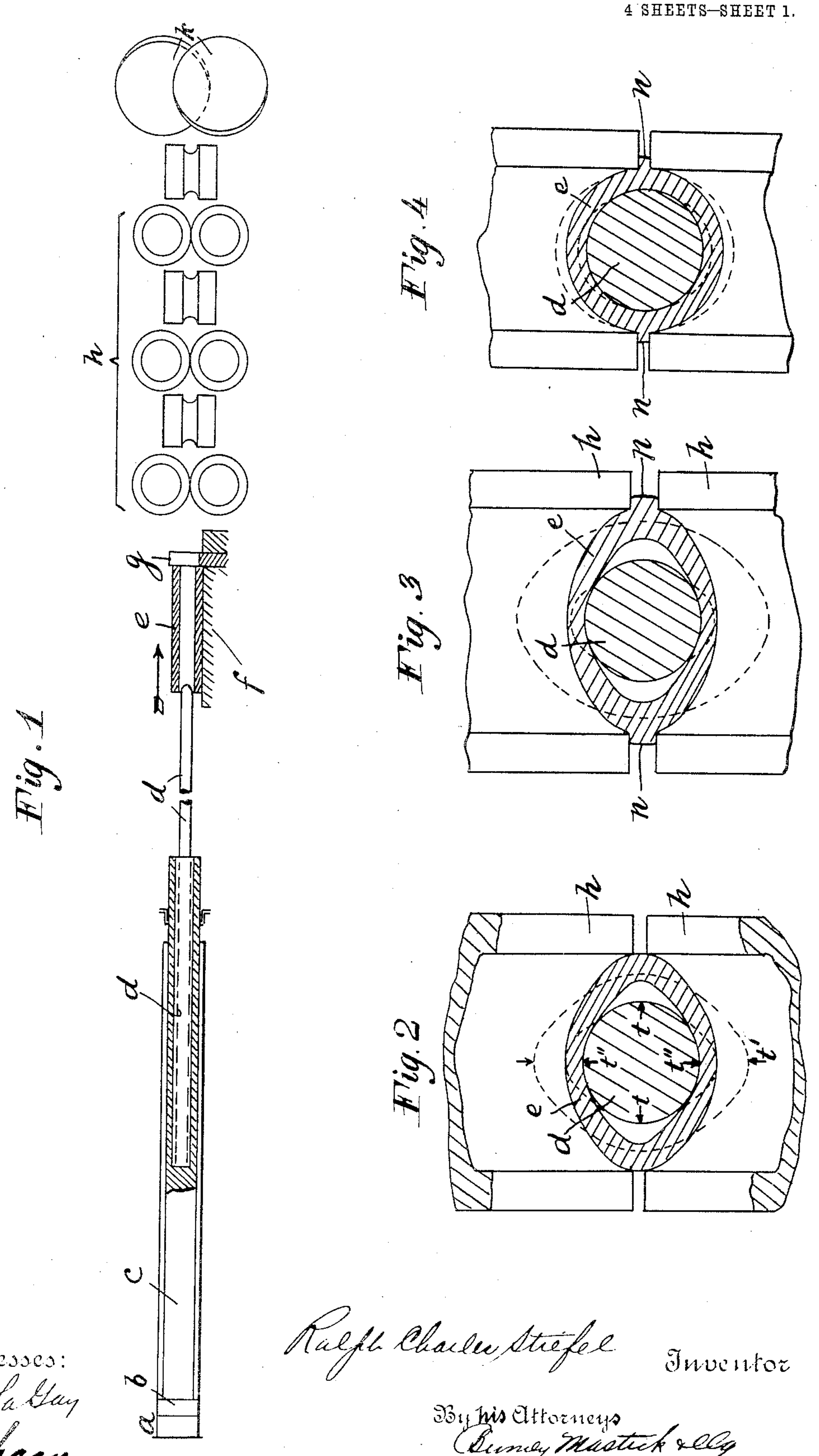
R. C. STIEFEL.

TUBE ROLLING.

APPLICATION FILED NOV. 12, 1909.

988,834. Patented Apr. 4, 1911.

4 SHEETS—SHEET 1.



Witnesses:

E. P. La Gay

A. Parham

Ralph Charles Stiefel Inventor

By his Attorneys

Briesen, Mastick & Ely

R. C. STIEFEL.

TUBE ROLLING.

APPLICATION FILED NOV. 12, 1909.

988,834. Patented Apr. 4, 1911.

4 SHEETS—SHEET 2.

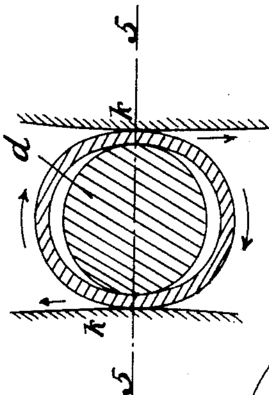


Fig. 6

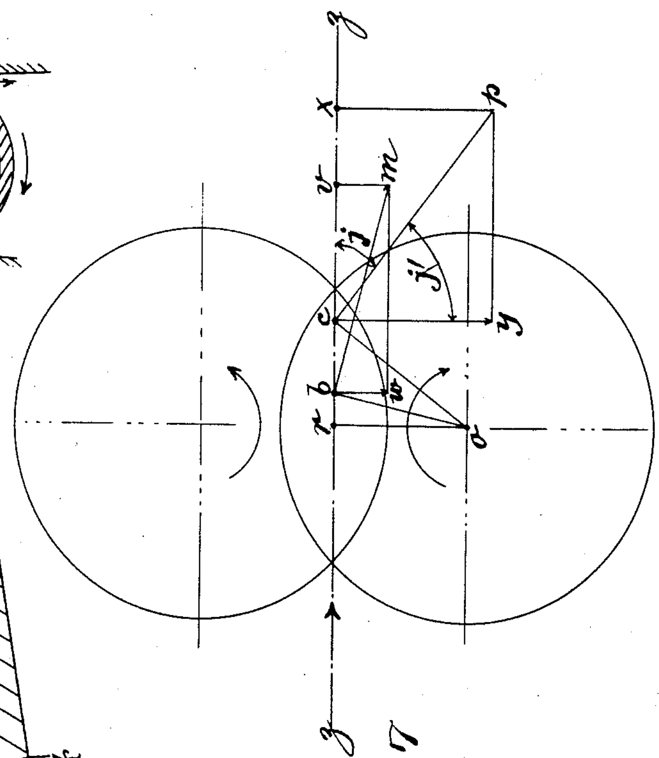


Fig. 7

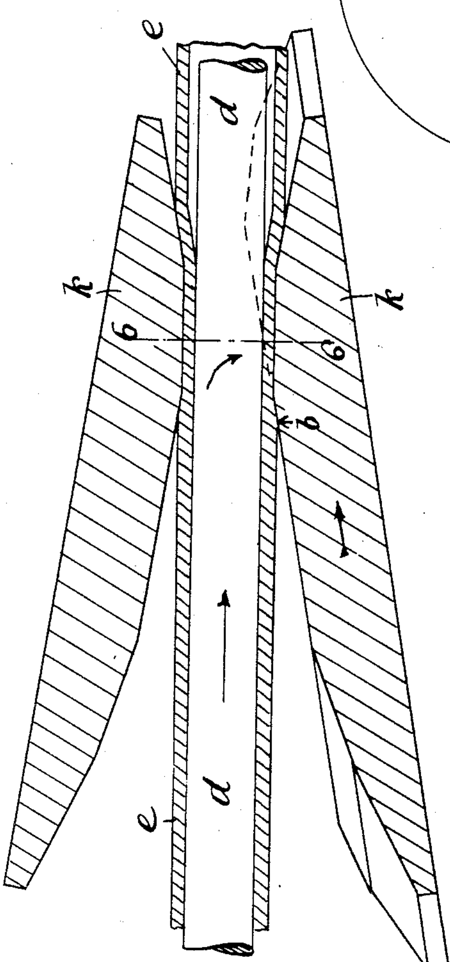


Fig. 5

Witnesses:

E. P. La Gay

A. Parham

Ralph Charles Stiefel Inventor

By his Attorneys

Cumey, Mastick & Ogden

R. C. STIEFEL.
TUBE ROLLING.
APPLICATION FILED NOV. 12, 1909.

988,834. Patented Apr. 4, 1911.
4 SHEETS—SHEET 3.

Fig. 9

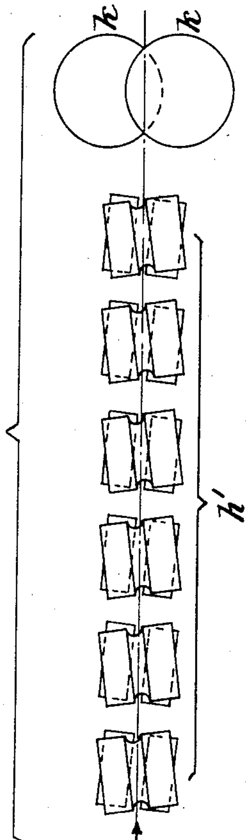


Fig. 8

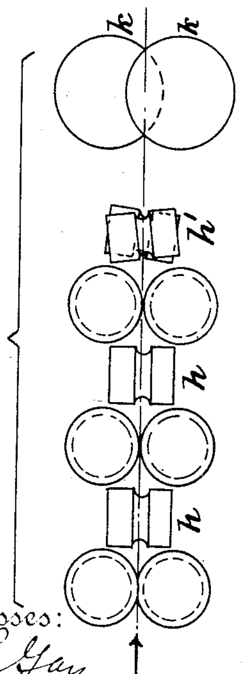
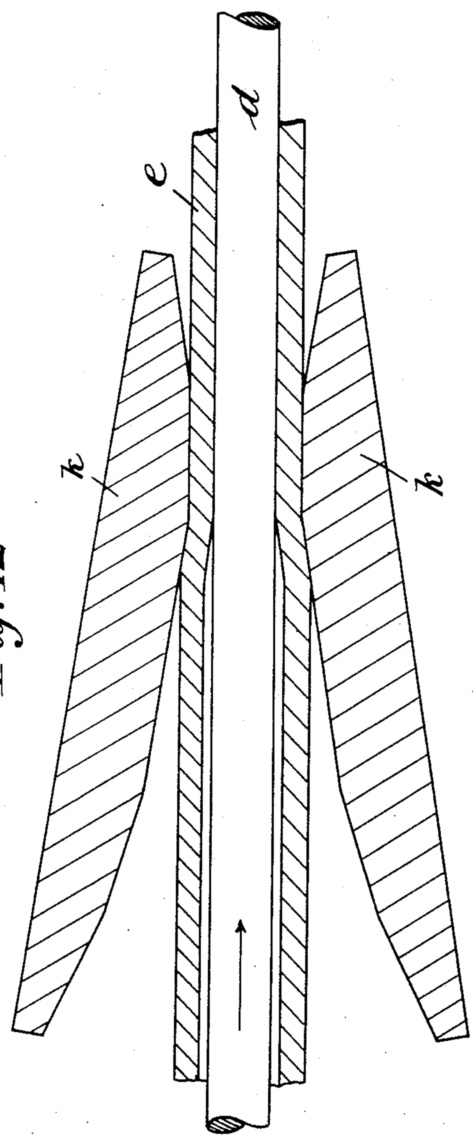


Fig. 12



Witnesses:
E. P. La Gay
A. Parham

Ralph Charles Stiefel Inventor

By his Attorneys
Briney, Mastick & Ogden

R. C. STIEFEL.

TUBE ROLLING.

APPLICATION FILED NOV. 12, 1909.

988,834. Patented Apr. 4, 1911.

4 SHEETS—SHEET 4.

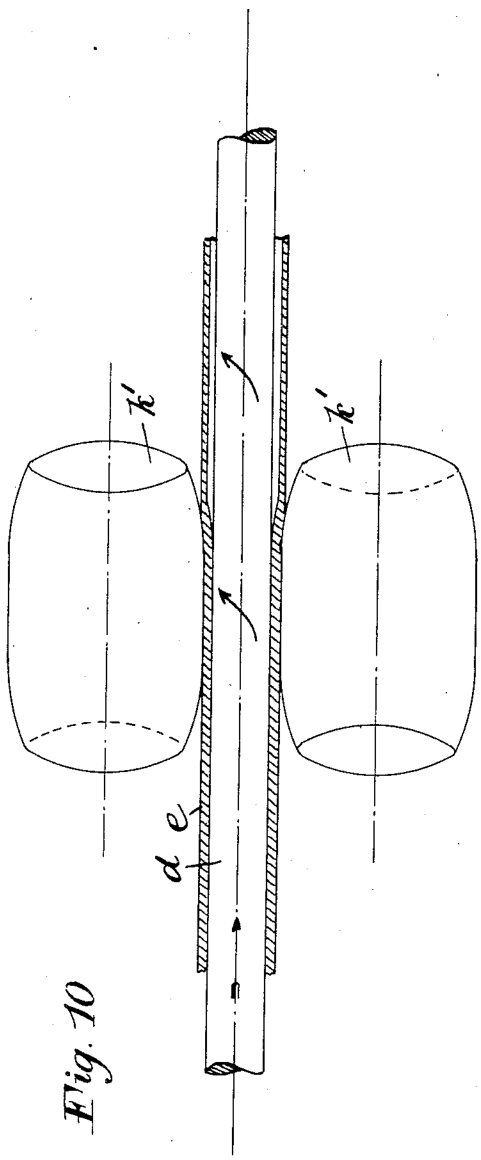


Fig. 10

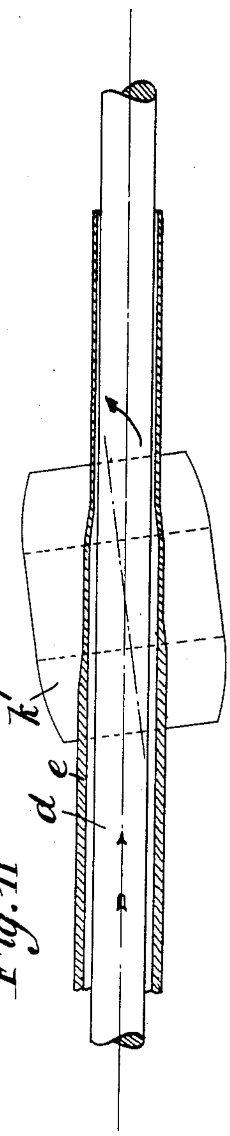


Fig. 11

Witnesses:
E. P. La Gay
A. Parham

Ralph Charles Stiefel Inventor

By his Attorneys
Burner, Mastick & Ogden

UNITED STATES PATENT OFFICE.

RALPH CHARLES STIEFEL, OF ELLWOOD CITY, PENNSYLVANIA, ASSIGNOR TO THE SHELBY STEEL TUBE COMPANY, OF PITTSBURG, PENNSYLVANIA, A CORPORATION OF NEW JERSEY.

TUBE-ROLLING.

988,834. Specification of Letters Patent. **Patented Apr. 4, 1911.**

Application filed November 12, 1909. Serial No. 527,640.

To all whom it may concern:

Be it known that I, RALPH CHARLES STIEFEL, engineer, a citizen of the United States of America, and a resident of Ellwood City, Pennsylvania, have invented certain new and useful Improvements in Tube-Rolling, of which the following is a specification, accompanied by drawings exemplifying the invention in certain preferred forms.

In the drawings Figure 1 is a diagrammatic view of instrumentalities for carrying out the process in one form. Figs. 2, 3 and 4 are cross sections of tubular blanks showing the effect of different grooved rolls for longitudinal rolling. Fig. 5 is a longitudinal section through the cross rolling bodies or disks of Fig. 1. Fig. 6 is a cross section on the line 6—6 of Fig. 5. Fig. 7 is a diagram of some of the motions involved. Figs. 8 and 9 are details showing modifications of Fig. 1. Figs. 10 and 11 are longitudinal sections on planes perpendicular to each other, showing the substitution of rolls for the disks of Fig. 1. Fig. 12 shows in longitudinal section a modified use of disks.

The invention relates to the art of rolling tubes and tubular blanks rapidly in a continuous process.

The object of the invention is to effect the rolling out of a tubular blank upon a mandrel in a most expeditious manner and preferably to accomplish substantially the entire reduction required of the tubular blank by a few sets of rolls and to produce a tube of substantially true circular shape delivered loose upon the mandrel bar.

In one operation of continuous tube rolling mills known in the art, where a long mandrel bar is inserted into the heated tubular blank or billet and the said blank, in unison with the mandrel bar, is passed through a series of sets of rolls with consecutively smaller grooves, it has been customary to use a tubular blank of an inside diameter somewhat larger than the diameter of the mandrel bar, so as to facilitate the rapid insertion of said mandrel bar into the blank prior to passing them in unison with each other through the rolls. It is evident that the wall of the tubular blank can only be effectively reduced in thickness after the blank has been reduced in diameter to such an extent as to tightly embrace the mandrel bar, and that therefore a certain amount of reduction in diameter occurs in such case before any substantial reduction of thickness of wall can commence. The accomplishment of said reduction of diameter, together with the total reduction required of the wall of the blank, necessitates naturally a greater number of roll pairs than would be required if the blank tightly embraced the mandrel bar before the two passed through the rolls.

Also, in the operation of such continuous mills, it has been customary to arrange the grooves of some of the rolls to produce a tube of pronounced oval shape only partly in contact with and adhering to the mandrel bar, facilitating the flow of the metal on the mandrel bar between said rolls by employing oval grooves and also facilitating the withdrawal of the mandrel bar from the tubes. In this manner a tube of non-circular shape is produced by the continuous mill process, said tube requiring further subsequent manipulation to give it a regular and true circular contour.

By the present invention in its preferred form I am able to overcome the disadvantages pointed out in the two preceding paragraphs.

I show in Fig. 1, partly in side elevation and partly in section, a cylinder *a* in which, by means of a suitable fluid, a plunger or piston *b* with a hollow body or piston rod *c* is caused to move back and forth at will; a mandrel bar *d* inserted in the hollow piston rod *c*; a tubular blank *e* resting on a support *f* and prevented from moving in the direction of the arrow by a disappearing stop *g* which is slotted large enough to allow the mandrel bar *d* to pass through, but too small to afford a passage for the blank *e*; a series *h* of sets or pairs of rolls with consecutively smaller grooves, said grooves being of pronounced oval or widened shape, as presently explained, in all the rolls; and a pair of rotary bodies *k* arranged to act on the tubular blank along one converging, one parallel, and one diverging portion, as in Fig. 5.

The operation is as follows: A tubular blank *e* with an inside diameter slightly smaller than or approximately equal to the diameter of the mandrel bar *d* is placed on its support *f* in front of the now raised stop *g*. The mandrel bar *d* is placed behind the tubular blank *e*, the hollow piston rod *c* being approximately at the end of its back stroke, and is wholly or partly inserted into the piston rod *c* or so guided that said piston rod on its forward stroke receives it in its hollow portion. When the mandrel bar *d* is so in place, the piston rod *c* is brought forward and the projecting mandrel bar is forced into the tubular blank *e*, causing the blank either to embrace tightly the mandrel bar if the inside diameter of the tubular blank, as is preferable, is slightly smaller than the diameter of the mandrel bar, or to closely fit around the mandrel bar with approximately no space between the bar and the inside surface of the blank if the inside diameter of the tubular blank is approximately equal to the diameter of the mandrel bar. It is evident that, in forcing the mandrel bar *d* through the tubular blank the bar will have to sustain a thrust whose tendency is to buckle or bend the bar, especially if a long mandrel bar of small diameter has to be used, as in rolling long tubes of small inside diameter. The object of the hollow piston rod *c* is, therefore, to form a side support for the slender mandrel bar at this stage of the operation, preventing the buckling of the bar under the load. The forward stroke of the piston is continued until the mandrel bar projects through the tubular blank *e* a sufficient distance to allow for the elongation of the tube upon it. The stop *g* is now withdrawn and the mandrel bar *d* and the tubular blank *e* move in unison with the piston toward the rods *h* until within the grip of the first pair of said rolls, which will thereupon cause the blank and bar to pass through and be reduced between the series of sets or pairs of rolls *h* and *k*. When the tubular blank and the mandrel bar have been gripped by the first pair the mission of the hollow piston rod is fulfilled and it may be brought back to its starting position, ready for the next tubular blank or billet.

In Fig. 1, the pushing and supporting member *c* is shown as a piston rod, operated in connection with a piston *b* and a cylinder *a;* but other mechanical means for causing said pushing and supporting member to move back and forth could be employed without affecting my invention.

The aforementioned distance that the mandrel bar *d* should project through the tubular blank or billet *e* at the time the stop *g* is withdrawn, depends upon the following conditions:—The velocity of rotation of each individual set or pair of rolls in the roll combination *h* is timed according to the reduction made in each pass in the tubular blank between the rolls and the mandrel bar, the metal, of course, leaving each pass at a velocity determined largely by the rotation of each set or pair of rolls and increasing with each consecutive set or pair in proportion to the reduction of the cross section of the tubular blank. However, it is evident that, although the mandrel bar is tightly gripped by the rolls, in the action of the rolls on the wall of the tubular blank or billet, it can not itself assume the several velocities of the tube in each of the consecutive passes, but will be given a velocity that is approximately an average of the several metal velocities. This causes the tubular blank or billet being stretched or rolled to run ahead of the mandrel bar at the exit end of the mill. As it also causes the mandrel bar to be drawn into the continuous roll sets faster than the tubular blank or billet enters the first set or pair of rolls, the mandrel bar must have a sufficient rear length that, at no time during the rolling, the rear end of the mandrel bar shall get ahead of the rear end of the tubular blank or billet. As now the working of the wall of the tubular blank or billet takes place between the rolls of the continuous roll sets *h*, the rotary bodies *k*, and the mandrel bar *d*, the latter must also project so far forward of the tubular blank *e* that no part of the metal of the tubular blank or billet will advance beyond the end of the mandrel bar at the time they reach the last working point, the rotary bodies *k*. If these rotary bodies are placed very close to the continuous roll sets *h*, the metal may advance ahead of the mandrel bar beyond the pass formed by said rotary bodies and a partial stripping take place. But in case these rotary bodies are placed so far away from the continuous roll sets *h* that the tubular billet is nearly free from the last pair of rolls of said continuous roll sets before entering the pass formed by the rotary bodies *k*, the mandrel bar should project through the tubular blank or billet *e* a sufficient distance at the time of withdrawing the stop *g* to insure that the tubular blank or billet will not be partly stripped off the mandrel bar in passing through the continuous roll sets *h*, previous to being worked in the pass of the rotary bodies *k*.

It is evident that as the tubular blank *e* tightly embraces the mandrel bar *d*, the reduction in thickness of wall commences in the first pair of the consecutive sets of rolls, thereby reducing the necessary number of sets of rolls or passes required for a given reduction of wall thickness. As the rounding of the tube takes place in the pass formed by the rotary bodies *k*, no attempt need be made to round the tube in the continuous roll sets *h*, so that all passes in these continuous roll sets *h* can thus be made widened or oval and so facilitate an equally free flow of the metal of the tubular blank or billet upon the mandrel bar in all the rolls, in two directions, crosswise as well as lengthwise.

Fig. 2 shows longitudinally of the pass, the acting portions of one set or pair of rolls *h* of the continuous roll sets. The mandrel bar d and the blank e are in cross section. The section in dotted lines shows the section of the tubular blank leaving the preceding pair of rolls which, as shown in Fig. 1, have their axes perpendicular to the axes of this roll pair h. The full drawn section of the tubular blank is the section after having been worked in the pass of the roll pair h. The tubular blank reaches said roll pair with the thinnest, or reduced, portions of its wall, as shown by the dotted section, pressed down onto the mandrel bar in line with points t by the reduction in the previous pass. The thickest portions at t' are standing off from the mandrel bar d in consequence of the crosswise flow of the metal on the bar in the preceding pass. In passing through the roll pair h, the thicker portions t' of the arriving section will be pressed down along the major axis of such section onto the mandrel bar and its thickness reduced till it becomes the thinnest at t'', the metal-flowing both crosswise and lengthwise. This crosswise flow of the metal from t'', together with the reversing of the major and minor axes of the arriving and the resulting oval, will naturally cause the metal at the thicker part of the section, or along the new major axis, to stand off from the mandrel bar at t an amount depending on the reduction taken and the previous periphery or degree of ovality of the arriving section. This ovality, with its resulting clearance between the wall of the tubular blank and the mandrel bar for a certain portion of the circumference of the mandrel bar, naturally allows a comparatively free and unrestricted flow of the metal crosswise and more so than should the metal embrace the whole or nearly the whole of the circumference of the mandrel bar as would be the case if a circular roll-groove were used. It also likewise allows a freer flow of the metal lengthwise, as only part of the circumference of the mandrel bar is in contact with the wall of the tubular blank, reducing only a portion thereof. This permits of an easier adjustment of the relative velocities of the mandrel bar and the metal referred to above with a consequent decrease in wear of acting surfaces and in power consumption. This crosswise flow of the metal, if unrestricted, would give a clearance between the mandrel bar and the inside of the tubular blank constantly increasing from pass to pass becoming greater than desirable. By properly proportioning the ovality of each subsequent section, this increase and excess of clearance are restricted and prevented and the rolling of damaging fins on the tube avoided. If the width of the pass corresponding to the major axis of the oval is restricted too much, however, for the thickness of metal and amount of reduction, the danger of finning will be apparent, and Fig. 3 shows this finning feature under such conditions, showing in dotted outline the metal arriving from the preceding pair of rolls, and the full drawn section e the result of the narrow or restricted pass, producing the fins at n by squeezing the metal out between the collars or flanges of the rolls. It is clear that if any of the passes of the roll sets are circular, as shown in Fig. 4, the tendency to produce fins at n, if any material reduction of wall thickness is attempted in the circular pass, will be still more pronounced, as seen in that figure.

As the tubular blank or billet is passing through the last pair or set of rolls of the continuous roll sets, Fig. 1, it enters into the pass formed by the rotary bodies k placed immediately following and in close proximity. Thus the tubular blank with the accompanying mandrel bar, when entering and being worked upon by the rotary bodies k, is still in the grip of part or of all of the sets or pairs of rolls constituting the continuous roll sets. The rotary bodies k form a pass embracing the tubular blank or now partly finished tube along longitudinal lines. They are revolved at rates corresponding to the flow and advance of the metal from the continuous roll sets, thereby crossrolling or rounding the wall of the billet. The action of the rotary bodies imparts to the metal a forward and a rotary motion, at the same time effecting a true circular shape of the tube. This rolling of the wall of the tube in the pass formed by the said rotary bodies and on the mandrel bar, also results in a slightly larger inside diameter of tube than the diameter of the mandrel bar, thus facilitating the subsequent removal of the bar. The pass formed by the rotary bodies k consists of a converging, a parallel, and a diverging exit portion, the converging portion of the pass forming the inlet for the metal to be rolled and providing a gradual approach to the point of contact. The parallel portion of the pass is formed by what could be called the main working surfaces of the rotary bodies, the converging portion of the pass changing into the parallel portion at a point where the distance between the surfaces of the two rotary bodies, measured diametrically across the axis of the tube and pass and perpendicular to the acting surfaces of the rolls is slightly smaller than the minor axis of the oval section of the tube arriving from the continuous roll sets h.

Fig. 5 is a horizontal sectional view of the rolling bodies k, the section being taken in a plane through the axis of the tube or pass and parallel to the axes of rotation of the rotary bodies k, showing in section the rotary bodies and the tubular blank or tube e, and in full-view the mandrel bar d. The direction of advance of the tube and mandrel bar is indicated by the arrow. Entering the converging portion of the pass, the tube is gripped by the rotary bodies and a rotary motion is imparted to same in addition to the forward motion. As the metal leaves the continuous roll sets with a pronounced oval section, there are two extreme positions of this section possible, relative to the width of the pass formed by the rotary bodies, one with the minor axis of said oval section in the sectional plane of Fig. 5 on plane 5—5 of Fig. 6; the other with the major axis in such plane. It is evident that an infinite number of intermediate positions between these two limits are possible. In the first position, which is preferred, a reduction of wall against the bar takes place immediately as the metal is gripped by the surface of the rotary bodies *k k*, the distance between those portions of the surfaces of the rotary bodies that form the parallel portion of the pass being slightly smaller than the minor axis of aforesaid oval section, *i. e.* smaller than the sum of the diameter of the mandrel bar and twice the minor thickness of the wall of the tube on leaving the last continuous roll set *h*. In the second extreme position the tube will likewise be given a rotary motion as soon as in contact with the surfaces of the rotary bodies which will occur smoewhat sooner owing to the greater length of the major axis, but the wall will not however be compressed against the bar by said rotary bodies until the tube has advanced at least to a point where the distance between the surfaces of the rotary bodies, does not exceed the diameter of the bar plus twice the major thickness of the tube on the major axis.

Fig. 6 is a sectional view looking forward, the section being taken on a plane 6—6 of Fig. 5, perpendicular to the axis of the blank or tube through the parallel portion of the pass formed by the rotary bodies *k k*, showing part of said rotary bodies, the tubular blank or tube *e* and the mandrel bar *d*. The arrows show the direction of rotation of the bodies involved. In the converging entering portion of the pass, the tube is gradually but slightly reduced in thickness until it enters the parallel portion of the pass, where the wall is rolled between the surfaces of the rotary bodies and the mandrel bar on the parallel contact lines, much in the manner of rolling a plate, although in this case an endless one. This parallel portion of the pass should thus finish the work of reducing the metal to a uniform thickness, started in the converging portion, and it also smooths the wall. It is evident that during this part of the process the tube if reduced to uniform thickness assumes the oval or elliptical shape shown in Fig. 6, the minor axis of the section reaching its minimum therein as seen from Figs. 5 and 6, the major axis being perpendicular thereto and the periphery being greater than on first entering the pass of these bodies. This major axis has naturally always the same position at the section 6—6 relative to the rotary bodies *k k*, the metal of the tube all the time revolving relatively to such axis in the direction of the arrows shown in Fig. 6. The gently diverging exit portion of the pass causes a rounding of the now uniform tube wall as it permits of the gradual expansion on the minor axis of the oval or elliptical section with a proportionate decrease of the major axis until the tube leaves the pass almost perfectly true to circle. In consequence also of the conditions stated the tube section is simultaneously loosened from the mandrel bar the periphery of the section of the tube having increased with the reduction of the wall thickness, and the wall having moved away from the bar in becoming circular.

With the arrangement shown in Fig. 1, where the rotary bodies *k k* are placed in close proximity to the continuous roll sets, the tubular blank or tube and the mandrel bar are still in the grip of all or some of the pairs of the continuous roll sets *h* when the bodies *k k* come in to action. The rotary motion is thus imparted only to the metal of the tube and particularly to that portion of same that is free from the grip of the rolls of the continuous roll sets *h*. The mandrel bar cannot rotate in the grip of the rolls of the continuous roll set *h*. On the other hand, the forward motion of the metal imparted by the rotary bodies should be determined by the velocity with which the metal is leaving the continuous rolls *h* and is to be governed thereby. During the greater part of the cross rolling by the rotary bodies these conditions continue and the distinctive features determining the cross rolling conditions are that both the metal and the mandrel bar enter into the pass formed by said rotary bodies with endwise motion only, both the metal and the mandrel bar being still in the grip of the rolls of the continuous roll sets *h*.

As the metal and the mandrel bar are delivered to the rotary bodies *k* with endwise motion only, the cross rolling action of the rotary bodies necessarily produces a twist of the metal of the tube as will be seen approximately by referring to the diagram Fig. 7. Fig. 7 shows in diagram the outline of the rotary, disk-shaped bodies *k k* and the axis *z—z* of the tube and mandrel bar, an arrow indicating the direction of the endwise motion of the metal and bar, and two arrows giving the corresponding directions of rotation of the rotary bodies. Let *o—r* be a perpendicular or radius from the axis *o* to the pass axis *z—z*. Let *b* represent the point of first contact, and *b m* the surface velocity of the rotary bodies at *b*. Then *b v* will represent the component of endwise velocity and $b\ w$ the component of crosswise or rotary velocity at b. Further let c represent the point of last contact, and $c\ p$ the velocity of the rotary bodies at said point. As before, $c\ x$ and $c\ y$ represent respectively the velocities of endwise and of rotary motion at said point c. The surface velocity increases in proportion to the respective radial distances $o\ r$, $o\ b$, $o\ c$, etc. from the axis of rotation. This velocity, as $c\ p$, at any point, as c, is proportional to its radius as $o\ c$. It is measured by the radius, multiplied by the constant angular velocity of the roll. Let j be the angle of divergence between the direction of motion as for example $c\ p$ and the line of the pass, being the angle $x\ c\ p$ or $r\ o\ c$. Then it follows that the feed components as $c\ x$, $b\ v$, etc. at every point in the line $z—z$ are equal and measured by one radius $o\ r$ times angular velocity. The cross velocity, as $c\ y$ is *nil* at r and increases as the tangent of the angle j being in fact equal to said feed velocity times this tangent, that is to say equal to $o\ r$ times the angular velocity times tan. j. Evidently then the feed is approximately uniform and the rotative tendency progressively faster, but the twist is somewhat lessened by slip and by increased periphery of the tube wall compared to the mandrel. The twist and slip in addition to facilitating the smoothing action are a known benefit in certain type of tubes as where peripheral strength to resist pressure is desired. The metal is rolled obliquely forward in relation to the axis of the tube. It is also evident that a tendency to a similar twist of the metal is produced between the last pair of continuous roll sets h and the point of first contact b between the rotary bodies $k\ k$ and the metal. This twist, however, is slight in proportion as the point of first contact is near point r, and is *nil* approximately when the two coincide, the rotary bodies imparting endwise motion only to the tube at that point. However, the twist of the metal between the last pair of rolls h and the pass of the rotary bodies $k\ k$ can be distributed over a longer distance and it can be eliminated altogether by arranging the last pair of rolls h obliquely relative to each other, the metal in this case being delivered to the rotary bodies $k\ k$ with the same obliquity as at point of first contact between the rotary bodies and the metal. This, however, does not impart to the mandrel bar a rotary motion, except in the last moments only, when the mandrel bar is in the grip of only the last pair of rolls. The mandrel bar during the greater part of the rolling is in the grip of all or of several of the roll pairs of the continuous roll sets h. In this case the distinctive features determining the rolling conditions are that the mandrel bar enters into the pass formed by the rotary bodies $k\ k$ with only endwise motion, while the metal enters said pass with both endwise and crosswise or rotary motion. Fig. 8 shows in side elevation the continuous roll sets h with the last pair of rolls arranged obliquely as just described and the rotary bodies $k\ k$ placed in close proximity to the last continuous roll set h'.

Instead of having only the last pair of rolls of the continuous roll sets h arranged with oblique axes, all the pairs of rolls may be thus arranged. Fig. 9 shows this arrangement, h' representing the rolls with axes arranged obliquely, and $k\ k$ representing the rotary bodies placed, as before, in close proximity to the continuous roll sets h. In this case it is evident that the tubular blank or billet and the mandrel bar, when passing through the continuous roll sets will rotate substantially in unison with each other in addition to having forward motion imparted to them. The axes of the last pair of rolls should preferably be given an obliquity or rotation such as to deliver the metal to the rotary bodies $k\ k$ with the obliquity and rotation corresponding to the first contact between said rotary bodies and the metal. The obliquity or the setting of the successive pairs of rolls h' should be such as to turn or deliver the metal of the tubular blank or billet to the next pair with a quarter turn in the distance between two consecutive roll pairs or otherwise so as to properly present the major axis to the rolls as already explained. In this case the distinctive features determining the rolling conditions are that both the metal and the mandrel bar enter into the pass formed by the rotary bodies k with endwise and with crosswise or rotary motion. It is evident that in this case the twist of the metal of the tube, previously mentioned as taking place between the last pair of continuous rolls h and the rotary bodies, is eliminated. The rotary bodies $k\ k$ can also be placed at sufficient distance from the continuous roll sets to allow the metal and the mandrel bar to become either completely or nearly free from the continuous rolls sets before entering the pass formed by the rotary bodies k.

It will be seen that the form of rotary bodies or disks $k\ k$ can be replaced by a set of cross rolls or rotary bodies with axes oblique to the pass axis and of a contour such as to form a narrow band or line contact between the surface of the roll and the metal to be rolled, constituting the parallel portion of the pass, and to form a converging approach to the above line contact and subsequent diverging surfaces effecting a gradual release of the grip of the rolls. Fig. 10 shows in sectional plan (or side elevation) and Fig. 11 in direction at right angle thereto a pair of such cross rolls with oblique axes, a mandrel bar d and a tubular blank or tube e. The arrow indicates direction of the forward motion of the tube and the mandrel bar. It will be seen that the effect of the cross rolls on the metal of the tube, while very similar to that of the rotary bodies *k k* described with reference to Figs. 5 and 6, eliminates nearly all twist of the metal by the cross rolls, such cross roll is a rotary body of comparatively uniform diameter, the greatest variation being in the converging and diverging portions of the pass. The parallel portion of the pass is formed by the central portion of the rolls having a slightly concave hyperboloidal longitudinal contour, as will be well understood.

As, from practical reasons the obliquity of the rolls is generally comparatively small and the length of the parallel portion of the pass or the hyperboloidal portion of the rolls comparatively short, it is evident that the theoretically proper variation of diameters, and the consequent difference in respect to twist is rather insignificant. The greatest variation occurs in the converging and diverging portions of the pass; but this variation is balanced by shortness of contact and light pressure, permitting slip.

Summarizing the different ways described for cross-rolling the tubular blank or tube on leaving the continuous roll sets *h*, we have the following:

In Fig. 1, both the metal and the mandrel bar enter into the pass formed by the rotary bodies *k* with endwise motion only, both the metal and the mandrel bar being in the grip of the rolls of the continuous roll set *h*; producing pronounced twist of the metal of the tube within the pass of the rotary bodies *k* and slight to no twist between the last pair of rolls of the continuous roll set *h*, and the rotary bodies *k*.

In Fig. 8, the mandrel bar enters into the pass formed by the rotary bodies *k* with only endwise motion, but the metal with both endwise and crosswise or rotary motion, we have nearly the same conditions between the contact lines of rotary bodies *k*, but the metal is delivered obliquely to these rotary bodies and with same obliquity as that in effect at the point of first contact between the rotary bodies *k* and the metal of the tube. We have twist by the last pair of rolls *h'*.

In Fig. 9 both the metal and the mandrel bar enter the pass formed by the rotary bodies *k* with both endwise and crosswise or rotary motion and we have substantially the same conditions as in Figs. 1 and 9 between the contact lines of rotary bodies *k*, but no twist back of point of their first contact. If the rotary bodies *k* be placed at sufficient distance from the continuous roll sets to allow the metal and the mandrel bar to leave the rolls of the continuous roll set before considerably entering the pass formed by the rotary bodies *k*, then while still having pronounced twist between the contact lines of the rotary bodies *k* we get no twist back of point of their first contact. If instead of the disk-like rolls *k* in the last instance we employ the rolls of Fig. 10, we have materially reduced twist between contact lines of the cross rolls and no twist back of point of first contact.

Instead of forcing the mandrel bar into the tubular blank as shown in Fig. 1 and described in connection therewith, the tubular blank can be caused to close around the mandrel bar with approximately no space between the bar and the inside surface of the tubular blank or billet, by passing the two in unison with each other through a pair of rotary bodies. These rotary bodies, being substantially the same as the rotary bodies *k* previously described, should be placed so that the tubular blank or billet with the mandrel bar are entirely freed from their grip before they enter the rolls of the continuous roll set *h*. Fig. 12 is a sectional view, the section being taken in a plane through the axis of the tubular blank or billet *e* and parallel to the axes of rotation of the rotary bodies *k*, showing the rotary bodies, the tubular blank or billet, and the mandrel bar *d*. The direction of advance of the blank and the mandrel bar is indicated by the arrow. The tubular blank with the mandrel bar in the correct relative position as previously described, are caused to enter the pass formed by the rotary bodies. When contact between the metal of the blank and the surface of the rotary bodies occurs in the converging portion of the pass, the metal is gripped by said rotary bodies and a rotary and a forward motion imparted to same. This rotary and forward motion exposes the whole circumference of the blank to the pressure of the rotary bodies and advances the blank into the contracted portion of the pass, gradually reducing the diameter of the blank and at the same time somewhat increasing the thickness of the wall. Thus the tubular blank is closed around the mandrel bar with approximately no space between the blank and the mandrel bar if the opening of the parallel portion of the pass is such that the wall of the tubular blank is not pressed appreciably against the mandrel bar *d*. Should by mistake the position of the rotary bodies have been so adjusted that the converging opening be such that the wall of the billet would be under considerable pressure between the rotary bodies and the mandrel bar, then an expansion of the billet in the parallel portion of the pass would result, substantially as described with reference to Figs. 5 and 6. Care must therefore be exercised in the operation of the rotary bodies for this purpose, so that said expansion of the billet does not result.

The rolling conditions when closing the tubular blank around the mandrel bar by means of rotary bodies, are substantially as previously described with reference to Fig. 7. The diverging portion of the pass formed by the rotary bodies, performs in this case no other function than permitting an easier exit of the metal with less risk of marking the surface of the blank than would be the case if the pass terminated abruptly with the parallel portion.

By grooves wider than concentric with the bar it will be understood that I compare the grooves with grooves of any given depth that are concentric with the bar and mean that the grooves are relatively flatter and wider than such concentric groove would be.

What I claim is:—

1. In the art of rolling tubes, the improvement consisting in forcing a billet or tube tightly upon a mandrel bar, then longitudinally rolling the tube on the bar between successive pairs of longitudinally acting rolls having grooves wider than concentric to the bar and which do not completely touch and confine the tube but act along limited paths, leaving it free to flow transversely as well as longitudinally, the successive pairs acting along different lines or paths along the surface of the tube, and then cross rolling the tube between cross-rolling bodies having rolling surfaces first convergent then substantially parallel with the bar and then divergent, whereby the tube wall is rendered substantially of uniform thickness and smooth and circular, and is loosened from the mandrel bar.

2. In the art of rolling tubes, the improvement consisting in forcing a billet or tube tightly upon a mandrel bar, then longitudinally rolling the tube on the bar between successive pairs of longitudinally acting rolls having grooves wider than concentric to the bar and which do not completely touch and confine the tube but act along limited paths, leaving it free to flow transversely as well as longitudinally, the successive pairs acting along different lines or paths along the surface of the tube and then cross-rolling the tube on the bar between cross-rolling bodies having surfaces providing a compressive portion and a slightly divergent exit portion of the pass, whereby the tube is rolled between the bar and the cross-rolling surfaces and then between the rolls only.

3. In the art of rolling tubes, the improvement consisting in forcing a billet or tube tightly upon a mandrel bar, then longitudinally rolling the tube on the bar between successive pairs of longitudinally acting rolls having grooves wider than concentric to the bar and which do not completely touch and confine the tube but act along limited paths, leaving it free to flow transversely as well as longitudinally, the successive pairs acting along different lines or paths along the surface of the tube and then cross-rolling between cross-rolling bodies.

4. Elongating and thinning the walls of tubes on a mandrel bar by longitudinally rolling a tube and bar in a plurality of successive sets of grooved rolls while allowing the metal freedom to flow transversely, and by cross-rolling the tube between suitable rolls while the bar is still under the grip of some of the grooved rolls, and thereby twisting the wall of the tube relatively to the bar and smoothing and rounding the tube.

5. Improvement in the art of rolling tubes which comprises passing a hollow billet or tube upon a mandrel bar between grooved longitudinally acting rolls and then between cross rolls and compressing and confining it while between the first said rolls only along lines or paths of substantially limited width allowing the metal to flow transversely during its elongation on the bar.

6. In tube rolling, the improvement comprising subjecting a tubular body of oval section upon a mandrel bar of circular section and diameter approximately equal to the minor internal axis of said body to the action of cross rolling surfaces forming a pass and having transverse surface speeds that differ effectively from that allowed or imparted to the bar and thereby rolling out the wall thickness to a uniform one between the bar and the bodies and rounding the tube between gently diverging portions of said surfaces.

7. In tube rolling, the improvement comprising subjecting a tubular body of oval section upon a mandrel bar of circular section and diameter approximately equal to the minor internal axis of said body to the action of cross rolling surfaces forming a pass and having transverse surface speeds that differ effectively from that allowed or imparted to the bar and thereby rolling out the wall thickness to a uniform one between the bar and the bodies.

8. In tube rolling, the improvement comprising subjecting a tubular body of oval section upon a mandrel bar of circular section and diameter approximately equal to the minor internal axis of said body to the action of cross rolling surfaces forming a pass and having transverse surface speeds that vary progressively, causing twist of the tube, and preventing or restricting the rotation of the mandrel bar under such action while rolling out the tube wall transversely and unifying its thickness, and then rounding the tubular wall between gently divergent parts of said rolling surfaces.

9. In tube rolling, the improvement comprising subjecting a tubular body of oval section upon a mandrel bar of circular sec-

tion and diameter approximately equal to the minor internal axis of said body to the action of cross rolling surfaces forming a pass and having transverse surface speeds that vary progressively, causing twist of the tube, and preventing or restricting the rotation of the mandrel bar under such action while rolling out the tube wall transversely and unifying its thickness.

10. In tube rolling, the improvement comprising fitting the blank or tube snugly onto a mandrel bar and then longitudnally rolling the metal into oval sections upon a bar and alternately converting major into minor axes and major thickness into minor thickness and then in the same heat and travel cross rolling the tube on the bar by first converting it to uniform thickness and elliptical section on the bar, and then between diverging surfaces rolling it to a round section loose upon the bar.

11. In tube rolling, the improvement comprising longitudinally rolling the metal into oval sections upon a bar and alternately converting major into minor axes and major thickness into minor thickness and then cross-rolling the tube on the bar by first converting it to uniform thickness and elliptical section on the bar and then between diverging surfaces rolling it to a round section.

12. The method of rolling tubes consisting in placing a hollow metal billet or tube upon a mandrel and elongating and reducing the tube upon the mandrel between grooved longitudinally acting rolls, and then passing the tube and mandrel between cross-rolling bodies and loosening the tube on the mandrel by the cross-rolling action of said bodies.

13. The method of rolling tubes consisting in placing a hollow metal billet or tube upon a mandrel and elongating and reducing the tube upon the mandrel between grooved longitudinally acting rolls, and then passing the tube and mandrel between cross-rolling bodies and loosening the tube on the mandrel and rounding the successively loosened portions between diverging portions of the cross-rolling bodies.

14. The method of forming tubes consisting in rolling a heated hollow billet or tube upon a mandrel to reduce its cross sectional area and before cooling cross rolling the rolled billet to loosen the tube on the mandrel and fix the diameter of the successively loosened portions.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

RALPH CHARLES STIEFEL.

Witnesses:

B. F. Goodrich,

Geo. L. Schreiber.