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ENCLOSED ROLLING MILL

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Fig. 1.

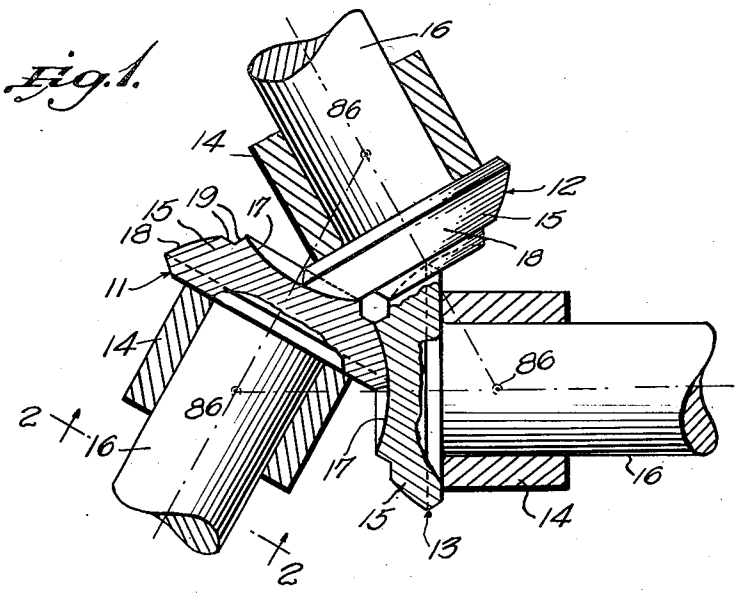
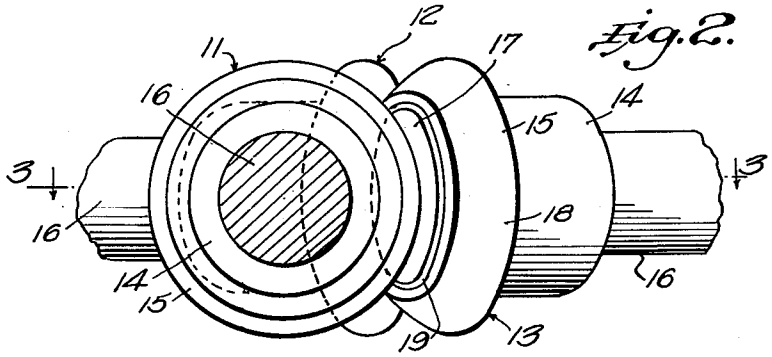


Fig. 2.



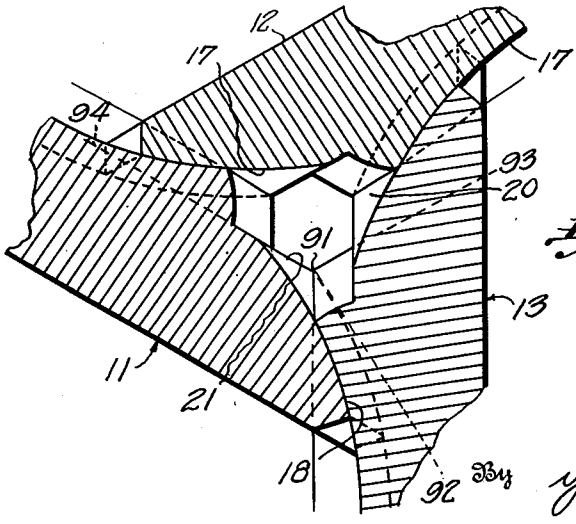


Fig. 3.

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Fig. 4.

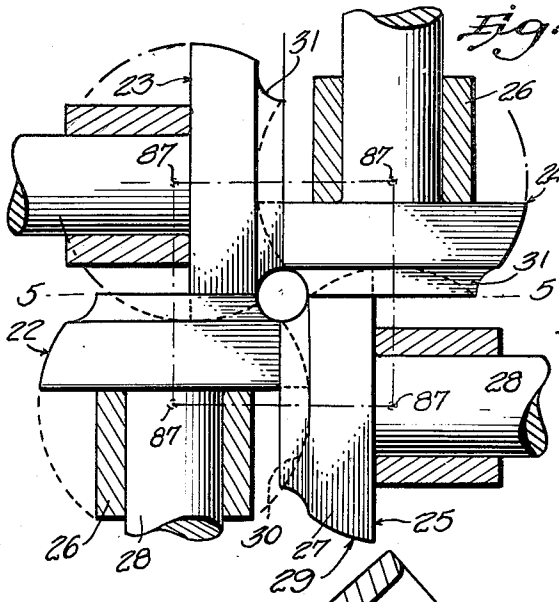
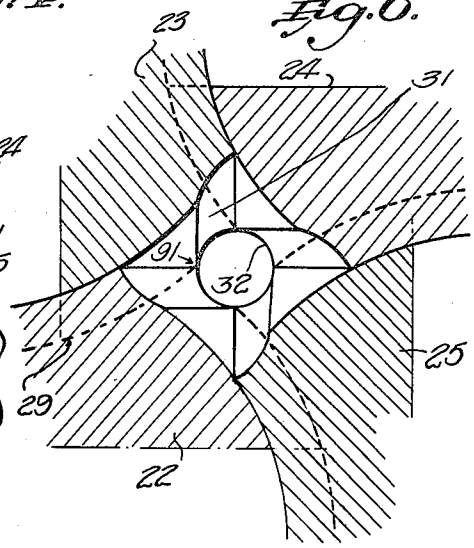


Fig. 6.



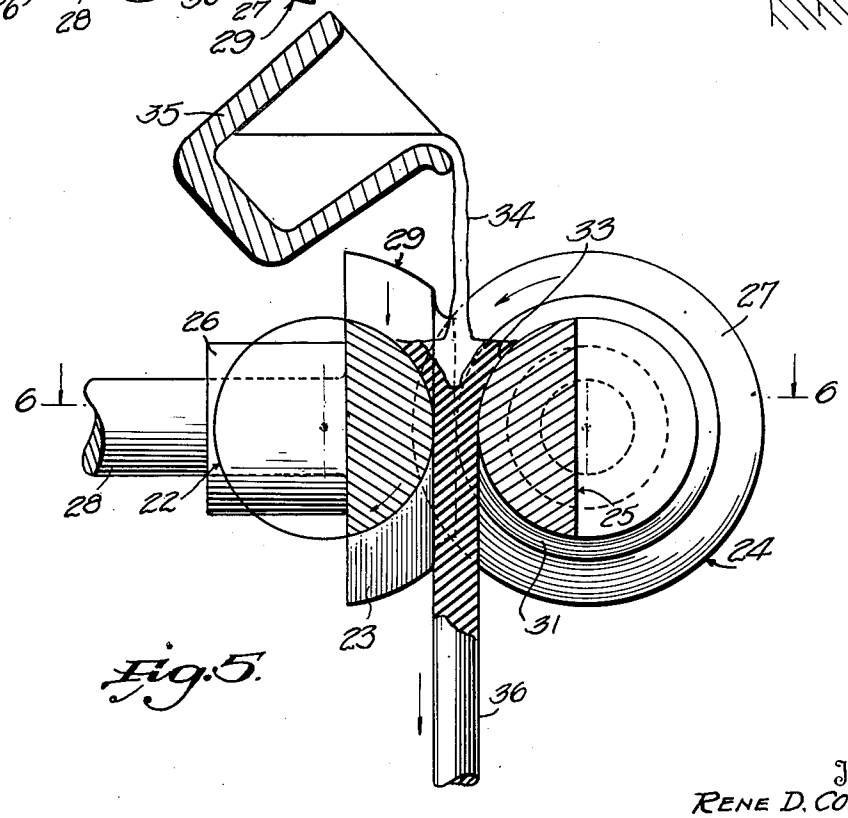


Fig. 5.

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Fig. 7.

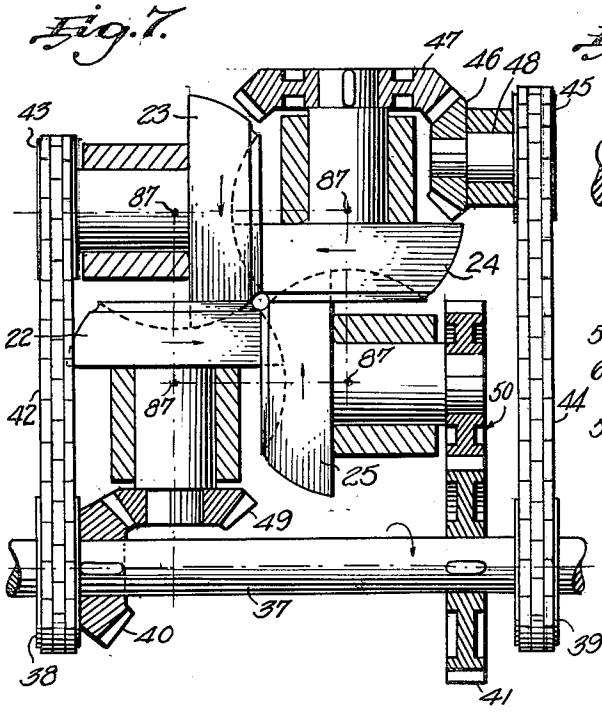


Fig. 8.

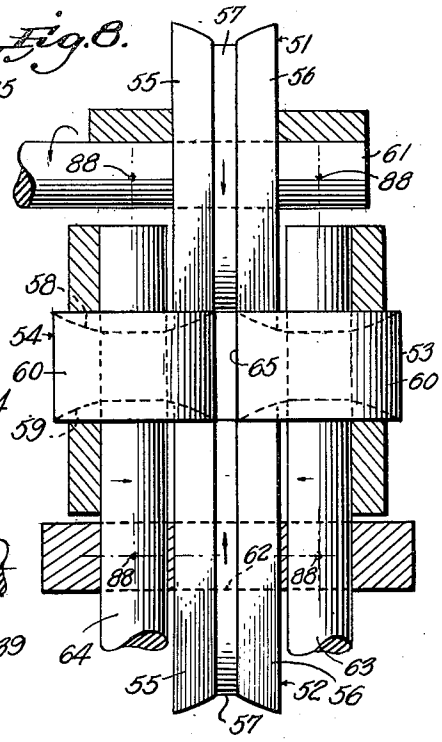


Fig. 9.

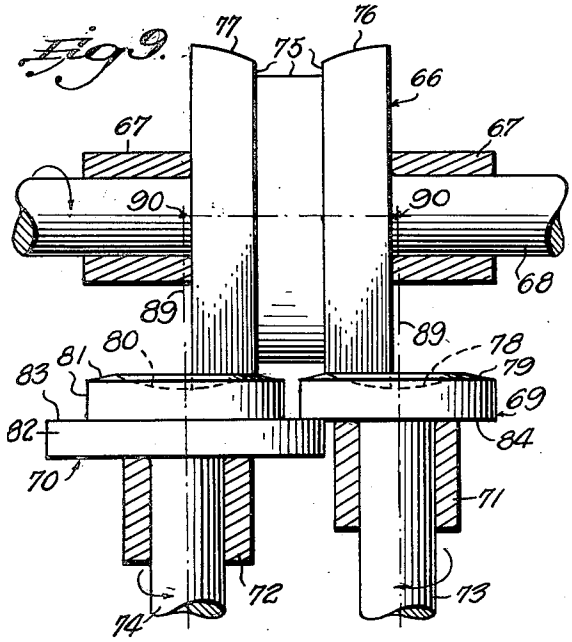
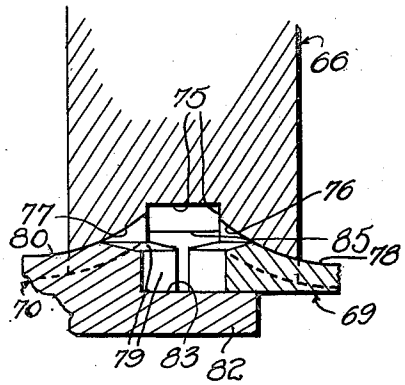


Fig. 10.



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Fig. 11.

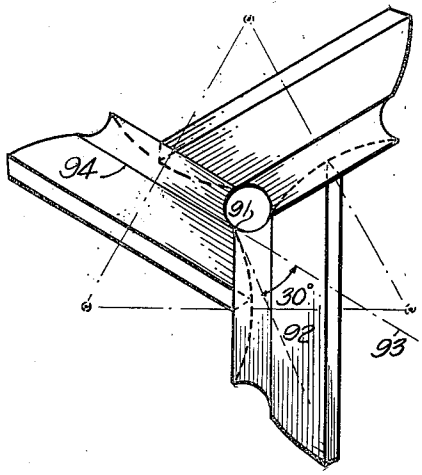


Fig. 12.

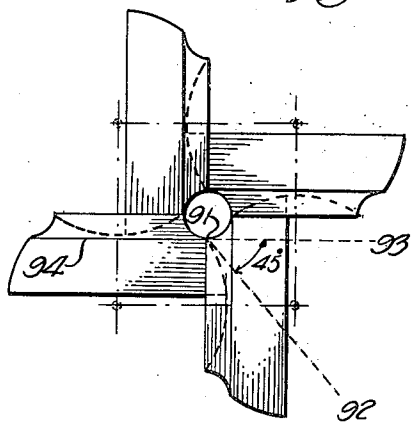


Fig. 13.

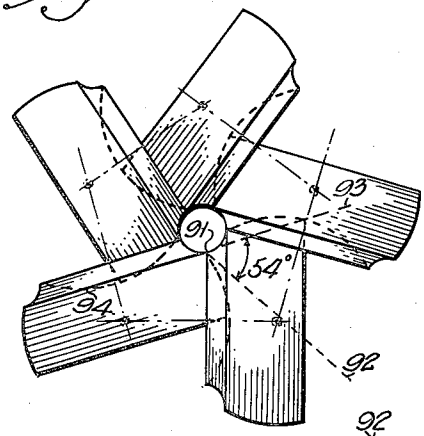
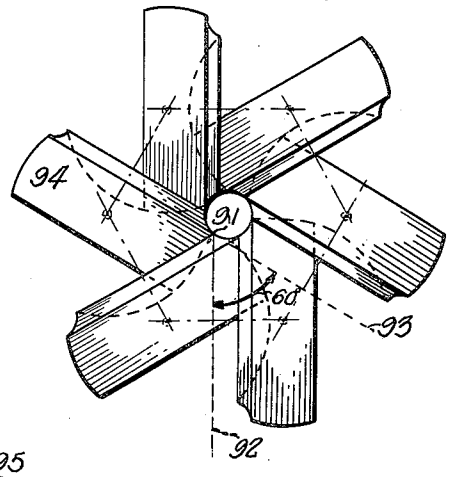


Fig. 14.



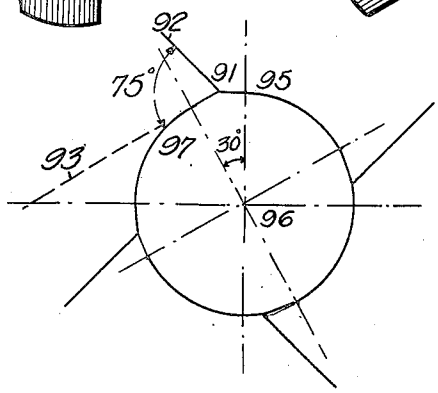


Fig. 15.

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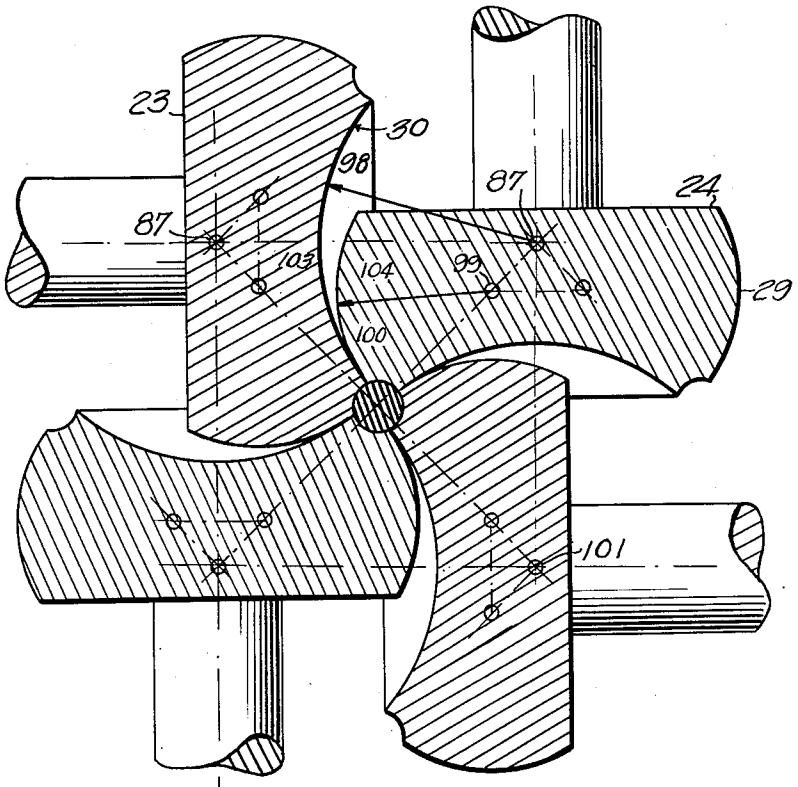
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FIG. 16



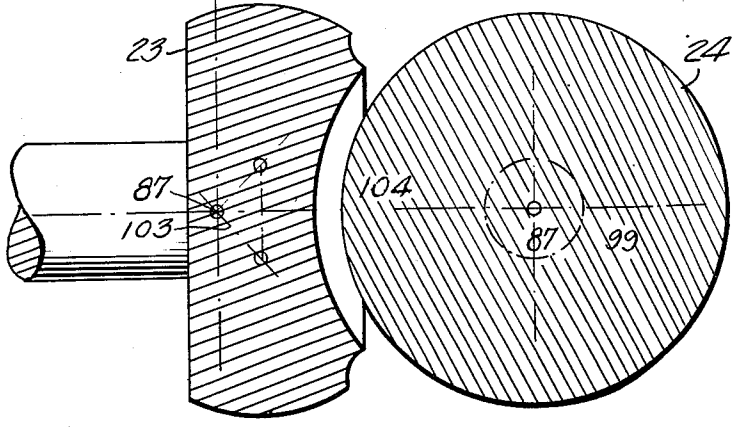


FIG. 17

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FIG. 18.

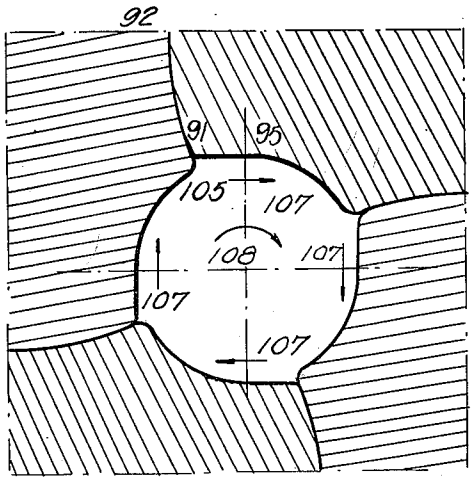
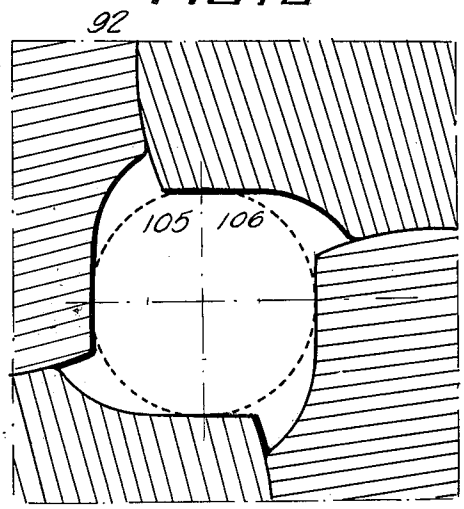


FIG 19



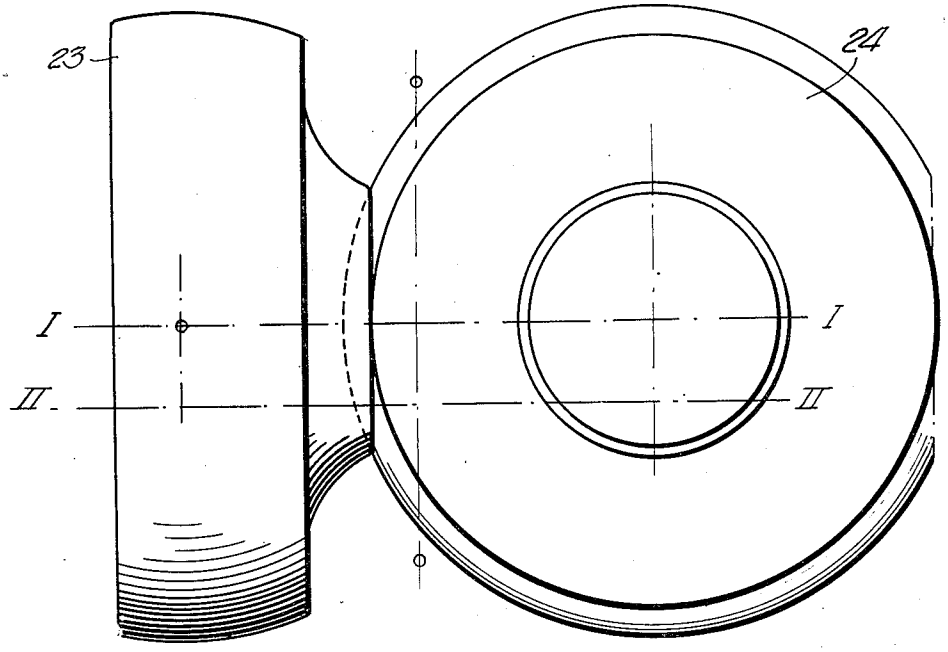


FIG. 20.

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FIG. 21.

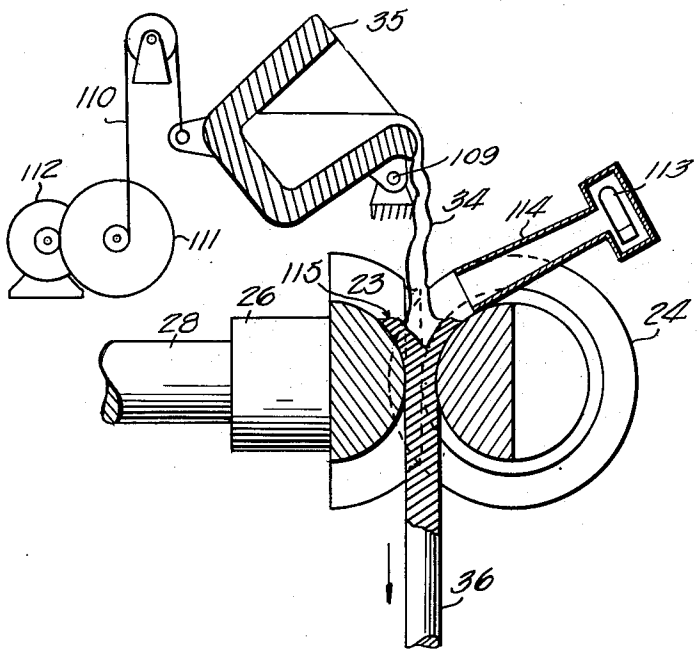
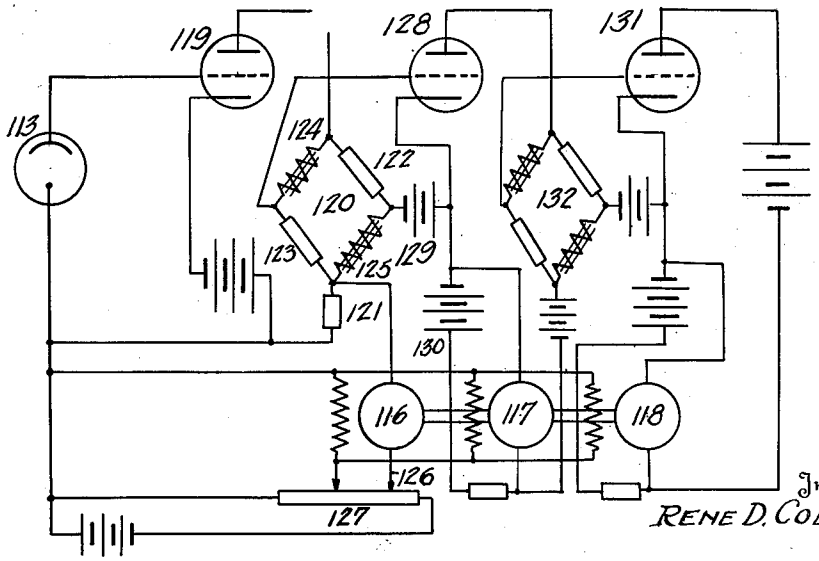


FIG. 22.



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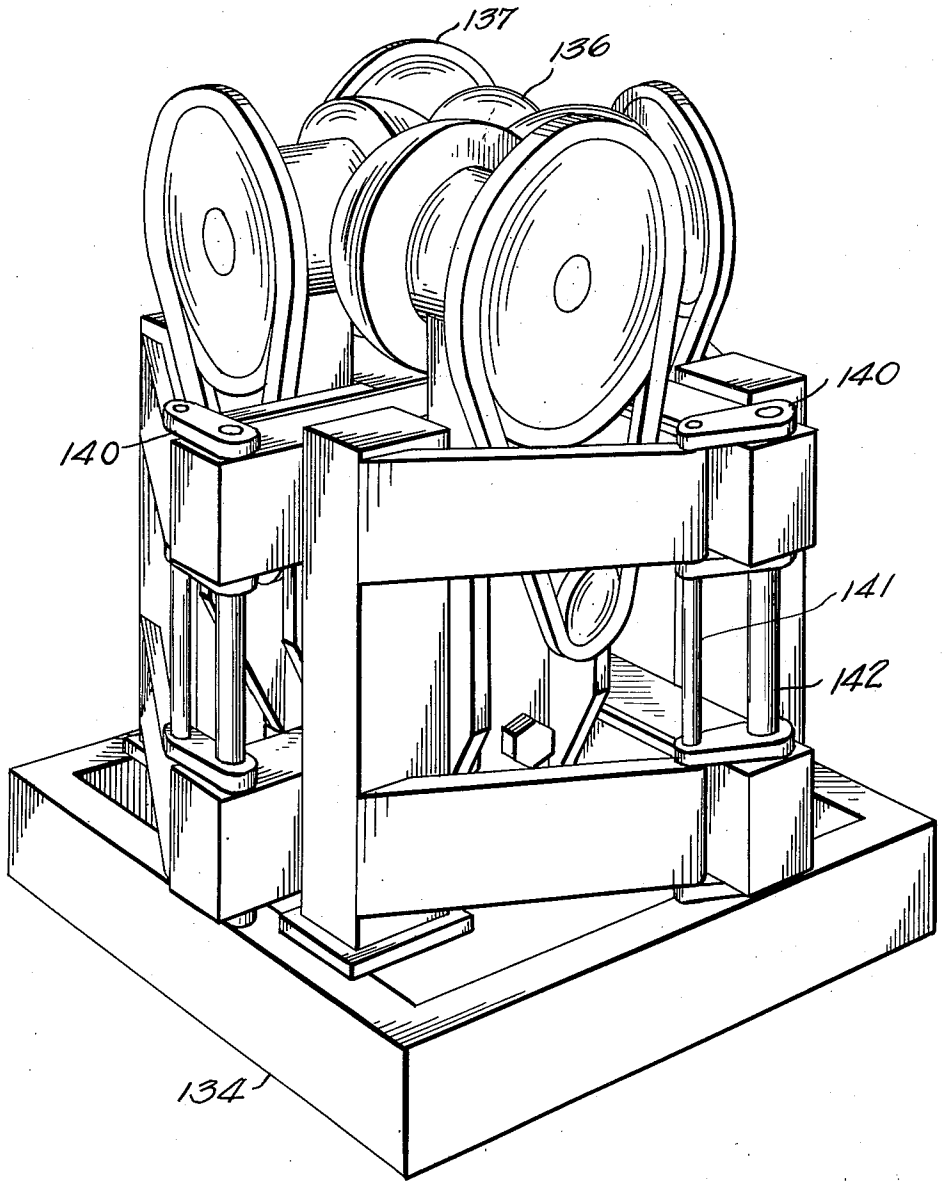
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FIG. 23.



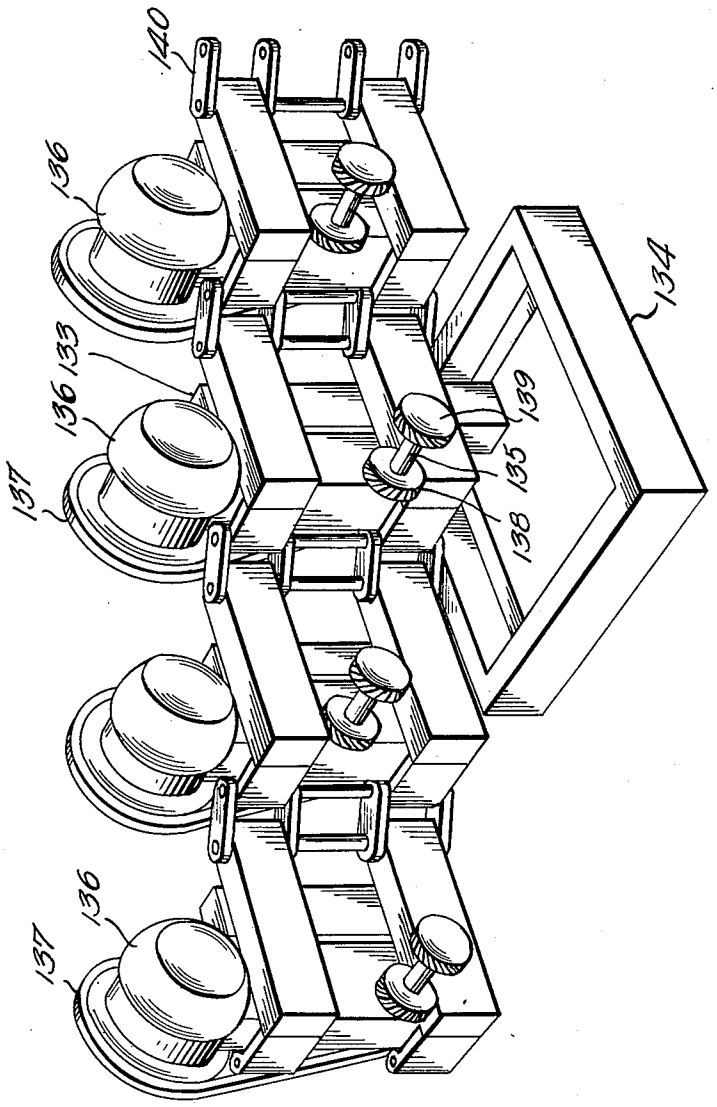
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FIG. 24.



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Patented July 15, 1952

2,603,114

UNITED STATES PATENT OFFICE

2,603,114

ENCLOSED ROLLING MILL

Rene D. Colinet, Philadelphia, Pa., assignor to La Soudure Electrique Autogene S. A., Brussels, Belgium, a Belgian company

Application March 21, 1945, Serial No. 583,887

2 Claims. (Cl. 80—34)

1

This application is a continuation-in-part of my copending application Serial No. 522,819, filed February 17, 1944, and now abandoned.

This invention relates to rolling mills of the type having forming rollers with cooperating spherical sealing surfaces and forming surfaces. It is therefore an object of the invention to provide the rollers with spherical sealing surfaces. A further object resides in profiling the rollers with forming surfaces to form a funnel in front of or preceding the final restricted configuration of the shape to be produced by the rollers.

Further objects will be apparent from the following description when considered with the accompanying drawings which show a number of preferred forms of the invention and in which:

Figure 1 is a top plan view of an enclosed mill according to the invention showing certain parts in section;

Fig. 2 is a vertical cross section of the mill of Fig. 1 taken on line 2—2 thereof;

Fig. 3 is a horizontal section of the central portion of the mill taken on line 3—3 of Fig. 2;

Fig. 4 is a top plan view of a modified construction;

Fig. 5 is a vertical section through the center of the cooperating rollers taken on line 5—5 of Fig. 4;

Fig. 6 is a horizontal section of the central portion of the mill taken on line 6—6 of Fig. 5;

Fig. 7 is a top plan view partly in section of the mill of Fig. 4 showing the drive connections;

Fig. 8 is a top plan view of another form of the invention for producing rectangularly-shaped bars;

Fig. 9 is a top plan view of a further modified mill for producing T-shaped bars;

Fig. 10 is a cross section of a portion of the rollers of Fig. 9 showing the cooperating rollers merging into the T-shape configuration;

Figs. 11 to 15 are diagrams pertaining to comparative rigidity of parts of the rollers subjected to pressure or strain.

Fig. 16 is a horizontal section of four rollers showing an example of non-rubbing sealing surfaces obtained by replacement of pure spherical surfaces by torus or ellipsoid surfaces;

Fig. 17 is a vertical section of the mill of Fig. 16;

Fig. 18 is a horizontal section taken on line I—I of Fig. 20;

Fig. 19 is a horizontal section taken on line II—II of Fig. 20;

Fig. 20 is a side view of the mill;

Fig. 21 is a vertical section through the center of the cooperating rollers;

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Fig. 22 is a wiring diagram of a photo-electric control system;

Fig. 23 is a perspective view of a modified mill in closed position; and

Fig. 24 is a perspective view of the mill of Fig. 23 in open position.

The invention is primarily directed to an improvement of the enclosed mill for use with hot or cold materials. By enclosed type is meant a mill wherein the rollers are so formed as to contact each other in the plane of the axes, leaving between them the shape of the product to be formed, which can be round, square, flat, tubular or any other cross section.

Whenever such enclosed rolling mill is used with a compressible material, that is, one which is soft or plastic enough to flow laterally when subjected to pressure, it is necessary to provide means to oppose such lateral flow, and to direct the material closely and as deeply as possible into the rollers. Otherwise, instead of reducing all of the material to the desired shape, the rollers may allow some of the material to spread laterally between them, and then would force this excess material into an edge or burr which would remain attached to the final product.

This difficulty becomes even greater with fluid materials which are supposed to solidify or coagulate in the rolling mill itself, such as hot liquid metals, certain plastics, compressible powders, quick-hardening pastes or mixtures, etc.

The means to oppose lateral flow or leakage between the rollers ahead of their contact plane, as referred to above, are usually stationary wedges filling in all gaps between the rollers, as far as they can possibly go toward the contact plane of the rollers. Such wedges become exceedingly thin and fragile at the very point where the pressure reaches its peak. Also they are unfit to withstand successfully both wear and heat action and they cannot be properly cooled. In all cases, they must be interrupted ahead of the tangent point of contact of the rollers, leaving a narrow gap unfilled between them, where lateral flow can still take place without restraint.

The provision of spherical sealing surfaces on the rollers themselves is designed to create supporting surfaces which oppose any lateral flow or leakage of the material, from a point far ahead of the contact plane of the rollers and where pressure is still non-existent or at least negligible, to the very center of the rolling mill where the material is forced into its final shape or configuration. Such a mill forms a funnel between the rollers, the inside walls of which are leak-

proof, yet move together toward the smaller orifice in a converging manner, thereby dragging the material along and forcing it through the outlet without any possible place of escape.

This result is obtained by assembling a number of rollers which, in addition to the usual shaping surfaces which join in the center to form the cross section of the final product, also have auxiliary surfaces which act as solid and tight walls all the way from a point ahead of where the material comes in contact with the rollers, to a point beyond where the finished product leaves the rollers after being shaped. To assure mutual contact between the rollers in all cross sections perpendicular to the direction of travel of the product, and not only in the axes plane as it would be the case for the rollers of known constructions, the following geometrical conditions must be fulfilled: at least three rollers must be used, the axes of which intersect in at least two points at a finite distance from the axis of the work; and any two adjacent rollers must have a common surface of mutual contact which is a sphere, the center of which is located at the junction of their respective axes of rotation. It is desirable, though not necessary, that these axes be located in the same plane, but the axes of adjacent rollers must always intersect. In a four-roller mill, for instance, with axes in different planes, the bight of two rollers diagonally opposed is at a level different from that of the bight of the other two rollers. Therefore, the product is first rolled in one direction across its longitudinal axis, and then, a little later but in the same rolling operation, in the direction perpendicular to the first one. This method of successive rolling in cross directions is similar to the standard practice of hot rolling of round bars and rods, and may be preferred in some cases. Rollers may, or may not, be identical. Each roller is provided with two separate spherical sealing surfaces extending to the forming or shaping surfaces.

Referring now to the drawings in which like reference characters refer to corresponding parts throughout, Figs. 1 to 3, 9 and 10 show three-roller mills and Figs. 4 to 8 show four-roller mills. Furthermore, the mill of Figs. 1 to 3 produces a bar having a hexagonal configuration, Figs. 4 to 7, a round configuration, Fig. 8 a rectangular configuration and Figs. 9 and 10 a T-shaped configuration. It is, of course, obvious that any desired shape can be produced as it is only necessary to appropriately contour the individual rollers.

The mill of Figs. 1 to 3 has three cooperating rollers **11**, **12** and **13** each rotatably mounted in a suitable bearing **14**. All three bearings are held rigidly in place by a sturdy frame not shown in the drawings. Each roller is a duplicate of the other two and includes a head portion **15** with a shaft **16** shown as being integral for simplicity. Each head portion **15** has two spherical sealing surfaces **17** and **18**, of which **17** is an end concave surface and **18** is an annular convex surface. Between these two spherical surfaces on each roller is the annular forming surface **19** of which for the hexagon configuration each roller will impress two sides. All three rollers are made to revolve around their respective axes, at equal speed and in a converging direction.

Fig. 3 illustrates how the rollers merge as a trough-like funnel **20** down to the ultimate configuration **21** in the form of the hexagon bar to be rolled. The spherical sealing surfaces **17** and **18** have exactly the same degree of curvature and the same diameter.

Figs. 4 to 7 illustrate an enclosed mill for producing round rods having four rollers **22**, **23**, **24** and **25** each rotatably mounted in a stationary bearing **26**. Each roller has a head portion **27** and an integral shaft **28**, and each head portion is provided with two spherical sealing surfaces **29** and **30** and the annular forming surface **31**. The two surfaces **29** and **30** of each two adjacent rollers cooperate with each other so that, as shown in Fig. 6, the annular surfaces **21** merge into the round configuration **32** from the trough-like funnel **33**. All rollers revolve at even speeds and in a converging manner.

Fig. 5 shows the liquid metal or plastic material **34** being poured from a crucible or container **35** into the funnel **33** formed by the head portions **27** of the rollers. The rolled rod **36** emerges from the bottom of the funnel after the revolving surfaces **31** have profiled and formed the solidifying material into the finished rod.

It must be observed that the spherical sealing surfaces have a sliding action against each other. They do not roll like gears meshing together. Therefore, any foreign matter like spatter from liquid metal, or any material particle that might adhere to the surface of the roller would not be pinched and flattened by the adjoining roller, but would be cleared away by the edge of that roller, in scraper-like fashion. This assumes, of course, that the particle has not welded itself deep into the roller by melting it below its surface. For that reason, any liquid steel being poured in a mill made of steel or iron rollers should never be overheated to such extent that spatter from it would be hot enough to melt the rollers locally. The rollers should be maintained as cool as possible through artificial cooling, for instance by a water jet or spray underneath the mill, directed toward the product and the rollers alike.

This sliding action of the spherical sealing surfaces requires that adjacent rollers revolve smoothly against each other, without appreciable clearance, but also without excessive pressure. Play would allow leakage, while pressure would mean undue wear or abrasion. It is preferable to build the rollers of a tough, wear-resisting material, such as a properly heat-treated tool steel, also to grind them smoothly and exactly after heat treatment, and above all to secure enough rigidity in the bearings and their supporting frame to eliminate relative motions under internal strain due to compression of the material in the mill. Means of fine adjustment of the bearings in all directions should be provided to bring the spherical surfaces in good contact, yet without excessive pressure, when assembling the mill, and also compensating for possible heat distortion by proper cooling, take-ups or releases, etc. Rollers should be easily removable from their shafts, for quick change when worn or for replacement of different shapes or sizes.

The rollers are self-lapping, and the quality of their contact improves with usage. The reason for this, is that the sliding action, therefore the wear, is greater at the periphery of each roller than it is near the annular forming surface, where the best contact is required because of higher pressure. At and near the neck of the mill, all surfaces travel practically together, parallelly and at the same speed, therefore with minimum friction and wear. The convex outer spherical surfaces and the forming surfaces are the only ones coming in contact with the material.

The concave central spherical surfaces never touch it. They should however be protected against spatter or other stray particles by the use of convenient guards.

As outlined above, it is obviously difficult to maintain the rollers in good sealing contact, and yet to avoid at the same time pressure between them. One method of overcoming this difficulty consists in a slight alteration of one or both of the sealing surfaces, so that they will contact each other under relatively high pressure only in the region close to the center of the mill, where the relative motion of the rollers is substantially a rolling action, exempt from sliding or pivoting friction. In all other regions where such sliding or pivoting occurs, the sealing surfaces are no more in contact, but remain close enough so that surface tension in case of liquids, and particle size in case of powder or fibres, will prevent any introduction of material in the narrow gap between the sealing surfaces.

Fig. 16 shows by way of example how such result may be practically obtained. This figure is a horizontal section on the plane of the axes of the roller in a mill as shown in Fig. 4, while Fig. 17 is a vertical section through the same mill on the axial plane of roller **23**. The internal or concave surfaces **30** of all rollers remain unchanged. They are purely spherical with center **87** and radius **87—98**. By the external or convex spherical surfaces **29** of all rollers have been replaced by torus surfaces. One of them is defined by a portion of circle of radius **99—100** and center **99** rotating around axis **87—101** while remaining rigidly attached to that axis. In the position shown, center **99** is on a straight line with **87** and the center of the mill, and at such distance from axis **87—101** as defined by the quantity: clearance/$(\sqrt{2}-1)$. By "clearance" is meant the distance considered desirable between the rollers, measured as **103—104** on axis **87—87** of roller **23**. In case of steel casting, a fair and satisfactory value of the clearance is $\frac{1}{64}$ inch to $\frac{1}{32}$ inch.

From the vertical section, Fig. 17, it can readily be seen that the clearance is constant in each vertical section parallel to axis **87—87**, although it gets smaller from one vertical plane to another when approaching the center of the mill. This is as it should be, since the pressure exerted by the rollers on the material increases toward that region, and also because the relative motion of rollers **23** and **24** becomes more and more a slideless rolling nearer to the center of the mill. Near the very center, positive contact is obtained between the rollers which can now be actually pressed hard against each other. They will not separate, regardless of the flexibility of the bearings and their supporting frames, as long as the operating pressure on the product remains inferior to the pre-set pressure put on the rollers during assembly.

A similar result would be obtained, either by the use of an ellipsoid of revolution defined by an ellipse rotating around its longer axis **87-101**, or by a roller having a narrow portion of spherical sealing surface, adjacent to the forming grooved surface, and followed by a wider spherical quasi-sealing surface of same center, but with a slightly reduced radius.

It is obvious that the shafts of the rollers can be driven by any suitable means. Preferably, all rollers should be power-driven at equal peripheral speed, measured on the annular forming surface. Sometimes, however, idler rollers are acceptable, as in Fig. 8. Fig. 7 illustrates various details of one way for driving the rollers **22** to **25**. As shown, the main shaft **37** is driven by any suitable means such as a motor, not shown. Two sprocket wheels or pulleys **38** and **39**, bevel gear **40** and pinion **41** are mounted to rotate with and on the shaft **37**. Sprocket wheel or pulley **38** drives a chain or belt **42** which in turn drives a sprocket wheel or pulley **43**, the latter being mounted to rotate the shaft of the roller **23**. Also sprocket wheel or pulley **39** drives a chain or belt **44** which drives a sprocket wheel or pulley **45**. This wheel **45** drives the shaft of the roller **24** through the intermediary of bevel gears **46** and **47** and shaft **48**. Bevel gear **40** meshes with a bevel gear **49** secured on the shaft of the roller **22**. Pinion **41** drives another pinion **50** secured on the shaft of the roller **25**. All drives are proportioned to insure equal speed of rotation for all four rollers. As shown in Fig. 7 the shaft **37** rotates in the direction of the arrow which will impart a direction of motion to each of the rollers as indicated by the arrows so that they shall all rotate toward the funnel and forming center for the bar to be produced. Another way, shown in Figs. 23 and 24, of driving the rollers would involve four auxiliary shafts forming a square around the mill, connected together through bevel or spiral gears. Each one of these shafts, in turn, would operate its corresponding roller through a chain drive or a pair of spur gears.

A particularly preferred form of mill frame consists in a number of panels, equal to the number of rolls, which are hinged to each other like a multiple panel door. Each panel holds one roll, its bearings, drive and accessories. To open the mill, for inspection, cleaning or roll-changing purposes, it is only necessary to remove one of the hinge-pins and to spread the panels open, without losing in that operation any of the fine adjustments which have been made to bring the rolls in proper contact with each other in a previous assembling. Fig. 23 illustrates this design in the case of a four-roll mill, shown closed and ready for operation. Fig. 24 represents the same mill as opened for inspection. One of the panels, marked **133** in Fig. 24, is rigidly affixed to the base **134**. Its shaft **135** extends backwards where it is driven by a motor, not shown, preferably through a speed variator. The corresponding roll **136** is operated by a chain drive **137**. That same shaft **135** holds two spiral gears **138** and **139**, which will mesh at 90 degrees with similar gears on the other panels, when the frame closes. This type of gears permit slight relative displacements of the shafts as long as they remain at right angles. When in mesh, all four rolls revolve together at identical speeds, from the outside drive on shaft **135**, through the spiral gears, the other shafts and the chain drives.

A further improvement consists in using hinge-pins which are eccentric in design, and which are interconnected so as to rotate with equal angular motion. By rotating these pins through a single drive, all panels move slightly toward the center of the mill, or away from it, in a perfectly concentric or symmetrical manner. In Figs. 23 and 24, the panels are connected through links **140** with a straight pin **141** on one side and an eccentric pin **142** on the other side. Rotating the eccentric pin is equivalent to changing the length of linkage **140**. A guiding slotted arm, not shown, rigidly attached to the panel at right in Fig. 23, compels the straight pin **141**

to move only at right angle to the roll axis of the panel at left in Fig. 23. If that condition is filled, and if simultaneous and equal rotation is applied to all four eccentric pins, through a single crank or lever with suitable connections not shown, all rolls will move together towards the center or away from it, equally and symmetrically. This not only enables to adjust the pressure on all rolls at the same time, in order to compensate for progressive wear, but it also permits to use various sets of rolls with slightly different diameters, provided all rolls in each particular set remain identical in size. Such would be the case, practically, for rolls which have been re-dressed after wear. Re-dressing a set of rolls consists in machining or grinding all outside convex sealing surfaces to a diameter slightly smaller than the original one, and doing the same to the inside concave surfaces. Since the inside concave sealing surfaces must be reduced in diameter to the same extent as the convex ones, the re-dressing operation requires of necessity a transfer of the centers of the sealing surfaces toward the shaft end of each roll. Re-dressing while keeping the centers where originally located would wrongly result in a reduction of the diameter of the convex surfaces, and in an increase of diameter for the concave surfaces, destroying the good mating of adjacent rolls. The displacement of the centers in each successive re-dressing depends on the depth of metal to remove from the sealing surfaces, and should best be determined from a full-size drawing. The distances between both centers (convex and concave sealing surfaces) of each roll are also reduced in a re-dressing operation, in proportion with the reduction of diameters. Therefore, the polygon of the rolls' axes in the mill also becomes smaller with each re-dressing, although this polygon remains unchanged in shape or symmetry.

The panel-type mill frame, with its inter-related eccentric hinge-pins, precisely provides for such contraction of the polygon of the axes, and accommodates for a number of sets of rolls, differing in dimensions from set to set, but not within each set. No modification is required to the fine adjustment originally made to position the first set of rolls correctly in the mill. The simplified procedure to change rolls includes the following steps: first, release all roll pressure by moving all panels away from center, through a single drive lever or crank; then remove one of the hinge-pins and spread the panels open. Unfasten all rolls and fasten the rolls of the new set. Close the panels, re-engage the hinge-pin and apply pressure through the lever or crank.

In the forms of the mill shown in Figs. 1 to 7 all of the rollers of each mill are identical as to size and shape. It is, however, possible to have different sizes and shapes of forming rollers in the mill as, for instance, shown in Fig. 8 which has two larges rollers **51** and **52** and two smaller rollers **53** and **54**. Each of the rollers **51** and **52** has two spherical sealing surfaces **55** and **56** with a cylindrical surface **57** between the two. Each of the rollers **53** and **54** has two side spherical sealing surfaces **58** and **59** and a cylindrical peripheral surface **60**. Suitable shafts **61**, **63** and **64** drive and rotate the respective rollers **51**, **53** and **54** in directions indicated by the arrows and at substantially equal peripheral speed, while roller **52** revolves as an idler around stationary shaft **62** which is eye-shaped at the ends to permit passage of shafts **63** and **64**.

The form or configuration of the bar produced in the mill shown in Fig. 8 is indicated at **65** which shows the actual forming or pressing contour for the work as confined by the surfaces **57** and **60**.

The mill of Figs. 9 and 10 is designed to produce a profiled bar of approximately T shape. This mill has a main roller **66** rotatably mounted in bearings **67** by means of a drive shaft or shafts **68**. Two auxiliary rollers **69** and **70** are rotatably mounted in bearings **71** and **72** respectively by means of drive shafts **73** and **74** respectively. The roller **66** has annular forming surfaces **75** and annular spherical sealing surfaces **76** and **77** one on each side of the surfaces **75**. The roller **69** has an end spherical sealing surface **78** and annular forming surfaces **79**. The roller **70** also has a similar end spherical sealing surface **80** and similar annular forming surfaces **81**. Roller **70** however has an integral annular abutment flange **82** of which the side or forming surface **83** abuts and contacts a side surface **84** of roller **69**. All three rollers are made to revolve at substantially equal peripheral speeds. Fig. 10 shows the ultimate T shape **85** produced by the merging surfaces **75** and **79** together with surface **83**.

In Fig. 1 the axes of adjacent rollers **11** to **13** intersect in points **86** which are also the centers of the spherical surfaces **17** and **18**. The shaping surfaces **19** are surfaces of revolution generated by a portion of the cross section of the product revolving around the axis of the corresponding roller.

In Figs. 4 and 7 the axes of adjacent rollers **22** to **25** intersect in points **87** which are the centers of the spherical surfaces **29** and **30**. In Fig. 8 the axes intersect in points **88** which are the centers of the spherical surfaces **55**, **56**, **58** and **59**.

If and when the axes of two adjacent rollers are parallel as axes **89** in Fig. 9, their corresponding point of intersection is at infinity and the common spherical surface becomes a plane surface **83** and **84** perpendicular to these axes **89**. The points **90** are spaced and accessible but the other point is at infinity. The exact radius of the sphere, or the exact location of the plane when the point of intersection is at infinity, is imposed by the geometrical condition that the sphere or plane must contain the point where the shaping surfaces of the corresponding rollers meet in the plane of the axes of these rollers. For instance, in Fig. 6, the spherical surfaces **29** or **30** contain point **91** where forming surface **31** of roller **23** meets forming surface **31** of roller **22**.

At the junction of the annular forming surface with the spherical sealing surfaces, the rollers present a sharp edge. The mechanical strength of that edge under pressure or strain from the compressed material can be measured by the angle between the tangents to both profiles meeting at the edge considered. In Fig. 3, such angle would be **92—91—93** for one edge, and **92—91—94** for the other edge. For constructive reasons, it is obvious that these angles should be as large as possible, and in no case smaller than 30 deg. for soft compressed materials, and 45 deg. for hard materials, with preferred values at or above 75 deg.

This condition will be a decisive factor in the choice of the number of rollers with respect to the desired shape of the product. A three-roller mill is particularly well adapted for hexagon shapes because, as Fig. 3 shows, angle **92—91—93** is 90 deg. while angle **92—91—94** is 150 deg. Such three-roller mill, however, would not be recommended for a circular shaped product because, as

Fig. 11 shows, angle 92—91—93 would be only 30 deg. Figs. 12, 13 and 14 indicate that this angle for a circular shape becomes 45 deg. for a four-roller mill, 54 deg. for a five-roller mill, and 60 deg. for a six-roller mill. Through a slight modification of the circular shape, as shown in Fig. 15 where short sections of the circle are replaced by tangents, it is possible to add to any of the 92—91—93 angles an increase equal to angle 95—96—97, for which a preferred value would be 30 deg., thus obtaining 60 deg., 75 deg., 84 deg., and 90 deg. for 3, 4, 5, and 6 rollers respectively.

This alteration of the circular shape has another important function, which becomes apparent in Figs. 18 and 19 showing the rollers, first when completely closed in the center of the mill; second, after they have started to disengage themselves from the rolled product, a little below center. It will be noted that opposite rollers move outwardly and parallelly as indicated by the arrows 107. The plane surface 91—95 in each roller, therefore, moves in its own plane, forcing the product to rotate clockwise as shown by arrow 108. In that motion, the excess material of the triangle 91—95—105 in Fig. 18 is rolled down transversely to the correct circular shape 105—106 in Fig. 19.

The advantages of this design are self-evident: a perfectly circular shaped product is obtainable although the rollers are given a non-circular shape at the bight, in a view to reinforce the mechanical strength of their edges. Another advantage is that the product is positively guided out of the mill by parallel planes. It will therefore be delivered perfectly straight and could not adhere to any roller in particular.

The rotation of the product combined with the longitudinal motion of the wire, result in a continuous twisting or helical motion of the product. Such motion may either be neutralized, or it may be preserved.

In the first case, it will only be necessary to reel the product in a stationary reeling device, and the wire will untwist itself after leaving the mill, while still in a plastic stage. In the second case, the twist can be preserved all along the product by giving the reeling device a continuous rotation around the axis of the wire or rod, in such direction and at such speed as to correspond to the rotation of the rod shown by arrow 108. Any burr or marking will then appear as a helix all along the wire which is a decisive advantage when subsequent cold drawing operations are involved, because of a more even wear of the dies.

Figs. 3, 6 and 10 actually illustrate the funnel created by the forming surfaces of the rollers. There are no open gaps in the funnel and thus no leakage of metal or plastic when used in the fluid state. It is not only possible to use the mills for metals in molten, hot or cold state but for quick-setting fluids and substances or plastics as well as for compressing fibers or powders. The products produced by the mills are in the shape of bars and slabs of any rollable cross section and indefinite length.

When used with hot liquid metal or alloy, these mills can operate either as a continuous mould, or casting machine, or as a regular rolling mill. In the first case, the metal would be permitted to cool just enough to acquire sufficient cohesion to hold itself together in bar form under the mill, where it would be cooled subsequently by water spray or otherwise. Very little pressure would be imposed on the machine in that case, ensuring little wear and low power consumption. In the second case, the cooling would be more pronounced, and the material would come out under appreciable side pressure from the rollers. Some pre-cooling could be provided also by provision of a refractory tube standing above the mill and shaped at the bottom to contact the rollers without excessive clearance. In such a case, hot metal poured in the tube would set or solidify partly in hot ingot form which, in turn, would be worked by the mill and rolled to the final shape. This process could be continuous, the ingot being fed at the top while dropping steadily toward the mill. Any of the above-mentioned products could be re-rolled or otherwise treated.

Means of feeding hot metal at constant level, either in the mill itself, or in the tube, should be provided. With light-emitting fluid metals, like steel, photoelectric devices could maintain a correct flow, while pyrometric or mechanical feelers would operate better on dark metals like lead or other low melting alloys and for pastes or plastics. The mills can also be used as frictionless outlet dies for extruding presses, being either power-driven or idle, with or without the usual central core or mandrel for tubular or hollow shapes or for covered wire, cables and welding electrodes sheathed with a protective coating.

Ladles with a bottom-pouring nozzle are preferred because of the length of the jet of liquid metal, measured between the nozzle and the spherical rolls, can be held short and vertical regardless of the size of the ladle. Also, such jet will respond immediately to any motion of the stopper, in increase or decrease of the output, under control of photoelectric or other devices depending upon the level of the liquid bath between the rolls of the mill.

Greater steadiness and stability of that level can be achieved if the servo-motor acting on the stopper of a bottom-pouring ladle, or on the tilting of a top-pouring ladle, is made to be sensitive, not only to the level of liquid metal between the rolls but also to the first derivative of that function, namely the speed by which such level rises or lowers. In cases of extreme inertia (heavy ladle of the tilting type), it may be indicated to render the servo-motor sensitive also to the second derivative of the level function, namely the rate of acceleration or deceleration of its variation or, in other words, the variation of the speed by which such level changes. This method is highly effective in the prevention of "hunting" around the position of ideal equilibrium, and in reducing the magnitude of the deviations from the optimum level.

Figure 21 shows a photo-electric control system for a tilting ladle, also adaptable to a bottom-pouring ladle or furnace. The ladle 35 is hinged at the lip 109 and its bottom is raised by a cable 110 pulled by a winch 111 driven by one or more electric motors 112. A photo-electric cell 113, fitted with a cone-shaped visor 114, receives the light emitted by the bath of molten steel 115 laying between the rolls of the mill. The higher the level of that bath, the wider the bath, the more light emitted and the greater the current generated by the cell. This current is amplified and automatically analyzed as shown in Fig. 22, by way of example only. Three direct current electric motors 116, 117 and 118 are used, all mechanically coupled to the same shaft 112 in Fig. 21. All three have independent magnetic

fields of adjustable intensity. Speed variation and reversal of torque are obtained through variation or reversal of the armature currents, the combined torque of all three motors acting on winch 111.

The current generated by photo-cell 113 is first amplified by a triode 119 and then sent through a Wheatstone bridge 120 before energizing motor 116. All four branches of the bridge have equal ohmic resistance, but two of them, 122 and 123, are strictly non-inductive resistors, while the other two 124 and 125 are coils with a high coefficient of self-induction. The armature of motor 116 is connected between the junction point of bridge 120 and resistor 121, and an adjustable contact 126 on potentiometer 127. This contact is positioned to nullify the voltage applied to motor 116 when the level of bath 115 is normal. The ladle 35 will be raised and the flow of metal 34 increased if the level is subnormal, or the ladle will be lowered and the flow decreased if the level is over-normal with, however, a double corrective action from motors 117 and 118. Motor 117 is connected, through amplifying triode 128, to junctions 123—124 and 122—125 of the bridge 120. These points are at equal voltage for any current emitted by triode 119, as long as that current does not vary. But if it does, the retarding effect of coils 124 and 125 results in a temporary unbalance of bridge 120. Motor 117 will tend to increase the metal flow 34 when the bath 115 is going down, regardless of its position. Inversely, it will tend to reduce the flow when the level is going up.. Similarly, motor 118 is made sensitive to the variation only of the current emitted by triode 128, by the use of a triode 131 and a second Wheatstone bridge 132 identical to the first one. This motor 118 will tend to increase the flow of metal 34 when the downward speed of the level 115 is increasing, or the upward speed decreasing. It will reduce that flow if the downward speed of the level decreases, or the upward speed increases. In order to render both motors 117 and 118 responsive to positive as well as negative unbalance of bridges 120 and 132, despite the unidirectional properties of triodes, some compensating device must be used, for instance a polarizing battery 129 in the grid of triode 128, the effect of which is exactly compensated when the bridge 120 is balanced, through another polarizing battery 130 shunting motor 117.

I claim as my invention:

1. A rolling mill comprising at least three rollers each rotatably mounted in sealing contact with one another having sealing and forming surfaces and all rotating at substantially equal peripheral speed in a converging direction, said rollers having their axes of revolution in a common plane and forming a funnel-shaped opening closed on all sides, each roller having a concave sealing surface of revolution closely enveloping a corresponding convex sealing surface of revolution of the adjacent roller, and said two surfaces intersecting the plane of the axes of the rollers along two distinct curves tangent to each other where they join the forming profile of the rollers and then extending outwardly in close conformity, but progressively diverging slightly from each other.

2. A rolling mill comprising at least three rollers each rotatably mounted in sealing contact with one another and all rotating at substantially equal peripheral speed in a converging direction, each roller having a concave sealing surface of revolution closely enveloping a corresponding convex sealing torus surface on the adjacent roller, said two surfaces intersecting the plane of the axes of the rollers respectively along a curve and a circle tangent to each other where they join the forming profile of the rollers, and then extending outwardly in close conformity, but progressively diverging slightly from each other.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,431,443	Cowles	Oct. 10, 1922
2,246,907	Webster	June 24, 1941
2,290,176	Garand	July 21, 1942

FOREIGN PATENTS

Number	Country	Date
181,562	Great Britain	June 22, 1922
517,871	Great Britain	Feb. 12, 1940