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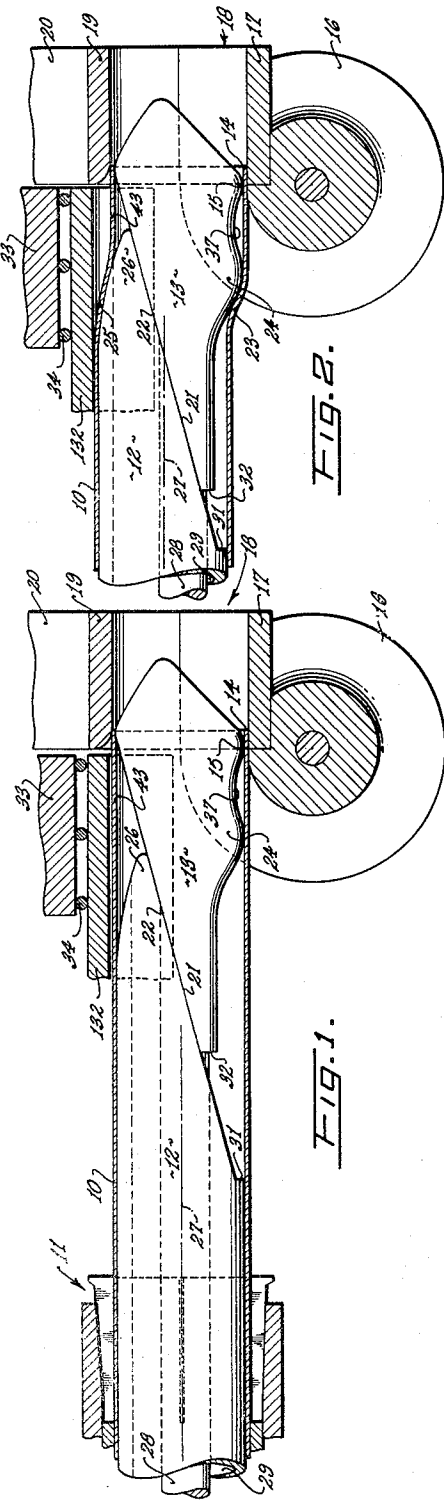
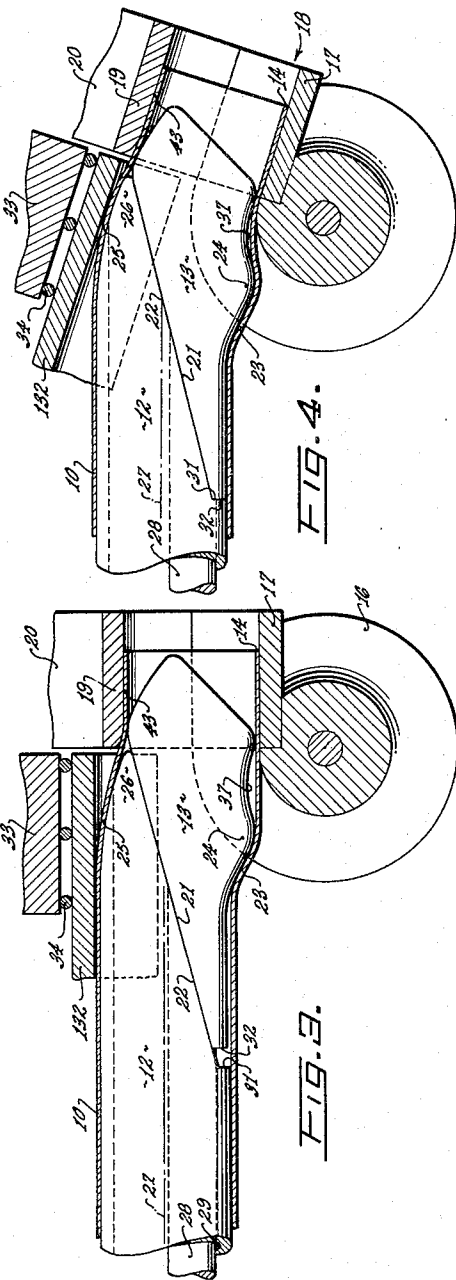
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APPARATUS AND PROCESS FOR BENDING SECTIONS OF TUBING

Filed Feb. 28, 1958

3 Sheets-Sheet 1



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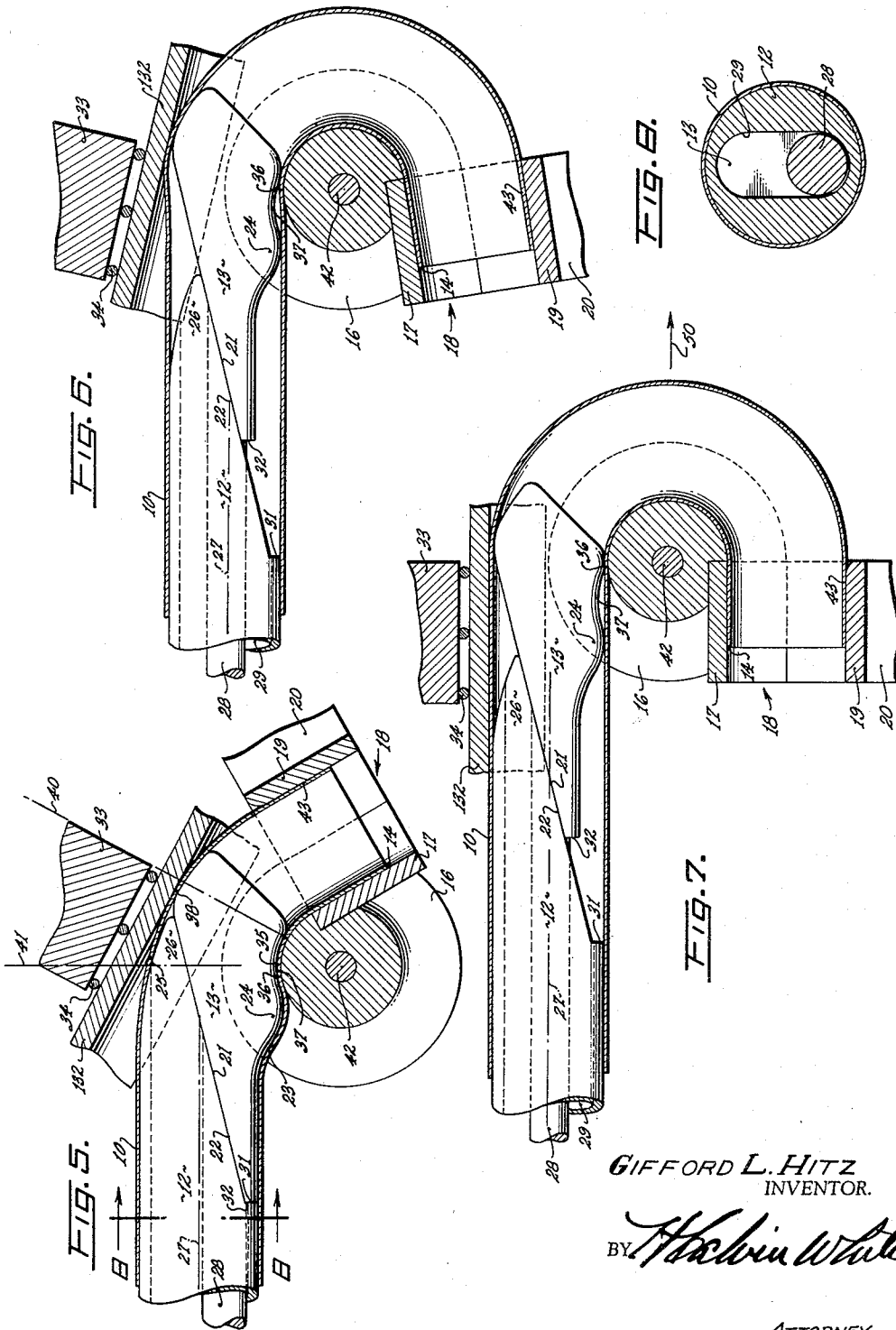
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Fig. 9.

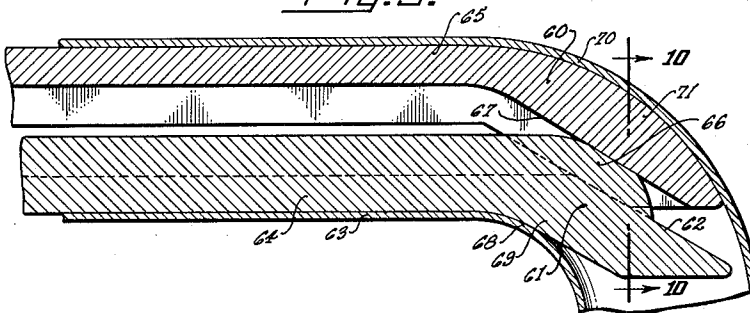


Fig. 10.

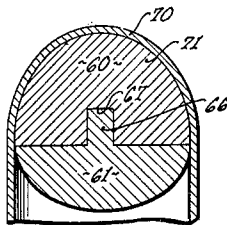


Fig. 11.

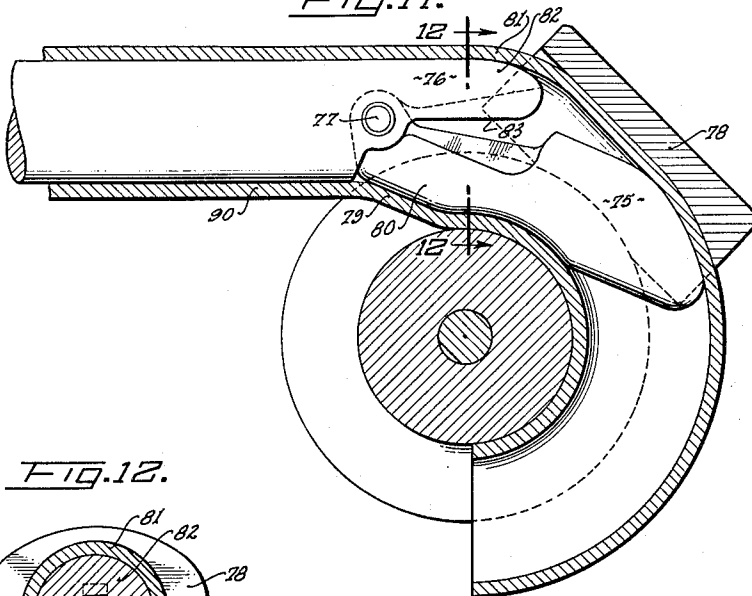
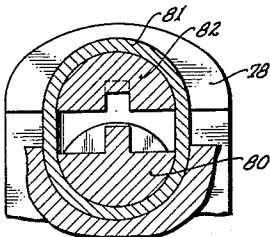


Fig. 12.



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APPARATUS AND PROCESS FOR BENDING SECTIONS OF TUBING

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19 Claims. (Cl. 153—32)

This invention relates generally to methods and apparatus for making bends in metal tubing, and more particularly has to do with the formation of tubing turns anywhere between the opposite ends of tubes with tangent lengths of undistorted tubing integral with one or both ends of the bend, while at the same time maintaining substantially uniform or controlled tube wall thickness at the turn as by means of a sectional or split mandrel.

The invention is generally predicated upon an application of the rather new concept that metal behaves differently under compressive loading beyond its yield point than under tensile loading beyond the yield point, contrary to the wide-spread older view that for all practical purposes the effects upon metal molecules of tensile and compressive loading can be treated as closely similar if not the same. The present application of this newer concept concerns methods of forming turns in elongated metal members, and is to be distinguished from older known methods of deforming metal to produce turns wherein no recognition was given to the difference in behavior of metal molecules loaded in compression as distinct from tension. Thus in prior processes the metal was deformed either cold or hot in a manner calculated to produce a resultant turn without particular regard for what happened to the molecules during the deformation beyond the yield point. As a result, metal being turned was subject to undesirable work hardening, especially in those instances where members within the classifications of tube, and pipe were cold worked in being permanently turned, and also, the forces and energies required to advance the members relative to the deforming bodies were of necessity undesirably great in order to overcome the resistance to member turning, which is related to the degree of work hardening of the metal being turned.

The present novel methods represent an application of the principle that the forces acting to bond or hold together metal molecules are disturbed less under compressive loading of the metal beyond the yield point than under tensile loading of the same metal beyond its yield point. This principle may perhaps be explained by considering that a given application of compressive loading is somehow more equally distributed among a larger number of molecules than is an equal tensile load application, from which it may be reasoned that the bonding forces are not disturbed as greatly under compressive loading as they are under tensile loading where fewer molecules absorb the applied loading. Visible striations in metal loaded in tension beyond the yield point illustrate the degree of disturbance and rupture of the molecular interbonding forces.

Basically, the present invention contemplates the formation of turns in metal tubing at any selected locations between the opposite ends of the tubing by performing a succession of operations upon the tubing including side loading beyond its yield point on the inside of the tube so as to offset laterally and enlarge a side portion thereof, advancing the tube forwardly in the direction of axial elongation thereof, retarding metal advancement at one portion of the offset angled away from the tube axis at one tube side to progressively offset the tube metal away from that axis during its advancement, and side loading beyond its yield point and toward that axis the opposite outer

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side of the advancing tube at a location forward of the offset in the axial direction of advancement so that the tube is progressively permanently turned away from that axial direction with the retarded metal at the inside of the formed turn, and so that the resultant tube is reduced in diameter from its maximum expanded dimension, and preferably to its original diameter.

The application of metal retardation forces maintains the existence of what may be termed a "protrusion" or wave-shaped "gathering" of the metal at one side of the tube and corresponding to the initially formed offset portion angled away from the tube axis, so that the tube metal is progressively offset away from that axis and is gathered into an enlarged cross sectional area during tube advancement. Furthermore, the tube metal is desirably retarded entirely through the application of compressive loading so as to minimize resultant work hardening of the metal being deformed, the retardation effect preferably being carried out by compressively rolling the one outer side of the advancing tube, with a mandrel within the tube aiding or otherwise stabilizing the metal retardation and guiding the metal into wave-shaped form. Thus, the retarded metal is compressively displaced around toward the opposite side of the tube, as a result of the action of the mandrel and roller compressively retarding and side loading the advancing tube metal beyond its yield point.

Referring to the mandrel itself, it is constructed to be inserted within an axially elongated tube with relatively movable mandrel sections collapsed together and adapted to be subsequently expanded to side load the inside of the pipe and forming an offset of enlarged circloid cross-section. Also, the mandrel may be collapsed after completion of the bend and withdrawn from the tube.

Additional steps of the process include side loading beyond its yield point the opposite inner side of the tube at another portion of the initially formed offset angled toward the tube axis in order to advance that other offset portion forwardly relative to the one offset portion maintained during tube advancement by metal retardation. Such side loading in combination with side loading of the opposite outer side of the advancing tube, as described above, accomplishes progressive permanent turning of the tube away from the axial direction of advancement thereof with the retarded metal at the inside of the smooth turn so formed, and the finally formed tube bend has a diameter reduced from the maximum diameter produced at the offset.

Refinements of the new method include guiding the permanently turned forward portion of the tube around a path having curvature substantially the same as that of the tube turn, and exerting compressive side loading on the outer opposite side of the tube in a direction extending at an angle of between 10 and 50 degrees with the normal to the initial tube advancement direction.

Other features and objects of the invention, as well as the details of an illustrative embodiment, will be more fully understood from the following detailed description of the drawings, in which:

FIG. 1 is an elevation showing an elongated metallic tube set up for being turned in accordance with the methods of the invention;

FIG. 2 is a similar elevation showing how an offset is initially formed in the tube;

FIG. 3 shows the offset formation being completed, with the tube beginning to advance;

FIG. 4 shows the tube advancing with metal advancement at the offset being retarded and with retarded metal advancing beyond the offset receiving initial side loading;

FIG. 5 shows all of the metal retarding and side loading operations being performed on the tube as it is turned throughout the preferred angle;

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FIG. 6 illustrates the retarding force and side loading against the tube being relieved as the turn formation is almost completed;

FIG. 7 shows the uniform cross-section and thickness of the tube after the formation of the turn therein;

FIG. 8 is a section taken on line 8—8 of FIG. 5;

FIG. 9 is an enlarged elevation showing a modified split mandrel;

FIG. 10 is a section on line 10—10 of FIG. 9;

FIG. 11 is an enlarged elevation showing another modified split mandrel; and

FIG. 12 is a section on line 12—12 of FIG. 11.

In the schematic showing of FIG. 1, the axially elongated, tube 10 is set up to be subsequently turned in such a way as to maintain the same tube cross-sectional tube area and wall thickness at the end of turn formation. Accordingly, where a turn is to be formed in the forward extent of the tube, the latter is advanced through a gripping collet assembly, and over a pair of upper and lower relatively retracted mandrels, designated as the mandrel shell 12 and spoon 13, until the forward end 14 of the tube extends over the tangent point 15 of a radius or semi-circular cross-section die roller 16, and into a U-shaped section 17 of a circular clamp 18 typically affixed to the roller. The tube is then gripped by means of the collet assembly 11 which is attached to a push mechanism, typically fluid actuated pistons and cylinders not shown, next, the movable inverted U-shaped section 19 of the clamp 18 is partially closed by means of the arm 20 toward the fixed section 17, leaving a slight clearance between the pipe and the movable section.

Referring now to FIG. 2, the mandrel shell 12 is advanced relative to the mandrel spoon 13 against which the shell forward incline 21 bears at the spoon incline 22 so that the spoon exerts a side load against the inside of the pipe, loading it beyond its yield point, and thereby effecting formation of an offset of enlarged cross-sectional area between forward and rearward portions of the pipe, the lower portion 23 of the offset being formed by spoon protrusion 24 and the upper portion 25 of the offset being controlled by the mandrel shell nose 26, as shown. Thus, the lower offset portion is angled away from the axis 27 of the tube, whereas the upper offset portion is angled toward that axis. Advancement of the mandrel shell may be accomplished by urging it and the tube forwardly in the direction of axis 27 while holding back the mandrel shell 13 by means of a rod 28 attached to the spoon and extending back through an opening 29 in the shell, as better seen in FIG. 8.

Thereafter, several motions of the elements are co-ordinated simultaneously as follows: the pipe is advanced by the collet assembly actuated by the push cylinders, the movable section of the clamp is closed against the forward portion of the tube to grip it firmly, and the mandrel shell 12 is advanced relative to the spoon 13 while maintaining contact at inclined inner faces at 21 and 22 thereof, all as shown in FIG. 3, these movements effecting completion of formation of the tube offset. Then, the radius die roller 16 and clamp 18 affixed thereto are rotated at the same speed as tube advancement by the collet assembly, illustrated in FIG. 4. Meanwhile, the mandrel shell has been advanced until shell and spoon shoulders 31 and 32 come into interengagement, and the shell and spoon together are advanced relative to the radius die roller 16 until they arrive at the position shown in FIG. 5. Also as shown in FIG. 4, an inserted semi-circular pressure die 132 is rotated about the axis of the roller 16 and simultaneously closed against the upper offset portion 25 of the advancing tube as by the action of the pressure die arm 33 transmitting loading to the die 132 through rollers 34 permitting relative motion therebetween in the direction of turning. Previous to this time, the pressure die 132 was spaced above the tube as shown in FIGS. 1 through 3.

Coming now to a description of FIG. 5 the tube 10 is

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shown being progressively advanced and turned with the mandrel spoon and shell and the pressure die 132 in fixed positions while the radius die roller 16 and clamp 18 are rotating to guide the forward end of the tube about the turn. At this time, the roller 16 and spoon protrusion 24 operate to retard tube metal advancement at the offset portion 23 so as to progressively gather and offset the tube metal away from axis 27 during tube advancement. Also, the roller 16 side loads the retarded metal flowing over the protrusion at 35 between the roller convex surface 36 and spoon concave surface 37, so that the retarded metal is further set back and the inner radius configuration is impressed thereon back toward the axis 27, with the tube metal flowing about the tube toward its opposite side being side loaded by the pressure die 132 at 38.

The latter side loading of the tube beyond its yield point at location 38 forward of the offset portion 25 progressively permanently turns the tube away from the axial direction 27 with the retarded metal at the inside of the turn. Also, the permanently turned tube has a diameter reduced below the maximum diameter produced at the offset. While the direction of side loading exerted by the pressure die 132 as indicated by the broken line 40 may form an angle of between 10 and 50 degrees with normal 41 to axis 27, the preferred angularity of such side loading is preferably about 28 degrees for thin walled tubing.

The invention also contemplates varying the torque applied to the die roller 16 through shaft 42 so as to pull the forward portion 43 of the tube gripped by the clamp 18 about the turn and thereby control metal retardation and the form of the wave defined by the regions 23 and 35. However, approximately five times as much tube push pressure or force can be exerted by or through the collet assembly 11 as compared with the pull force exerted by the clamp 18 during rotation thereof. Other ratios of push to pull pressure by these means may be required in accordance with the physical characteristics of different metals, the effects of different turn curvatures and different tube wall thicknesses.

As the forward portion 43 of the tube approaches the end of the turn the following movements are co-ordinated simultaneously as illustrated in FIG. 6; pushing pressure exerted by the collet assembly on the tube for advancing it is discontinued, either by releasing the collet assembly or by diminishing the pressure exerted by the main push cylinders on the collet, increased torque is delivered to the radius die roller 16 and the clamp 18 so that the latter pulls the forward portion of the tube through the final few degrees of turning to complete the bend, the pressure die 132 is turned counterclockwise back to its initial position above the tube, and both mandrels are withdrawn rapidly simultaneously, the shell being displaced more than the spoon. Thus, the offset in the tube is readily eliminated during the final few degrees of tube turning, since the mandrels no longer side load the inside of the tube, but offset elimination is not completed until final completion of the bend.

Thereafter, rotation of the radius die roller is discontinued, the mandrels are withdrawn sufficiently to permit the tube to be completely withdrawn in the direction of arrow 50 in FIG. 7 and the clamp 18 is released. Finally, the tube with its completed bend is removed in the direction of arrow 50 and the radius die roller and mandrels are returned to their initial position shown in FIG. 1.

While the actuators connected with the various tube loading elements described above are not shown, it will be understood that they, along with appropriate controls for cycling the operation of the various loading elements may be suitably connected with the elements in accordance with known principles.

In FIGS. 9 and 10 a somewhat modified split mandrel is shown to include a mandrel shell 60 that is forward of the mandrel spoon 61, and in interengagement therewith along the incline 62, the shell being shown in re-

tracted position with respect to the spoon as during forming of a bend in the tube 63 described supra. Such relative retraction of the shell and advancement of the spoon is effected by manipulation of the mandrel extensions 64 and 65 projecting rearwardly through the tube bore. A tongue 66 on the spoon is received in a longitudinal guide groove 67 in the shell for holding the spoon and shell against relative sideward displacement normal to the plane of FIG. 9. In operation as shown, the lower portion 68 of the tube offset is formed by the spoon protrusion 69, while the upper portion 70 of the offset is controlled by the mandrel shell nose 71. After the bend is completed, the shell and spoon may be relatively advanced and retracted while in sliding engagement along interface 62, to such an extent that the tube may be removed endwise off the mandrels.

In FIGS. 11 and 12 another modified mandrel assembly is shown to include a spoon 75 forward of the shell 76 and hinged thereto at 77, so as to be swingable in the plane of the tube bend. As the tube 90 is advanced and externally side loaded by the forward pressure die 78 of the type previously described at 32 in FIGS. 1-8, the hinged spoon swings clockwise into the position illustrated so that the lower portion of the tube offset 79 is formed by the spoon protrusion 80. The upper portion 81 of the offset is controlled by the mandrel shell bore 82. After the bend is completed, the tube may be pulled forwardly and endwise off the mandrel assembly, causing the spoon to swing counterclockwise into axial alignment with the shell, both of which are then within the confines of the forwardly elongated tube bore. In addition, the underside 83 of the shell acts as a stop for the spoon limiting the extent to which the latter may swing upwardly.

I claim:

1. The method of forming a turn in an axially elongated metal tube, that includes side loading beyond its yield point the inside of the tube to offset laterally and substantially enlarge only that side portion thereof which is to become the inside of the tube turn, advancing the tube forwardly in the direction of axial elongation thereof, retarding metal advancement at one portion of the offset angled away from said axis at said tube side to progressively offset the tube metal away from said axis during said advancement, side loading beyond its yield point and toward said axis the opposite outer side of the advancing tube at a location forward of said offset in said axial direction so that the tube is progressively permanently turned away from said axial direction with the retarded metal at the inside of said turn, and varying said side loading to control the enlargement of said tube side portion at a location along the tube at which said turn is to be merged with a length of the tube not having said turn.

2. The method of forming a turn in an axially elongated metal tube, that includes side loading beyond its yield point the inside of the tube to offset laterally and substantially enlarge only that side portion thereof which is to become the inside of the tube turn, advancing the tube forwardly in the direction of axial elongation thereof, retarding metal advancement at one portion of the offset angled away from said axis at one tube side to progressively offset the tube metal away from said axis during said advancement, side loading beyond its yield point and toward said axis the retarded metal advancing beyond said offset at said one tube side, side loading beyond its yield point and toward said axis the opposite outer side of the advancing tube at a location forward of said offset in said axial direction so that the tube is progressively permanently turned away from said axial direction with the retarded metal at the inside of said turn and so that the turned tube has an outer diameter less than the maximum cross dimension of the tube at said offset, and varying said side loading to control the enlargement of said tube side portion at a location along the tube at which said turn is to be merged with a length of the tube not having said turn.

3. The method of forming a turn in an axially elongated metal tube, that includes side loading beyond its yield point the metal tube at its inside to offset laterally and substantially enlarge only that side portion thereof which is to become the inside of the tube turn, advancing the tube forwardly in the direction of axial elongation thereof, compressively retarding metal advancement at one portion of the offset angled away from said axis at one tube side to progressively offset the tube metal away from said axis during said advancement, compressively side loading beyond its yield point and toward said axis the retarded metal advancing beyond said offset at said one tube side, compressively side loading beyond its yield point and toward said axis the opposite outer side of the advancing tube at a location forward of said offset in said axial direction so that the tube is progressively turned away from said axial direction with the retarded metal at the inside of said turn and so that the turned tube has an outer diameter less than the maximum cross dimension of the tube at said offset, and varying said side loading to control the enlargement of said tube side portion at a location along the tube at which said turn is to be merged with a length of the tube not having said turn.

4. The method of forming a turn in an axially elongated metal tube, that includes side loading beyond its yield point the metal tube at its inside to relatively laterally offset and substantially enlarge only that side portion thereof which is to become the inside of the tube turn, advancing the tube forwardly in the direction of axial elongation thereof, compressively retarding metal advancement at one portion of the offset angled away from said axis at one tube side to progressively offset the tube metal away from said axis during said advancement, compressively side loading beyond its yield point and toward said axis the retarded metal advancing beyond said offset at said one tube side, compressively side loading beyond its yield point and toward said axis the opposite outer side of the advancing tube at a location forward of said offset in said axial direction so that the tube is progressively turned away from said axial direction with the retarded metal at the inside of said turn and so that the turned tube has an outer diameter less than the maximum cross dimension of the tube at said offset, pulling the permanently turned forward portion of said tube around a path having curvature substantially the same as that of said turn and with sufficient tension below the yield point of the metal to control the degree of final turning, and substantially eliminating said side loading to eliminate the enlargement of said tube side portion at a location along the tube at which said turn is to be merged with a straight section of the tube.

5. The method of forming a turn in an axially elongated metal tube, that includes side loading beyond its yield point the metal tube at its inside to offset laterally and substantially enlarge only that side portion thereof which is to become the inside of the tube turn, compressively retarding metal advancement at one portion of the offset angled away from said axis at one tube side to progressively offset the tube metal away from said axis during said advancement, compressively side loading beyond its yield point and toward said axis the retarded metal advancing beyond said offset at said one tube side, compressively side loading beyond its yield point the opposite inner side of the tube at an opposite portion of the offset angled toward said axis to advance said opposite offset portion forwardly relative to said one offset portion, compressively side loading beyond its yield point and toward said axis the opposite outer side of the advancing tube at a location forward of said offset in said axial direction so that the tube is progressively turned away from said axial direction with the retarded metal at the inside of said turn, said side loading steps acting to shrink the tubing during turning to a cross sectional shape substantially the same as the cross sectional shape of the unturned tubing, and substantially eliminating said side

loading to eliminate the enlargement of said tube side portion at a location along the tube at which said turn is to be merged with a straight section of the tube.

6. Apparatus for forming a turn in an axially elongated metal tube comprising means engaging the tube and advancing it forwardly in the direction of axial elongation thereof, means extending within the tube bore acting to side load the inside of the tube to offset laterally and substantially enlarge only that side portion thereof which is to become the inside of the tube turn and to retard metal advancement at one portion of the offset angled away from said axis at said tube side to progressively offset the tube metal away from said axis during said advancement, said means including a pair of mandrels relatively movable within the tube bore to vary said side loading, means side loading beyond its yield point and toward said axis the opposite outer side of the advancing tube at a location forward of said offset in said axial direction so that the tube is progressively turned away from said axial direction with the retarded metal at the inside of said turn.

7. The invention as defined in claim 6 in which said mandrels have interengaged surfaces angled with respect to said tube axis direction, said mandrels being relatively slidable along said surfaces to effect relative displacement of the mandrels normal to said axis thereby side loading the inside of said tube, a certain mandrel having a substantial enlargement protuberant only at said offset side portion of the tube.

8. The invention as defined in claim 7 including means connected with the mandrels and extending rearwardly through the tube bore to the tube exterior for relatively moving said mandrels.

9. The invention as defined in claim 7 in which one of said mandrels is relatively forward of the other and engages the inside of the tube at said offset.

10. The invention as defined in claim 7 in which one of said mandrels is relatively rearward of the other and engages the inside of the tube at said offset.

11. The invention as defined in claim 6 in which one of said mandrels is forward of and hinged to the other mandrel.

12. The invention as defined in claim 6 including means side loading beyond its yield point and toward said axis the retarded metal advancing beyond said offset at said one tube side, whereby the turned tube has an outer diameter less than the maximum cross section of the tube at said offset.

13. The invention as defined in claim 6 including means outside the tube guiding the permanently turned forward portion of the tube around a path having curvature substantially the same as that of said tube bend.

14. The invention as defined in claim 13 comprising a clamp engaging the outside of said permanently turned tube forward portion.

15. The invention as defined in claim 6 in which said means side loading the opposite outer side of the tube comprises a concave die surface.

16. The method of forming a turn in an axially elongated metal tube containing a pair of relatively movable mandrels, that includes producing relative movement of the mandrels in a direction extending at an angle to the direction of the tube axis thereby to side load beyond its yield point the metal tube at its inside to offset laterally and substantially enlarge only that side portion thereof which is to become the inside of the tube turn, axially advancing the tube over said relatively moved mandrels thereby to retard metal advancement at one portion of said offset angled away from said axis at one tube side and to offset progressively the tube metal away from said axis during said advancement, side loading beyond its yield point and toward said axis the retarded metal advancing beyond said offset at said one tube side, and side loading beyond its yield point and toward said axis the opposite outer side of the advancing tube at a location forward of said offset in said axial direction so that the tube is progressively turned away from said axial direction with the retarded metal at the inside of said turn and so that the turned tube has an outer diameter less than the maximum cross dimension of the tube at said offset.

17. The method as defined in claim 16 including the step of producing reverse relative movement of said mandrels in the tube bore after formation of said tube turn so that said mandrels cease to side load the inside of the tube, and thereafter relatively removing the remainder of the tube from said mandrels.

18. The method as defined in claim 17 in which said reverse relative movement of the mandrels is accomplished gradually during tube advancement thereover.

19. The method of claim 16 including advancing the tube axially relative to said mandrels prior to production of said relative movement of the mandrels.

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