

Dec. 9, 1941.

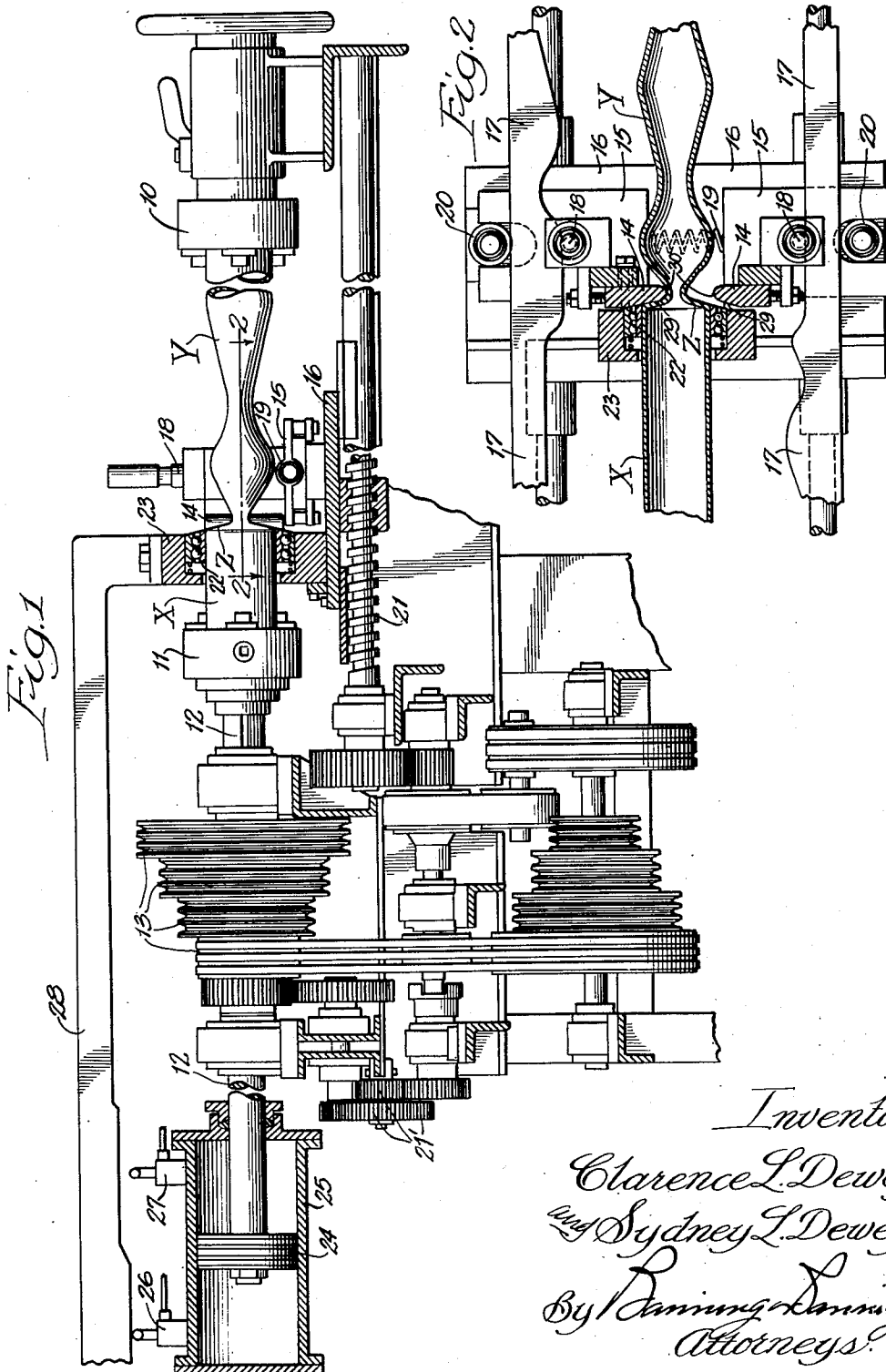
C. L. DEWEY ET AL

2,265,723

METHOD OF CONFIGURING TUBING AND REGULATING THE WALL THICKNESS THEREOF

Filed April 28, 1938

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 3

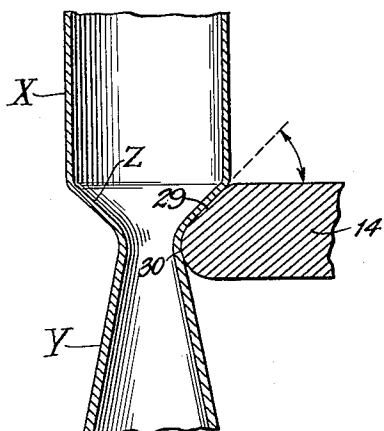


Fig. 4

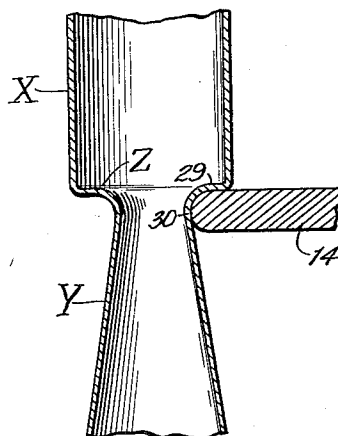


Fig. 5

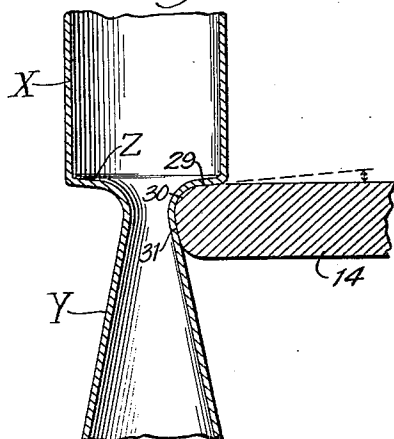


Fig. 6

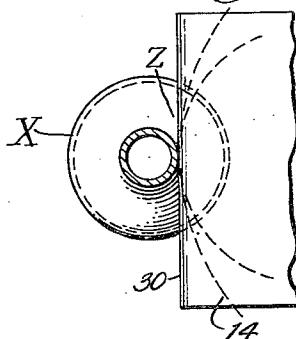
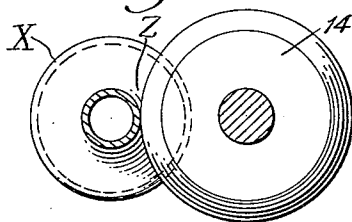


Fig. 7



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UNITED STATES PATENT OFFICE

2,265,723

METHOD OF CONFIGURING TUBING AND
REGULATING THE WALL THICKNESS
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Application April 28, 1938, Serial No. 204,900

9 Claims. (Cl. 113—53)

The present invention is directed to a method of imparting the desired exterior contour and wall thickness to metallic tubes originally of uniform cross sectional diameter, by causing the metal to flow down through a shoulder or offset which is evolved by the rotation of the tube in relation to the forming tool concurrently with the advance of the forming tool against the shoulder so evolved, and by reinforcing the undeformed tubing immediately in advance of the shoulder so that the deformative action is confined to the region immediately adjacent to the edge and forward face of the forming tool.

As a result of this confinement and the concurrent advance of the forming tool against the shoulder formed in the rotating tube, the line of attack of the acting surface of the forming tool will be along a spiral of very low pitch, so that at each instant only a minute quantity of metal will be actively undergoing deformation and caused to flow down along the active surface of the forming tool from the brink of the shoulder to the base thereof, at which latter point the deformative action is completed and the intended external configuration imparted to the exterior of the tubing.

In order to attain these results it is necessary that the speed of advance of the forming tool be relatively slow in relation to the speed of rotation of the tubing, so that each section of the tubing, as it passes through the zone of deformation, will be repeatedly, though progressively, brought into contact with the active surface of the forming tool during the progress of the latter through the zone of deformation through which each section of the tubing must pass.

By thus confining the line of attack to a definitely restricted region, at each instant, and by limiting the region in which the deformative stresses are active, it is possible to subject the tubing to an extreme degree of deformation, which in the resulting tubing will be exemplified by a radical reduction in diameter, although the degree of such reduction will at all times be controlled by the radial positioning of the forming tool with respect to the tube axis, which position in the present case is determined by the configuration of an elongated template or pattern, whose acting edge displays the pattern line which it is desired to impart to the exterior of the deformed section of the tubing.

The deformative operation with the resultant diminution in diameter results in a redistribution of the metal, which must of necessity result either in a lengthening of the tube or in a

thickening of the walls or various combinations of these two resultants, to compensate for the reduction in diameter to which the tube is subjected; and the present invention makes provision for the predetermined control of these factors within appropriate limits, so that it is possible not only to impart the desired external configuration to each portion of the deformed section of tubing but also to regulate the wall thickness thereof by properly directing or regulating the direction and volume flow of the metal actively responsive at each instant to the deformative stresses and in a manner which will hereafter be pointed out in detail.

By a proper regulation of the various factors involved in the redistribution of the metal it is possible to rapidly and accurately impart the desired configuration and wall thickness not only to relatively soft and ductile metals, such as copper or aluminum, but also to radically deform the contour and regulate the wall thickness of relatively stiff steel tubing and to impart configurations thereto which involve a degree of deformation in excess of anything heretofore attempted in so far as we are aware.

The tubing thus configured may be used for numerous purposes, including spindles or like structural elements included in furniture or furnishings of various descriptions, as well as configured rods required for the transmission of power in machinery or elsewhere, and the method may also be employed in the shaping of units recurrently formed in a single length of tubing and afterwards cut to provide duplicate products of equal length, shape, and wall thickness.

From the following description of the various operations included in the present method, it will be understood that where movements are defined as between the forming tool and the tube, it is the intention to refer to relative rather than absolute movements, although for clarity of description it is preferred to make reference to machines or appliances in which absolute radial and longitudinal movements are imparted to the forming tool or tools rather than the tube, and in which a rotary movement is imparted to the tube rather than the tool.

It will also be understood that in the regulation of the various factors presently to be described, such regulation can be advantageously and intelligently controlled within considerable limits, so that it is not possible to define in detail each possible combination of circumstances which may arise, although the description hereinafter given is one which is directed to a method which

has been successfully employed throughout a wide range of possible configurations and upon tubing of steel, copper, brass and aluminum of various diameters and grades of wall thickness, all of which are amenable to the presently defined operations within wide limits of deformation and wall thickness, and with a proper selection of forming tools to meet individual requirements in conformity with the principles herein-after more fully pointed out.

In order to more clearly bring out the nature of the present method and the various factors involved, reference is made to the accompanying drawings illustrating a suitable form of machine and various forming tools which may be advantageously employed therewith, and in which,

Figure 1 is a longitudinal section of the machine partly broken away in the center;

Fig. 2 is a sectional plan view of the principal operating parts taken on line 2—2 of Fig. 1;

Fig. 3 is a sectional detail illustrating the active surface of a forming tool having a relatively large angle of facial obliquity and a relatively large radius of edge curvature for increasing the wall thickness of the tubing;

Fig. 4 is a similar view showing the active surface of a forming tool having a zero or negligible angle of facial obliquity and a relatively small radius of curvature for reducing the wall thickness of the tubing;

Fig. 5 is a similar view showing a tool having in part a straight edge surface for smoothing out or ironing down any grooves or ridges which may remain in the tubing after it passes the more active region of deformation;

Fig. 6 is a rear side elevation of a forming tool having a straight acting edge in the longitudinal direction, and illustrating in dotted lines various possible departures from the straight edge formation; and

Fig. 7 is a rear face view of a tool in the form of a roller rather than a fixed bar, for the purpose of reducing friction where such reduction is desirable.

The machine itself forms the subject matter of a co-pending application, Serial No. 180,798, filed December 20, 1937, now Patent 2,162,327 dated June 13, 1939, so that it is not here deemed necessary to describe in full detail all of the parts of said machine save in so far as may be necessary to a clear understanding of the factors involved and the controls exercised in the deformation of the metal which occur during the configuration of the tube.

In the drawings, X illustrates the original or undeformed condition of the tubing, and Y the tube in its resultant or deformed condition, and Z the zone of active deformation within which the metal is flowing down in the evolution of a constantly advancing shoulder which measures the reduction in diameter before and after the operations herein described.

The deformed end of the tube is clamped within a chuck head 10 which, as shown, need not be positively driven (although it may be), but which must clamp and hold the end of the tube with a sufficient grip to prevent the release and bodily displacement longitudinally when subjected to the tension caused by the forward advance of the forming tool against the shoulder evolving within the zone of deformation. The opposite end of the tube—the end of the undeformed section X—is gripped and held by the chuck head 11 with sufficient firmness to impart a rapid rotation to the tube, which rotation is, of course, imparted

to all portions of the tube and to the chuck head 10.

In order to accommodate variations in tube lengths which are incidental to its reduction in diameter during the process of deformation, the chuck head 11 is carried by a grooved shaft 12 which is free to move longitudinally but has splined thereon a set of pulleys 13 adapted to be driven by belts and power connections which need not be described in detail. The forming tool 14 is mounted on a slide plate 15 which in turn is carried by a carriage 16 mounted for longitudinal travel with respect to the axis of the tube. For some purposes it is desirable to provide a set of two or more forming tools, which may either act concurrently upon opposite sides of the shouldered portion of the tubing, or which may if desired be regulated to act in succession or by relayed series upon different sections of the tube, and such a duplication of parts is illustrated in Fig. 2, although it will be understood that the description of one of the tools with its associated mountings is applicable to all.

The tools shown in Fig. 2 are in the form of straight fixed bars having rounded acting edges and obliquely disposed forward faces, although a tool in the form of a roller like that shown in Fig. 7 may be employed and mounted in the manner shown in full detail in copending application Serial No. 180,801, filed December 20, 1937.

The carriage is longitudinally movable with relation to a fixed template 17, the inner edge of which is configured to display in outline the external configuration which it is desired to impart to the tube, and in order to transmit to the tool the proper in and out radial movements conformable to the pattern on the template, a roller 18 is mounted upon the slide plate and is held in contact with the configured edge of the template by the action of a spring 19 which constantly forces the slide plate (or plates) outwardly.

In order to permit employment of a relatively thin or light template, which may be easily positioned or removed where substitution is desired, and to insure its exact spacing with respect to the axis of the tube at or near the region subjected to the thrust of the forming tool, a roller 20 is provided on the carriage, which bears against the rear straight edge of the template which runs parallel with the axis of the tube, so that, as the carriage advances, the template will be held in an exact spaced relationship to the axis of the tube irrespective of other means which may be provided for securing the template in position.

The carriage is advanced by the action of a screw feed 21 which is in train through reducing gears 21' with the driving mechanism for rotating the tube, so that the tube will be rotated at a relatively high rate of speed in relation to the advance of the carriage, although the ratio may be varied by the substitution of different gears in the reduction train or by varying the pitch of the screw, depending upon the desired ratio of rotation of the tube to the speed of advance of the carriage. In all cases, however, the ratio chosen will be one which brings each portion of the rotating tube repeatedly into contact with the active surface of the forming tool during the period while the metal of the tube is flowing down through the shoulder and progressing through the zone of deformation; that is to say, the width of the zone of deformation will be measured longitudinally from the crest of the shoulder to the extreme base thereof, which lat-

ter represents the point of ultimate reduction in diameter.

For tubing up to one and a half inches in diameter this width longitudinally will ordinarily measure about a quarter or three-eighths of an inch, while the width or pitch of the spiral line of attack which represents the amount of metal subjected to deformation at any particular instant will ordinarily be about one-thirty-second of an inch. Larger tubing, however, will usually require a wider zone which will ordinarily measure about 15% to 30% of the original tube diameter. In most cases, a suitable ratio might be one rotation of the tube for each one-thirty-second of an inch advance of the forming tool, at which rate it would require eight rotations of the tube to pass through a one-quarter inch width zone of deformation, or twelve rotations to pass through a three-eighths inch zone.

With certain grades of metal, a somewhat more abrupt pitch in the spiral line of attack may be employed to advantage, but it is not believed that less than four rotations of the tube during its passage through the zone of deformation can be advantageously employed, particularly in cases where but a single forming tool is used, and for stiffer grades of metal, such as steel, a relatively low pitched line of attack is deemed necessary or highly desirable. Where two or more forming tools are used to act concurrently and at different circumferential angles against the shoulder, the speed of deformation may be increased accordingly, and such an arrangement will be found desirable in order to more effectively resist any tendency for the tube to bend or flex during the deformative action, since when two or more forming tools are employed they will mutually cooperate in maintaining the tube accurately centered.

In view of the fact that it is necessary to localize and confine all of the deformative action between the crest and the base of the evolving shoulder, it is necessary to reinforce the undeformed section of the tubing immediately at the crest of the shoulder, so that the flow of the metal will begin at this point and continue inwardly until it passes under the most advanced portion of the edge of the forming tool. For this purpose, we provide a bushing 22 in the form of a rotatable ring which is mounted within ball bearings carried by a block or standard 23 on the carriage, which ring closely encircles and embraces the tube at a point in actual or practical contact with the forward face of the forming tool, so that the only escape for the metal, as the forming tool advances, is by flowing down in advance of the forward face and under the inner edge of the forming tool. Thus the deformation will begin abruptly at this point and will not be distributed forwardly thereof, and the deformed end of the tube being gripped by the chuck head 10 will resist the thrust of the advancing forming tool against the evolving shoulder and prevent the tube as a whole from being dragged forward with the tool, which is a factor wholly independent of the compensating movement of the chuck head 11 occasioned by the variation in tube length incidental to its reduction in diameter.

In the process thus far described, no description has been given of the particular factors which control the resultant wall thickness in the deformed tube, which resultant thickness may be controlled by giving to the metal flowing through the evolving shoulder either an abrupt or an easy line of flow, dependent upon the configuration of the forming tool employed. The

wall thickness may, within limits, also be controlled by either resisting the natural tendency of the tube to elongate during its reduction in diameter where an increase in wall thickness is desired, or by assisting the natural tendency to elongate where a thinning of the walls is desired.

By a proper combination of both of these factors, namely, the application of regulated longitudinal stress upon the tube as a whole, and by the regulation of the angle of flow of the metal through the evolving shoulder, it is possible to secure a desired wall thickness within wide limits and independently of the configuration imparted to the exterior of the tube, so that every part of the tube not only can be configured as desired but can have the desired wall thickness imparted thereto.

By whatsoever means this result is attained, it will be found that the regulation of the resultant wall thickness is due to the control exercised upon the rate of volume flow of metal through the evolving shoulder per unit of advance of the forming tool, whether this result be attained by the shaping of the tool or by the application of regulated stress to the tube as a whole, or by a combination of both factors. The rate of advance of the tool measures off the rate of production of the deformed tool section, and the wall thickness will be dependent upon the amount of metal passing through the zone of deformation and which thereby becomes distributed within the walls of the resultant tubing. Of course, these factors are in turn dependent upon the diameter given to the tube section, at any particular instant, by the radial position of the forming tool, but by a proper coordination of the rate of volume flow of metal for any resultant diameter, all of the factors are brought under control so that the wall thickness may be regulated within wide limits.

It has been found, where the reduction in diameter is slight, or in other words where the flow of the metal is restricted to relatively minute proportions, that the factors governing the regulation of wall thickness are relatively impotent, but where a considerable reduction in diameter is required, these factors rise into immediate importance, since the volume of metal, active or under flow, at any particular instant, becomes considerable, so that the regulative forces are concentrated upon and become effective in the metal actively flowing, which is of particular importance where a longitudinal stress is applied to the tube as a whole, and which becomes effective only in the region where the metal is active. In other words, a compression will not tend to thicken the walls throughout the tube, but its effect will be wholly concentrated into the region wherein the metal is actively undergoing deformation, and similar results attend the application of tension to the tube as a whole.

It will be understood, however, that the application of longitudinal stress to the tube, either as compression or as tension, is a factor which in many cases need not be utilized, since very advantageous results have been secured in the deformation of numerous grades of metal tubing by the employment of properly configured forming tools in cases where the tube was permitted to naturally expand or contract in response to its diminution in diameter without any attempt to control this factor. However, where the nature of the tubing requires that all available factors be employed in the regulation of the wall thickness, the application of longitudinal stress may

be utilized to great advantage in a manner to supplement the normal effects of the tool configuration, or even to counteract or compensate against such effects.

Where it is desired to apply longitudinal stress to the tube during the deformation thereof, suitable means to that end may be employed, and in the present instance, for purposes of illustration, we have employed a piston 24 on the end of the grooved shaft 12 carrying the chuck head 11 which engages the undeformed end of the tube, which piston operates within a cylinder 25 into which may be admitted fluid pressure through valve controlled ports 26 and 27. The valves may be automatically regulated by a configured template 28 secured to and advancing with the carriage, so that pressure, acting in the desired direction and in the required amount, may be admitted into the appropriate end of the cylinder to apply the required compression or tension to the end of the tube. This constitutes an interference with the normal expansion (or possible contraction) of the tube, and where compression is applied it will tend to crowd the tube rearwardly and thus accelerate the flow of metal through the evolving shoulder, so that the quantity of metal displaced per unit of advance of the forming tool will be increased, with a consequent thickening of the walls in the deformed section. Conversely, a tension on the end of the tube will retard the volume flow of metal through the shoulder per unit of tool advancement, so that less metal will be delivered into the resulting walls with a consequent diminution in wall thickness.

By configuring the fixed template 17 to secure the desired external configuration and by harmoniously configuring the movable template 28 to accelerate or retard the flow of metal, the wall thickness as well as the configuration for each section of the tube may be computed and attained within a relatively wide range of variation and independently of the angle of flow of the metal through the evolving shoulder, which, however, constitutes an important factor which may be harmoniously related to the application of longitudinal stress in the manner which is described and which will now be set forth in more complete detail.

The forming tool 14 may be variously configured within relatively wide limits, as indicated in Figs. 3 to 7 inclusive. The acting surface of the forming tool 14 comprises the forward face 29 along or around the margin of the tool, in conjunction with the forwardly presented portion of the rounded edge 30. These surfaces necessarily merge into one another and afford a continuously smooth surface, in front of which and under which the metal is compelled to flow during the period of deformation. By properly configuring these surfaces, the flow of metal may within wide limits be either retarded or accelerated, with a consequent reduction or increase in the resultant wall thickness.

Fig. 4 illustrates a tool having an abrupt forward face 29, which as shown is a flat face with no angle of obliquity. This face merges into a rounded edge having a relatively small radius of curvature. As a result of this configuration, the metal is compelled to flow through a very abrupt shoulder, which may be at right angles or any lesser angle, and which is compelled to pass through a short curve around the inner edge of the forming tool. The metal in this instance is, therefore, subjected to a forward thrust having

a large longitudinal component, so that the flow will be retarded and the metal stretched as it flows through the shoulder, with a resultant thinning of the wall.

Fig. 3 represents the opposite set of conditions in that the forward face is given a large angle of obliquity and the edge a large radius of curvature, with the result that the flow of metal through the evolving shoulder will be facilitated and volume rate accelerated, and more metal will pass through the shoulder per unit of advance of the forming tool, with a resultant thickening of the wall as compared with the conditions first discussed.

It is not intended that the angle of obliquity shown in Fig. 3 is necessarily the limiting angle, although it is substantially an angle of 45°, and ordinarily is as large an angle as can be used to advantage. At the other extreme, as in Fig. 4, the angle of obliquity is 0, and it will be understood that within this range it is possible to vary this angle and to combine the different facial angles with varying radii of edge curvature, depending upon the conditions encountered, which among other factors includes the extent of the reduction in diameter to which the tube is being subjected at any instant in the progress of the deformation.

It will be understood that the angle of obliquity above referred to is the angle subtended between the flat center portion of the forward face and the oblique plane of the sloping marginal portion which merges into the curved edge. Ordinarily, the tool will advance with its forward center face in a plane coincident with the transverse right angle plane through the axis of the tube, although for some purposes it may be desirable to vary the angularity of the tool as a whole with respect to this plane. For most purposes, however, the plane of advance of the tool will be coincident with the transverse plane of the tube, and departures from this condition may introduce modifying factors, which, however, do not vary the essentials of the method here involved.

In some cases it may be desirable to increase the width of the acting edge of the tool by providing a flattened area 31, as in Fig. 5, which increases the extent of active contact of the tool with the work, which may be desirable in cases where a relatively uniform taper is being produced and where it is desirable to more thoroughly smooth down or iron out any perceptible ridges which may remain in the surface of the tube after the deformative process has in the main been completed. Ordinarily the grooving will be too slight to be easily perceptible or objectionable, in view of the very low pitch in the spiral line of attack, but where extreme smoothness is desired, and under appropriate conditions, a tool of the character shown in Fig. 5 may be employed to advantage.

The facial and edge contours hereinbefore described may be applied to a tool in the form of a straight bar like that illustrated particularly in Fig. 6, or these configurations may be applied to the roller more particularly illustrated in Fig. 7. For many purposes, the fixed bar form of the forming tool, or the roller form, may be utilized interchangeably, although the factors tending to effect retardation in the flow of the metal will ordinarily be accentuated where the bar form is employed, so that the substitution of a roller for a bar of the same edge configuration, or vice versa, may result in variations in the wall thickness. However, where extreme de-

formation of heavy tubing, as for instance steel tubing, is desired, it will usually be found that the roller form is preferable, in that the friction is reduced and the necessity for the use of large quantities of lubricant is likewise reduced.

As illustrative of the results obtained by the use of different tools of a series, each acting upon metal tubing of the same grade, and the tools differing from one another in the angle of obliquity and/or the acting edge of the tool, we submit the following table:

Test	Resultant wall thickness	Forming tool angle and radius	
		Face	Radius
	Inches	Degrees	Inches
1	.087	60	$\frac{3}{16}$
2	.070	30	$\frac{5}{16}$
3	.070	00	$\frac{7}{16}$
4	.066	00	$\frac{3}{4}$
5	.062	00	$\frac{5}{16}$
6	.055	00	$\frac{7}{16}$
7	.046	00	$\frac{5}{32}$
8	.036	00	$\frac{3}{16}$
9	.018	00	$\frac{3}{16}$

Samples 1 and 2 show the effect of an angle face in increasing wall thickness. Note that although Sample 2 used a smaller radius than 3, the addition of a positive angle to the face resulted in equal wall thickness. Samples 3 and 9 show progressively thinner walls as the radii of the forming tools decreased, and the metal was progressively subjected to the greater stresses occasioned by the more abrupt turn required in passing under the edge of the forming tool.

In Fig. 2 we have illustrated a convenient means for employing tools having different configurations in a relay series upon different sections of the metal tubing. This illustrates the manner in which the different tools may be sequentially brought into action at the proper time by the configuration of the templates which act upon the respective tools. As shown, the upper tool is for the time being in active service, since the undulating contour of the template at this period tends to force the upper tool inwardly, while at the same time the lower tool is retracted and inactive since it rides against a uniformly depressed portion of the template. However, as the carriage advances, the upper template will be retracted and the lower template will be moved inwardly at the same instant, so that the lower tool will uninterruptedly continue the work and impart to the tubing the differing wall thickness characteristic of the operation of the lower tool. In this way the wall thickness can be automatically regulated by the operation of the tools in a relay series, which operations, if desired, may be supplemented by the application of longitudinal stress at each instant appropriate to the end in view.

It will be seen from the foregoing description that the present invention is one which controls and utilizes certain factors which determine the volume flow of the metal through the evolving shoulder, which, howsoever controlled, is the factor which ultimately determines the resultant wall thickness of the tube section at a point of any given diameter. Of course, the character or texture of the metal in the tubing is a factor which influences the responsiveness of the metal to any particular set of conditions, but, subject to this qualification, the control of the various factors in the manner hereinbefore pointed out permits

a wide range in the configuration imparted to the deformed section of the tubing, and within wide limits permits variable wall thicknesses to be obtained where desired, or on the contrary permits the production of a uniform wall thickness throughout a section of tubing differing at various points in its exterior contour.

Although for most purposes it is desired to reinforce the undeformed section of tubing by the employment of a bushing, or the equivalent, in a plane immediately adjacent to or in coincidence with the crest of the shoulder evolved under the advance of the forming tool, or in other words to bring the bushing into actual contact with the face of the forming tool, nevertheless a slight gap between the two may in some circumstances be permissible provided it is not sufficient in width to permit any outward bulging or ridging of the metal within the gap, since it is necessary in all cases that the metal be sufficiently confined at this point to uniformly regulate its flow around a clearly and uniformly defined crest or angle and to prevent any displacement of the metal at a point in advance thereof. It will thus be understood that where reference is made to a reinforcement of the tubing in close proximity to the forming tool, we mean to convey the idea either of actual contact between the forming tool and bushing or the equivalent or such close adjacency between these coacting elements as to occasion the evolution of a clearly defined and uniformly evolving shoulder free from irregularities which might interfere with the uniform flow of the metal through the shoulder and into the deformed section of lesser diameter.

We claim:

1. The method of configuring a tube initially having a uniform cross section which consists in applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation between the tube and the tool, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be repeatedly and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder.

2. The method of configuring a tube initially having a uniform cross section which consists in applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation between the tube and the tool, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder.

der and imparting variable radial movements to the tool to impart variations in the resulting contour of the tube, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be repeatedly and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder.

3. The method of configuring a tube initially having a uniform cross section which consists in applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation between the tube and the tool, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be repeatedly and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder, and in regulating the resultant wall thickness by controlling the rate of volume flow of metal through the evolving shoulder per unit of advance of the forming tool.

4. The method of configuring a tube initially having a uniform cross section which consists in applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation between the tube and the tool, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder and imparting variable radial movements to the tool to impart variations in the resulting contour of the tube, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be repeatedly and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder, and in regulating the resultant wall thickness by controlling the rate of volume flow of metal through the evolving shoulder per unit of advance of the forming tool.

5. The method of configuring a tube initially having a uniform cross section which consists in

applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation between the tube and the tool, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be repeatedly and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder, and in regulating the resultant wall thickness by directing the flow of metal through the shoulder at an angle determinative of the volume flow of metal per unit of advance of the forming tool.

6. The method of configuring a tube initially having a uniform cross section which consists in applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation between the tube and the tool, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be repeatedly and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder, and in regulating the resultant wall thickness by subjecting the tube to predetermined longitudinal stress to control the rate of volume flow of metal through the evolving shoulder per unit of advance of the forming tool.

7. The method of configuring a tube initially having a uniform cross section which consists in applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation between the tube and the tool, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be repeatedly

and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder, and in regulating the resultant wall thickness by subjecting the tube to predetermined longitudinal stress to control the rate of volume flow of metal through the evolving shoulder per unit of advance of the forming tool and at a predetermined angle of flow.

8. The method of configuring a tube initially having a uniform cross section which comprises applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation, about the axis of the tube, between the tube and place of application of said deformative pressure, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of the tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder and imparting variable radial movements to the tool to impart variations in the resulting contour of the tube, the rate of advancement per cycle of relative tube rotation being substantially less than the length of the limited tube section currently subjected to deformative pressure to prevent appreciable spiral grooving of the tube by causing every portion thereof to be re-

peatedly and progressively subjected during rotation to the pressure of the forming tool while passing through the region of deformation and in holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder.

9. The method of configuring a tube which comprises applying to a progressively advancing limited section of the tube a deformative pressure by a tool positioned to displace the tube wall inwardly while imparting relative rotation, about the axis of the tube between the tube, and the place of application of said deformative pressure, reinforcing the tube immediately in advance of the section undergoing deformation, thereby causing the metal of tube to flow inwardly behind the line of reinforcement in the evolution of a low pitched spirally extending shoulder and continuously relatively advancing the forming tool against the evolving shoulder and imparting variable radial movements to the tool to impart variations in the resulting contour of the tube, the rate of advancement per cycle of relative tube rotation being such as to prevent substantial spiral grooving of the tube by causing every portion thereof to be progressively subjected during rotation to the pressure forming tool while passing through the region of deformation, and holding the tube against bodily longitudinal displacement under the forward thrust imparted against the evolving shoulder.

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