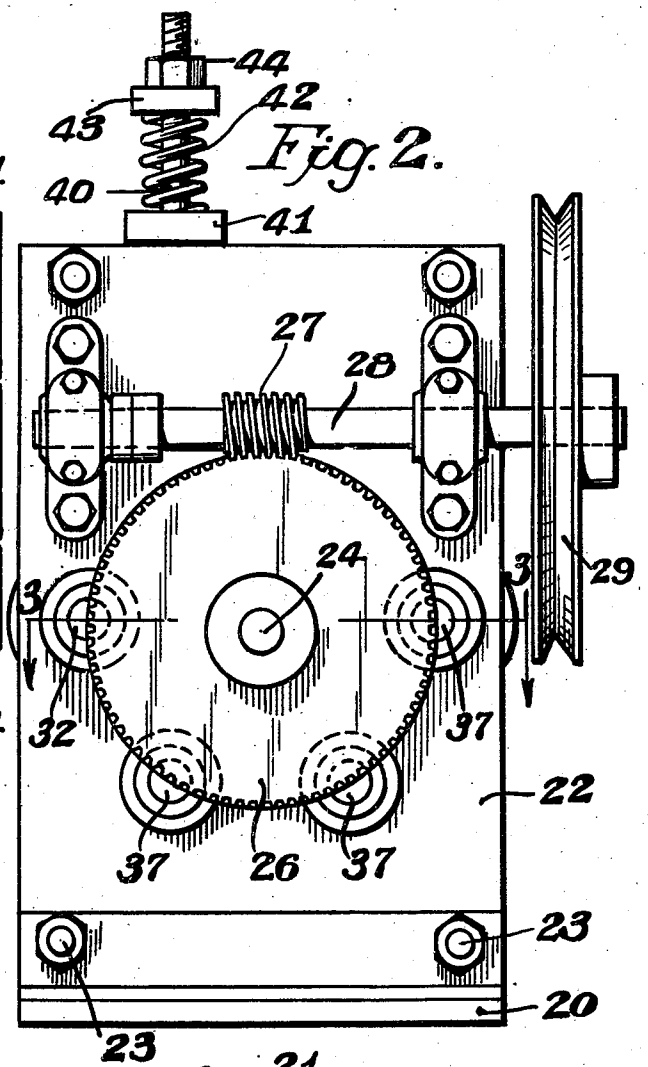


Fig. 2.

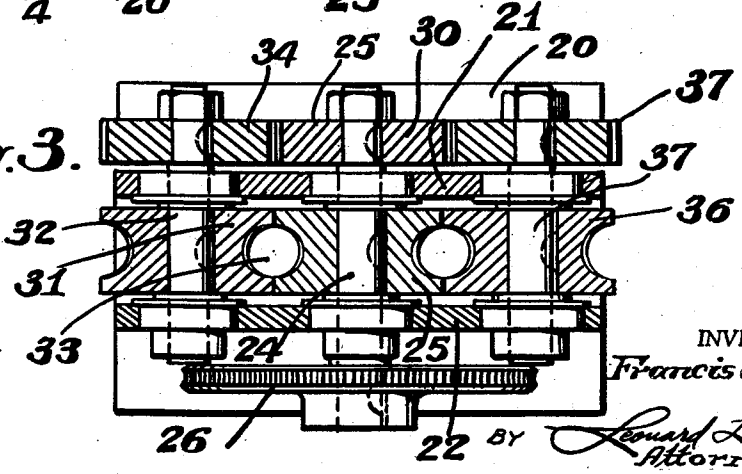


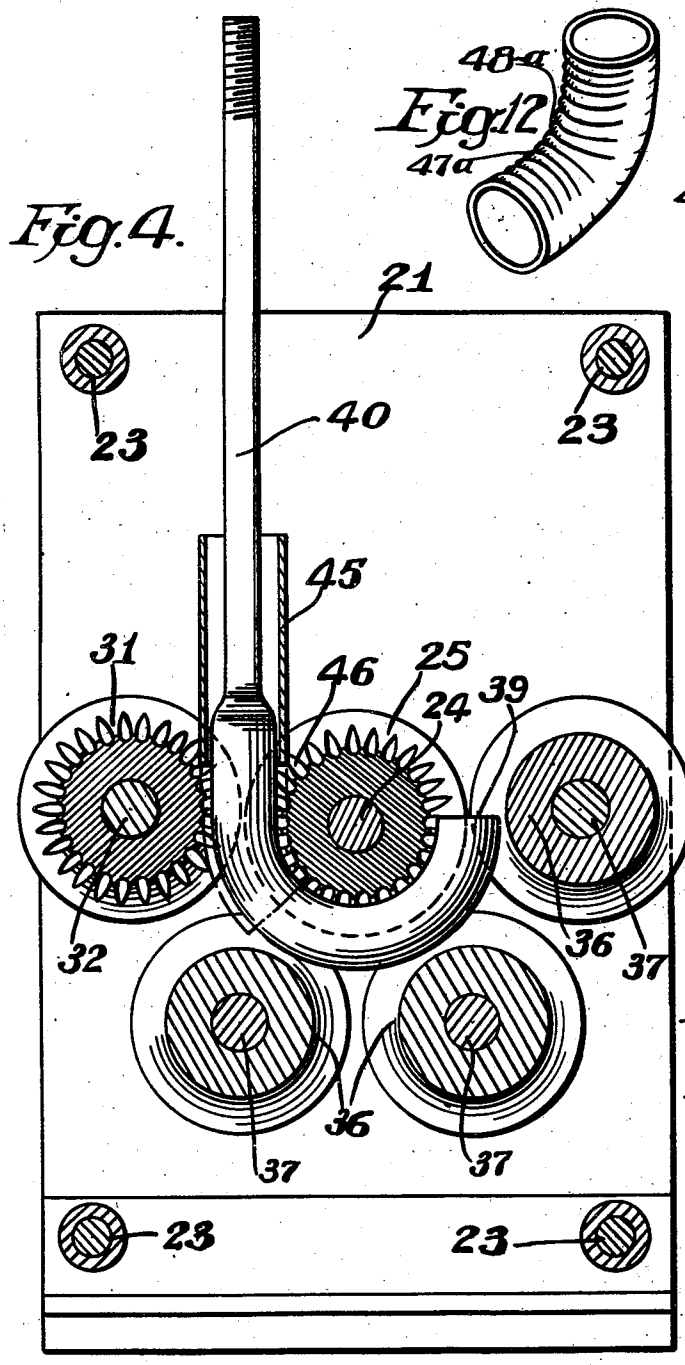
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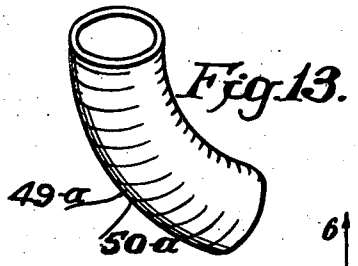
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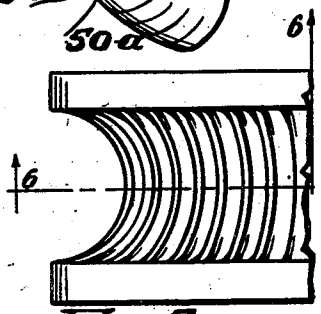
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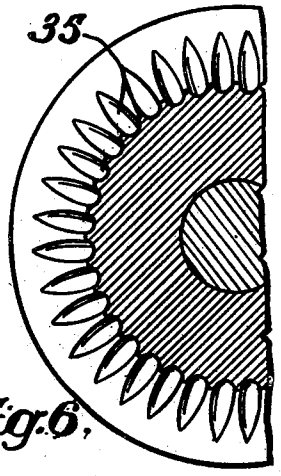
MACHINE FOR AND METHOD OF BENDING TUBING

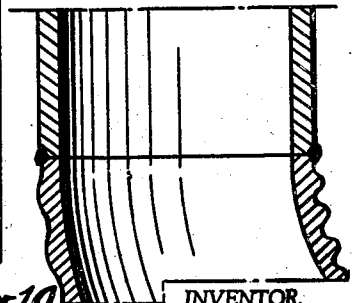
Filed Jan. 9, 1942 3 Sheets-Sheet 2











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MACHINE FOR AND METHOD OF BENDING TUBING

Filed Jan. 9, 1942 3 Sheets-Sheet 3

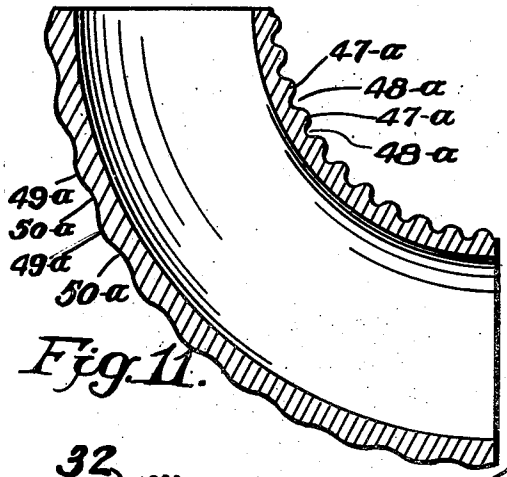


Fig. 11.

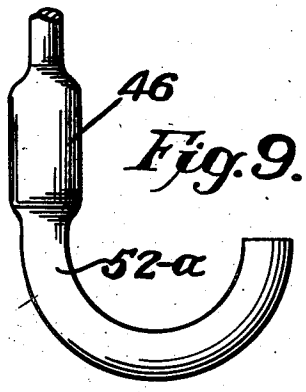


Fig. 9.

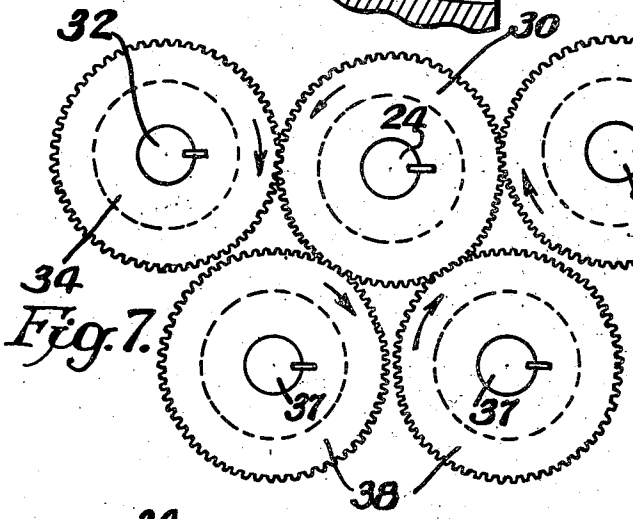


Fig. 7.

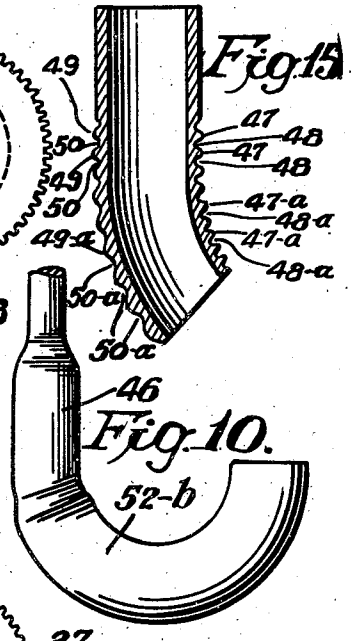


Fig. 15

Fig. 10.

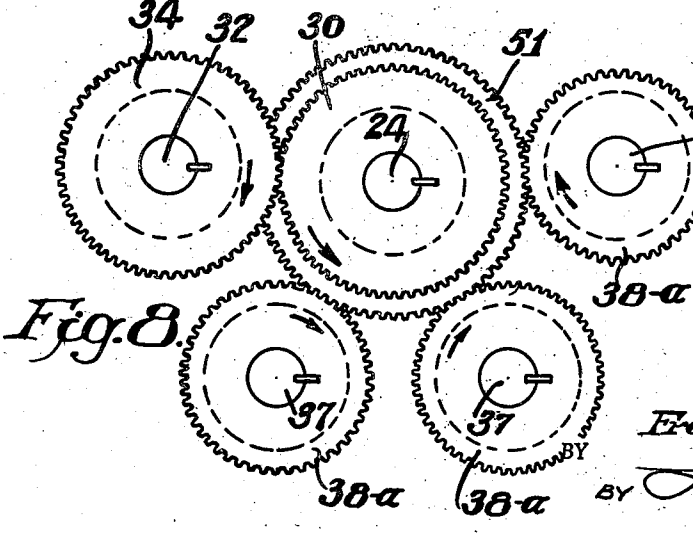


Fig. 8.



Fig. 16.

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Patented Feb. 2, 1943 2,310,091

UNITED STATES PATENT OFFICE

2,310,091

MACHINE FOR AND METHOD OF BENDING TUBING

Francis M. Kepler, Upper Darby, Pa.

Application January 9, 1942, Serial No. 426,257

18 Claims. (Cl. 153—54)

The present invention relates to a method of and apparatus for bending pipe, tubing, or the like, and it relates more particularly to a method of and apparatus for forming smooth bends in pipe, tubing or the like, so that the bent sections maintain their smooth inner wall surfaces.

An object of the present invention is to provide a simple and efficient method of bending sections of pipe or tubing without the use of heat. Another object of the present invention is to provide a method for bending sections of pipe or tubing or the like in such a way as to provide smoothly bent sections without distorting or changing the inner wall surfaces of the pipe or tubing. Still another object of the present invention is to provide a method for bending pipe or tubing without disturbing the smooth inner walls thereof by causing the metal of the outside walls to be displaced in accordance with the respective lengths of the inner and outer edges of the curve. Another object of the present invention is to provide a method for bending sections of pipe or tubing and, at the same time, uniformly increasing or decreasing the inside dimensions of the pipe or tubing.

Another object of the present invention is to provide apparatus for carrying out the above-stated objects.

With the above and other objects and advantages as are apparent from the following specification, appended claims and accompanying drawings, the present invention is directed to a new and useful method of and apparatus for bending sections of pipe or tubing by passing the sections over a snugly fitting internal curved mandrel and between the concave corrugated faces of diametrically-opposed driving rolls thereby to cause the metal of the outer walls of the sections to become corrugated with alternate crests and troughs extending respectively radially outward and radially inward of the original outside dimension of the sections, without disturbing the inside walls of the sections, and subsequently passing the so-corrugated sections through forming rolls thereby smoothly to bend said sections and to cause the corrugations upon the inner edge of the bend to become deeper and the corrugations upon the outer edge of the bend to become shallower.

For the purpose of illustrating the invention, there are shown in the accompanying drawings forms thereof which are at present preferred, since the same have been found in practice to give satisfactory and reliable results, although it is to be understood that the various instrumentalities of which the invention consists can be variously arranged and organized and that the invention is not limited to the precise arrangements and organizations of the instrumentalities as herein shown and described.

Referring to the accompanying drawings in which like reference characters indicate like parts,

Figure 1 represents a front elevational view of one embodiment of the present invention,

Figure 2 represents a side elevational view of the embodiment shown in Figure 1,

Figure 3 represents a horizontal cross-sectional view along the line 3—3 of Figure 2,

Figure 4 represents a vertical cross-sectional view along the line 4—4 of Figure 1,

Figure 5 represents a fragmentary elevational view of the driving roll shown in Figure 4; illustrating the semi-circular groove formed therein and the corrugations,

Figure 6 represents a cross-sectional view along the line 6—6 of Figure 5,

Figure 7 represents an elevational view of the gearing shown in Figures 1 and 3,

Figure 8 represents a view similar to that of Figure 7, but showing an alternative gearing arrangement,

Figure 9 represents a fragmentary elevational view of a mandrel alternative to that shown in Figure 4,

Figure 10 represents a view similar to that of Figure 9, but showing still another modification of the mandrel,

Figure 11 represents a cross-sectional view of a section of tubing after it has been bent into a 90° curve in accordance with the present invention,

Figure 12 represents a perspective view on a reduced scale of the bent section shown in Figure 11, showing the appearance of the section along the inner edge of the curve,

Figure 13 represents a perspective view similar to that of Figure 12, but showing the appearance of the bent section along the outer edge of the curve.

Figure 14 represents a fragmentary cross-sectional view showing a bent section constructed in accordance with the present invention as it appears when affixed to a straight section.

Figure 15 represents a cross-sectional view of a pipe section as it appears during the process of the bending; the appearance of the section during the different steps of the process being illustrated.

Figure 16 represents a perspective view similar

to that of Figure 12 but showing a section of tubing which has been bent through approximately 180° of arc in accordance with the present invention.

In one embodiment of the present invention shown in Figures 1 to 7, I may provide a base 20 to which are attached generally upright side plates 21 and 22. A plurality of spacing bolts 23 connect the side plates 21 and 22.

A drive shaft 24 passes through suitable openings in the side plates 21 and 22 and is rotatably mounted therein and carries a driving roll 25 intermediate the plates 21 and 22.

A spur gear 26 is mounted upon the end of the shaft 24 outside of and adjacent to the side plate 22 and is adapted to be driven by the worm 27 carried by the shaft 28 which is turned by the V-belt pulley 29, which in turn may be actuated by any prime-mover.

A gear 30 is mounted at the other end of the shaft 24 outside of and adjacent to the side plate 21.

A driving roll 31 is keyed to and carried by the shaft 32 which is rotatably mounted within the side plates 21 and 22. The driving rolls 25 and 31 have semi-circular grooves formed about their outer peripheral edges and are so disposed that the outermost portions of their peripheral edges contact each other to define a generally circular and vertically extending opening 33 therebetween.

A gear 34 is mounted upon the drive shaft 32 outside of and adjacent to the side plate 21. The gear 34 meshes with the gear 30 on the shaft 24 so that the driving rolls 25 and 31 rotate in opposite directions at the same rate of speed; the portions of both rolls defining the opening 33 moving downwardly.

The grooves of the driving rolls 25 and 31 are provided with corrugations 35 extending perpendicularly across the grooves; the corrugations being deepest at the center portion of the grooves and becoming shallower at the outer axial edges of the grooves.

A plurality (as, for example, 3) of rolls 36 are disposed peripherally about the driving roll 25 upon shafts 37 journalled within the side plates 21 and 22. Rolls 36 are provided with generally semi-circular grooves formed in their outer peripheries and are adapted to define generally circular openings with the adjacent portions of the roll 25. The grooves in the rolls 36 are, preferably, uncorrugated.

Gears 38 may be provided upon the shafts 37 to mesh with the gear 30 on the shaft 24 and to rotate the rolls 36 oppositely from the roll 25. It is possible, and, indeed, it may sometimes be preferred, to omit the gears 38 so that the rolls 36 are free or idle rolls.

The rolls 36 are preferably so disposed that, with the driving roll 31, they provide a plurality of generally circular openings extending more or less approximately around one-half the circumference of the driving roll 25.

A mandrel 46 having a circular cross-section and having a semi-circular portion 52 and a straight portion 46 is positioned about the center driving roll 25; its cross-section being somewhat less than the openings defined between the roll 25 and the rolls 31 and 36 so that an annular clearance is provided between the mandrel 39 and the adjacent pairs of rolls. A reduced stem 40 extends upwardly from the straight portion 46 to a point above the upper edges of the side plates 21 and 22.

The mandrel is held in position intermediate the rolls (when not in operation) by a spring-supporting plate 41 which rests upon the upper edges of the side plates 21 and 22 and through which the mandrel stem 40 passes. A coil spring 42 is disposed about the mandrel stem 40 above the spring supporting plate 41. A washer 43 is disposed about the mandrel stem 40 above the coil spring 42 and a nut 44 is screw-threadedly attached to the uppermost end of the mandrel stem 40. When the nut 44 is tightened, the coil spring 42 is compressed between the washer 43 and the spring-supporting plate 41, and the mandrel is thus more or less resiliently supported intermediate the rolls when the machine is not in operation. As will hereinafter be described, parts 41 to 44 inclusive are intended to be left off when the machine is in operation; the mandrel being held in position by the tubing being bent under pressure of the driving and bending rolls so that it may be considered as a "free floating" mandrel.

The embodiment shown in Figure 1 is adapted to bend steel or other metal tubing which may be either seamless or welded tubing or pipe into a smoothly curved elbow. The final curved tubing may extend through any desired arc by varying the length of tubing inserted relative to the circumferential dimension of the main driving roll 25. Thus, the final bent tubing may extend through more or less approximately 90° of arc as shown in Figures 11, 12 and 13 by employing a length of tubing corresponding more or less approximately to one-quarter of the circumference of the main driving roll 25. By employing a section of tubing which is equal to or longer than half the circumference of the main driving roll 25, the final bent tubing can extend through 180° of arc.

The operation of the present invention will now be described. The nut 44, the washer 43, the coil spring 42 and the spring supporting plate 41 are first removed from the mandrel stem 40. A length of steel tubing is then placed over the mandrel stem 40 and upon the uppermost straight portion 46 of the mandrel 39. Parts 41 to 44 are left off the mandrel stem 40.

Power is then applied to the V-belt pulley 29 and is transmitted through the shaft 28, the worm 27, the spur gear 26 and the drive shaft 24 to the driving roll 25. The power is also transmitted from the drive shaft 24 through the gears 30 and 34 and the shaft 32 to the driving roll 31. The driving rolls 25 and 31 thus rotate downwardly at the opening 33 defined therebetween. The tubing 45 is caught by the corrugations 35 on the driving rolls 25 and 31 and is forced downwardly upon the mandrel 39.

Since the mandrel fits snugly within the tubing 45, it is held in position within the tubing 45 under pressure of the rolls 25 and 31 and may be considered as a floating mandrel.

While, in Figure 4, there is shown only a single piece of tubing 45 being bent, it is possible and is contemplated to have a continuous supply of sections 45 bent. That is, sections 45 are inserted over the mandrel stem 40 as fast as room is available for them so that straight sections are set in and bent sections are removed from the machine in a continual flow. These sections may be of the length shown in Figure 4 so that bent sections corresponding to those shown in Figures 11 to 13 are obtained or the sections may be approximately twice the length shown in Figure 4 so that bent sections extending through approximately 180° of arc as shown in Figure 16 are obtained.

The tubing is thus forced through the annular clearance existing between the mandrel 39 and the adjacent portions of the grooved driving rolls 25 and 31.

This annular clearance is such that the metal of the outer wall of the tubing 45 is displaced by the corrugations 35 in the manner shown in Figure 14; alternate crests and troughs being formed with the crests extending outwardly beyond the original outer diameter of the tubing 45 and with the troughs extending inwardly of the original outer diameter of the tubing.

Since the portion 46 of the mandrel 39 fits more or less snugly within the tubing 45, the inner wall of the tubing remains smooth and generally unaltered in passing through the annular clearance between the driving rolls 25 and 31.

As the tubing 45 is forced further down upon the curved portion 52 of the mandrel 39 by the driving rolls 25 and 31, it is bent more or less smoothly along its axis into the curvature of the semi-circular portion 52; the bent tubing being forced along between the roll 25 and the rolls 36 finally to emerge in the form shown in Figures 11 to 13.

As hereinabove stated, the rolls 36 may be free or idle rolls, in which case the subsequent movement of the bent pipe 45 is effected by the driving roll 25 alone. On the other hand, the rolls 36 as well as the roll 25 may be power driven as shown in Figures 1, 3 and 7 in which case both rolls 25 and 36 cooperate to force the bent pipe 45 along. Where the rolls 36 are power-driven, they may be so geared as shown in Figure 7 that they rotate at the same rate of speed as the roll 25.

Where the rolls 36 are power-driven, it may be preferred to rotate the rolls 36 at a somewhat higher rate of speed than the roll 25 in order to accommodate the more rapid movement on the outside edge of the curved section 45. That is, the portion of the curved section 45 adjacent the rolls 36 moves at a somewhat greater rate of speed than that portion of the section 45 adjacent the roll 25. Where this difference in speed is pronounced, as for example, where sections of tubing or pipe of large outside diameter are being bent, it should preferably be compensated for by rotating the rolls 36 at a somewhat higher rate of speed than the roll 25.

In order to rotate the rolls 36 at a higher rate of speed than the roll 25, the gearing arrangement shown in Figure 8 may be used.

In the arrangement shown in Figure 8 the main power shaft 24 is provided with a gear 30 as before; the gear 34 driving the power roll 31 meshing with the gear 30 to drive the rolls 25 and 31 at the same rate of speed as hereinabove described. A somewhat larger gear is also keyed to the outer end of the shaft 24 adjacent the gear 30. The shafts 37 carrying the rolls 36 are provided with somewhat smaller gears 38—*a* which mesh with and are driven by the larger gear 51. In this way, rolls 36 are driven at a somewhat higher rate of speed than the rolls 25 and 31.

As shown in Figure 15, when the tubing 45 first passes through the annular clearance between the portion 46 of the mandrel 39 and the driving rolls 25 and 31, the crests 47 and troughs 48 formed by the driving roll 25 are generally the same size as the crests 49 and the troughs 50 formed by the driving roll 31. As the tubing 45 is bent, however, the configurations of the crests and troughs are changed to accommodate the change in shape of the tubing. Thus, the crests 47 and troughs 48 become deeper and closer together as shown at 47—*a* and 48—*a* due to the compression which occurs along the inner side of the curve. On the other hand, the crests 49 and the troughs 50 become shallower and further apart as shown at 49—*a* and 50—*a* due to the stretching of the material along the outer side of the curve.

The inner wall of the tubing 45 remains smooth due to the close-fitting portion 52 of the mandrel 39.

By modifying the shape of the mandrel 39, and the clearances between the roll 25 and the rolls 36, it is possible to change the inside diameter of the tubing during the bending operation.

Thus, if the curved portion of the mandrel is reduced in cross-section slightly beyond the opening 33 as shown in greatly exaggerated view at 52—*a* in Figure 9, the inside diameter of the tubing is reduced correspondingly under the pressure of the roll 25 and the rolls 36. On the other hand, if the curved portion of the mandrel is increased in cross-section slightly beyond the opening 33 as shown in greatly exaggerated view at 52—*b* in Figure 10, the tubing will be forced upon the increased portion by the driving rolls 25 and 31 so that the inside diameter of the tubing will be increased correspondingly with a slight increase in the outside dimension of the tubing as well.

Thus, it is possible to bend the tubing 45 while maintaining a smooth inner wall surface and at the same time it is possible to maintain the original inside diameter, or to increase the inside diameter or to decrease the inside diameter, as desired.

Since this entire bending and shaping operation is performed cold, it is apparent that the present invention affords a rapid, inexpensive, and highly desirable bending step which has many advantages over old-type bending devices.

Thus, the present invention provides a smoothly bent pipe or tubing section which has a smooth and uniform inner wall surface so that a minimum of turbulence and resistance is created during the passage of fluid therethrough. Furthermore, the present invention makes it possible to bend a piece of tubing without changing its inside characteristics or dimensions so that it can be connected (by welding or other means) to a straight piece of similar tubing, as shown in Figure 14, to provide a pipe line which is substantially uniform throughout its entire length regardless of bends. Thus, no constrictions or irregularities are presented in the path of fluid flow so that friction is greatly decreased and power loss during fluid transmission is minimized.

While the present invention has been described in connection with the bending of relatively short pieces of tubing or pipe, it is equally well adapted to bend a continuous relatively long length of tubing or pipe. Where a continuous length of pipe is bent, the bent portion may be cut off to the desired length. Thus, the continuous bent tubing may be cut into 180° lengths or 90° lengths or any other desired lengths.

The expression "free-floating mandrel" as used in the following claims designates a mandrel which is supported and held in position only by the tubing or pipe being bent; no direct support or connection being present between the

mandrel and the rest of the machine during operation.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it is therefore desired that the present embodiments be considered in all respects as illustrative and not restrictive, reference being had to the appended claims rather than to the foregoing description to indicate the scope of the invention.

Having thus described the invention, what is hereby claimed as new and desired to be protected by Letters Patent, is:

1. A method of bending tubing or the like comprising passing the tubing over a smooth snugly-fitting mandrel and through the generally circular opening defined by a pair of juxtaposed driving rolls, each roll having an annular semi-circular channel formed in its outer periphery, said channels having generally transverse corrugations formed therein, thereby to form diametrically opposed series of semi-circular corrugations in the outer surface of said tubing while maintaining a smooth inner surface on said tubing, and subsequently passing the so-corrugated tubing over a curved mandrel between a pair of juxtaposed channeled bending rolls thereby to bend said tubing while deepening the corrugations along the inner edge of the bend and flattening the corrugations along the outer edge of the bend and while maintaining a smooth inner surface on said tubing.

2. A method of bending tubing or the like comprising passing the tubing over a smooth snugly-fitting mandrel and through the generally circular opening defined by a pair of juxtaposed driving rolls, each having an annular semi-circular channel formed in its outer periphery, said channels having generally transverse corrugations formed therein, thereby to form diametrically opposed series of semi-circular corrugations in the outer surface of said tubing while maintaining a smooth inner surface on said tubing, and subsequently passing the so-corrugated tubing over a curved mandrel between a pair of juxtaposed channeled bending rolls thereby to bend said tubing while deepening the corrugations along the inner edge of the bend and flattening the corrugations along the outer edge of the bend and while maintaining a smooth inner surface on said tubing, said curved mandrel having a cross-section somewhat smaller than the original inner cross-section of said tubing whereby said tubing is reduced in inside diameter by said pair of juxtaposed channeled bending rolls.

3. A method of bending tubing or the like comprising passing the tubing over a smooth snugly-fitting mandrel and through the generally circular opening defined by a pair of juxtaposed driving rolls, each having an annular semi-circular channel formed in its outer periphery, said channels having generally transverse corrugations formed therein, thereby to form diametrically opposed series of semi-circular corrugations in the outer surface of said tubing while maintaining a smooth inner surface on said tubing, and subsequently passing the so-corrugated tubing over a curved mandrel between a pair of juxtaposed channeled bending rolls thereby to bend said tubing while deepening the corrugations along the inner edge of the bend and flattening the corrugations along the outer edge of the bend and while maintaining a smooth inner surface on said tubing, said curved mandrel having a cross-section somewhat larger than the original inner cross-section of said tubing whereby said tubing is enlarged in inside diameter.

4. In a method of bending tubing or the like, the step of initially passing said tubing over a smooth snugly-fitting stationary mandrel and between a pair of juxtaposed driving rolls, each having an annular concave channel formed in its outer periphery, said channels having generally transverse corrugations formed therein, thereby to form diametrically-opposed series of generally semi-circular corrugations in the outer surface of said tubing while maintaining a smooth inner surface on said tubing.

5. A method of bending tubing or the like comprising initially passing the tubing over a smooth snugly-fitting mandrel and through the generally circular opening defined by a pair of juxtaposed driving rolls, each having an annular semi-circular channel formed in its outer periphery, said channels having generally transverse corrugations formed therein, thereby to form diametrically opposed series of semi-circular corrugations in the outer surface of said tubing while maintaining a smooth inner surface on said tubing, and subsequently passing the co-corrugated tubing over a free-floating curved mandrel between a pair of juxtaposed channeled bending rolls thereby to bend said tubing while deepening the corrugations along the inner edge of the bend and flattening the corrugations along the outer edge of the bend and while maintaining a smooth inner surface on said tubing, and subsequently passing the so-corrugated tubing over a curved mandrel thereby to bend said tubing while deepening the corrugations along the inner edge of the bend and flattening the corrugations along the outer edge of the bend and while maintaining a smooth inner surface on said tubing.

6. A tube-bending machine comprising a central driving roll having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a channeled bending roll in juxtaposition to said central driving roll and forming a generally circular bending-opening therewith; and a mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening and having a curved portion continuing around said central driving roll and passing through said bending-opening.

7. A tube-bending machine comprising a central driving roll having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a channeled bending roll in juxtaposition to said central driving roll and forming a generally circular bending-opening therewith; and a mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening and having a curved portion continuing around said central driving roll and passing through said bending-opening, said curved portion having a somewhat smaller cross-section than said straight portion.

8. A tube-bending machine comprising a central driving roll having an annular generally semi-circular channel formed in its outer periph-

ery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a channeled bending roll in juxtaposition to said central driving roll and forming a generally circular bending-opening therewith; and a mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening and having a curved portion continuing around said central driving roll and passing through said bending-opening, said curved portion having a somewhat larger cross-section than said straight portion.

9. A tube-bending machine comprising a central driving roll having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled bending rolls peripherally disposed in juxtaposition to said central driving roll and forming generally circular bending-openings therewith; and a mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening and having a curved portion continuing around said central driving roll and passing through said bending-openings.

10. A tube-bending machine comprising a central driving roll having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled bending rolls peripherally disposed in juxtaposition to said central driving roll and forming generally circular bending-openings therewith; means for driving said juxtaposed driving roll and said bending rolls from and in conjunction with said central driving roll; and a mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening and having a curved portion continuing around said central driving roll and passing through said bending-openings.

11. A tube-bending machine comprising a central driving roll having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled bending rolls peripherally disposed in juxtaposition to said central driving roll and forming generally circular bending-openings therewith; means for rotating said juxtaposed driving roll at generally the same rate of speed as said central driving roll; means for rotating said bending rolls at a somewhat higher rate of speed than said central driving roll; and a mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening and having a curved portion continuing around said central driving roll and passing through said bending-openings.

12. A tube-bending machine comprising a central driving roll having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled idle rolls peripherally disposed in juxtaposition to said central driving roll and forming generally circular bending-openings therewith; and a mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening and having a curved portion continuing around said central driving roll and passing through said bending-openings.

13. A tube-bending machine comprising a frame; a central driving roll rotatably mounted in said frame and having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll rotatably mounted in said frame in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled bending rolls rotatably mounted in said frame and peripherally disposed in juxtaposition to said central driving roll and defining generally circular bending-openings therewith; and a mandrel supported from said frame, said mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening, said straight portion having a smaller cross-section than said forming-opening and providing an annular clearance therein, said mandrel having a curved portion continuing around said central driving roll and passing through said bending-openings and forming annular clearances therein.

14. A tube-bending machine comprising a frame; a central driving roll rotatably mounted in said frame and having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll rotatably mounted in said frame in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled bending rolls rotatably mounted in said frame and peripherally disposed in juxtaposition to said central driving roll and defining generally circular bending-openings therewith; and a mandrel resiliently supported from said frame, said mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening, said straight portion having a smaller cross-section than said forming-opening and providing an annular clearance therein, said mandrel having a curved portion continuing around said central driving roll and passing through said bending-openings and forming annular clearances therein, said curved portion having a somewhat smaller cross-section than said straight portion.

15. A tube-bending machine comprising a frame; a central driving roll rotatably mounted in said frame and having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll rotatably mounted in said frame in juxtaposition to said central driving roll and defining a generally cir-

cular forming-opening therewith; a plurality of channeled bending rolls rotatably mounted in said frame and peripherally disposed in juxtaposition to said central driving roll and defining generally circular bending-openings therewith; and a free-floating mandrel disposed within said frame, said mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening, said straight portion having a smaller cross-section than said forming-opening and providing an annular clearance therein, said mandrel having a curved portion continuing around said central driving roll and passing through said bending-openings and forming annular clearances therein, said curved portion having a somewhat larger cross-section than said straight portion.

16. A tube-bending machine comprising a frame; a central driving roll rotatably mounted in said frame and having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll rotatably mounted in said frame in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled bending rolls rotatably mounted in said frame and peripherally disposed in juxtaposition to said central driving roll and defining generally circular bending-openings therewith; means carried by said frame for rotating said driving rolls and said bending rolls at predetermined speed; and a free-floating mandrel disposed within said frame, said mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening, said straight portion having a smaller cross-section than said forming-opening and providing an annular clearance therein, said mandrel having a curved portion continuing around said central driving roll and passing through said bending openings and forming annular clearances therein.

17. A tube-bending machine comprising a frame; a central driving roll rotatably mounted in said frame and having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll rotatably mounted in said frame in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled bending rolls rotatably mounted in said frame and peripherally disposed in juxtaposition to said central driving roll and defining generally circular bending-openings therewith; means carried by said frame for rotating said juxtaposed driving roll at the same rate of speed as, but in the opposite direction from, the central driving roll; means carried by said frame for rotating said bending rolls at a somewhat higher rate of speed than, and in the opposite direction from, said central driving roll; and a free-floating mandrel disposed within said frame, said mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening, said straight portion having a smaller cross-section than said forming-opening and providing an annular clearance therein, said mandrel having a curved portion continuing around said central driving roll and passing through said bending-openings and forming annular clearances therein.

18. A tube-bending machine comprising a frame; a central driving roll rotatably mounted in said frame and having an annular generally semi-circular channel formed in its outer periphery, said channel having generally transverse corrugations formed therein; a similarly channeled and corrugated driving roll rotatably mounted in said frame in juxtaposition to said central driving roll and defining a generally circular forming-opening therewith; a plurality of channeled idle rolls rotatably mounted in said frame and peripherally disposed in juxtaposition to said central driving roll and defining generally circular bending-openings therewith; means for rotating said driving rolls in opposite directions at the same rate of speed; and a free-floating mandrel disposed within said frame, said mandrel having a straight portion generally tangent to said central driving roll and passing through said forming-opening, said straight portion having a smaller cross-section than said forming-opening and providing an annular clearance therein, said mandrel having a curved portion continuing around said central driving roll and passing through said bending-openings and forming annular clearances therein.

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