

Feb. 15, 1938.

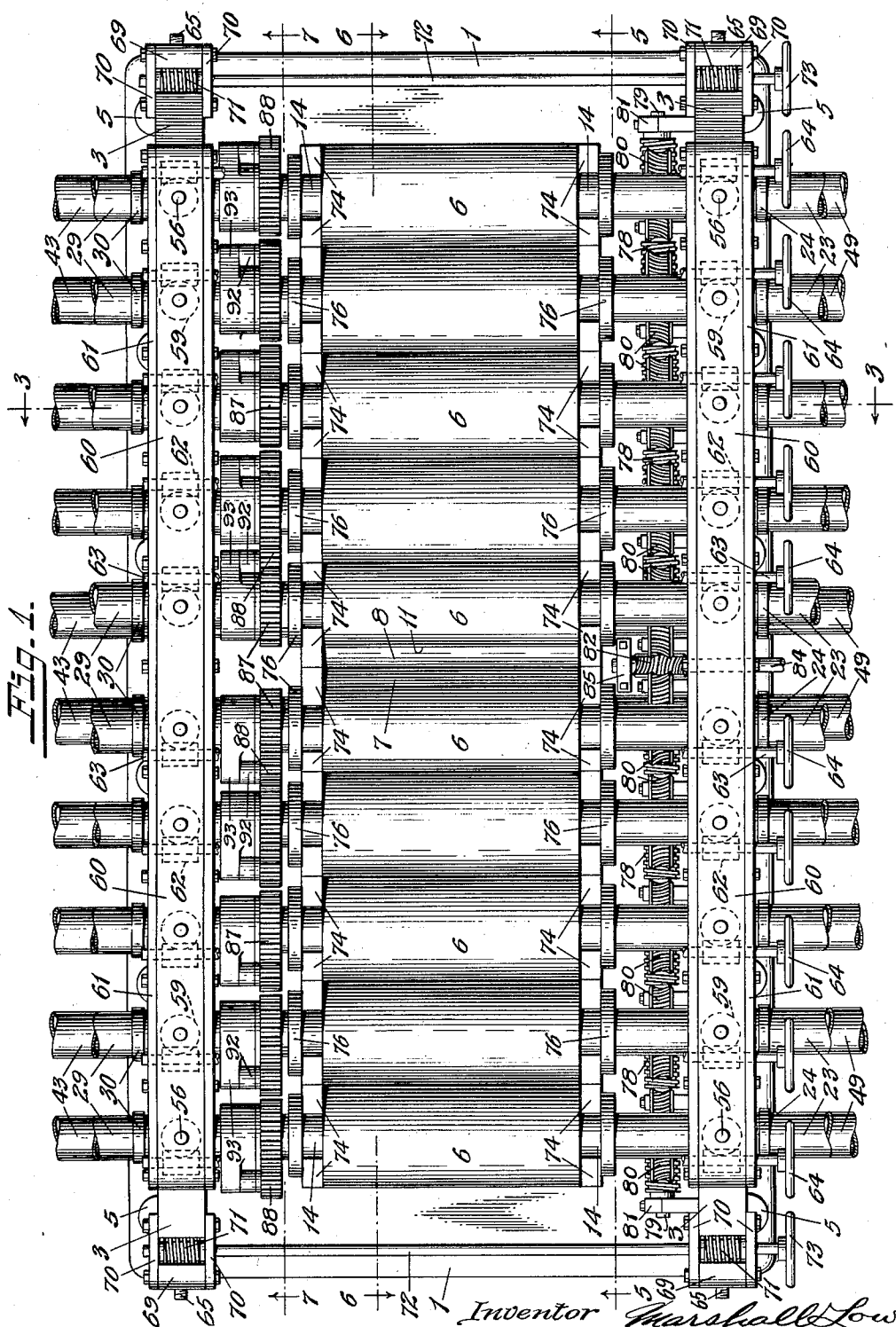
M. LOW

2,108,753

METHOD OF AND APPARATUS FOR SHAPING METAL DELIVERED IN A MOLTEN CONDITION

Original Filed July 9, 1934

6 Sheets-Sheet 1



Feb. 15, 1938.

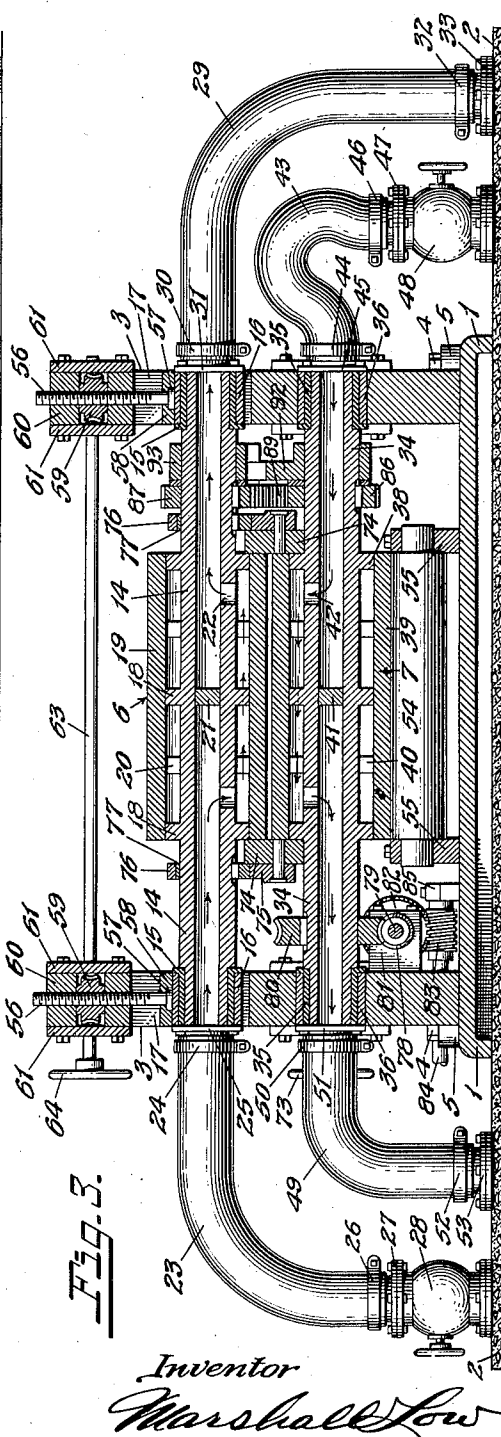
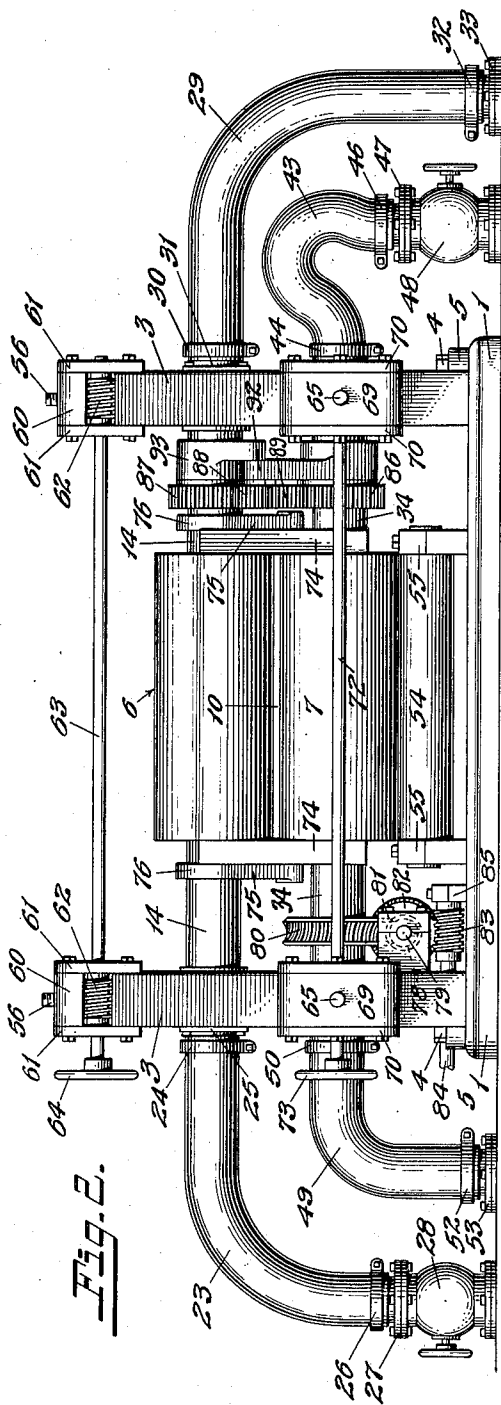
M. LOW

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METHOD OF AND APPARATUS FOR SHAPING METAL DELIVERED IN A MOLTEN CONDITION

Original Filed July 9, 1934

6 Sheets-Sheet 2



Inventor
Marshall Low

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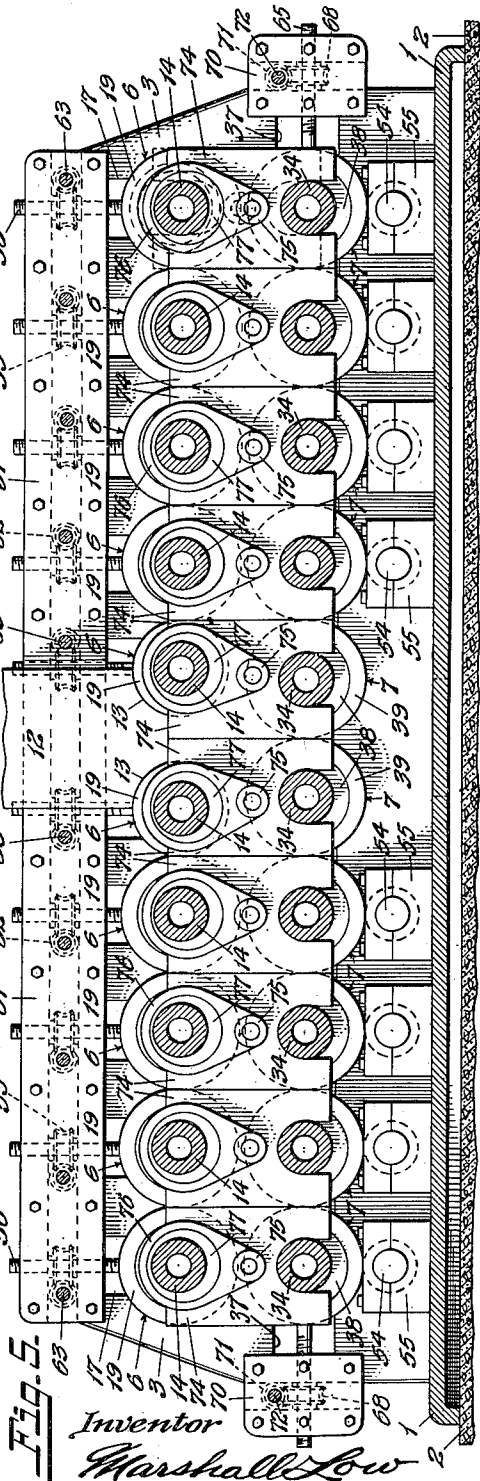
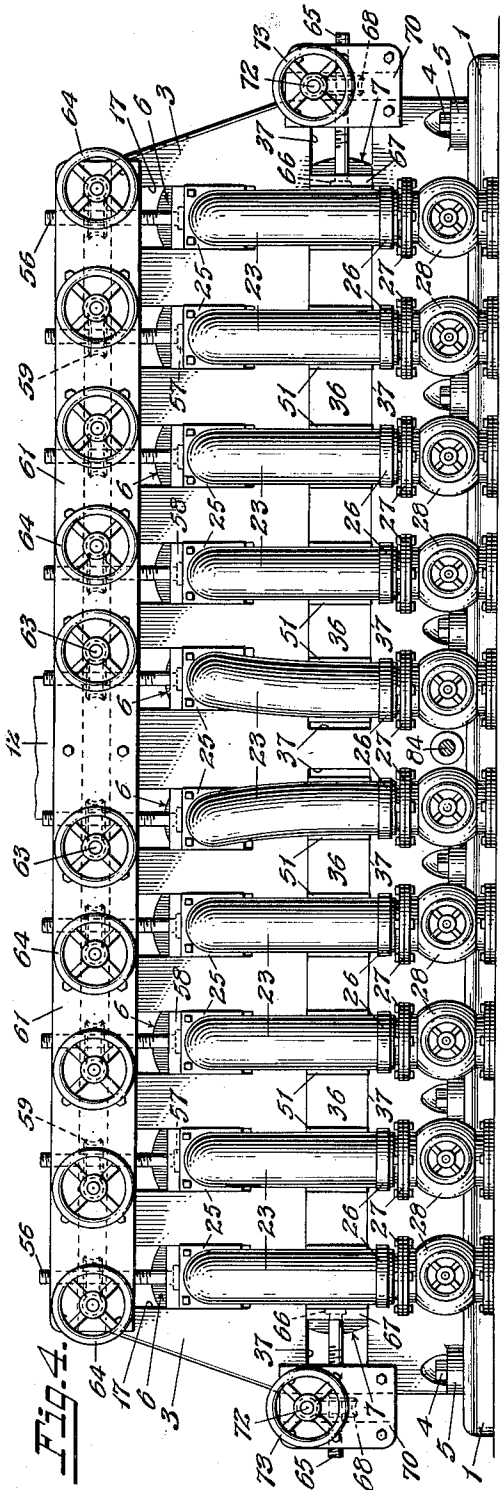
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METHOD OF AND APPARATUS FOR SHAPING METAL DELIVERED IN A MOLTEN CONDITION

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6 Sheets-Sheet 3



Inventor
Marshall Low

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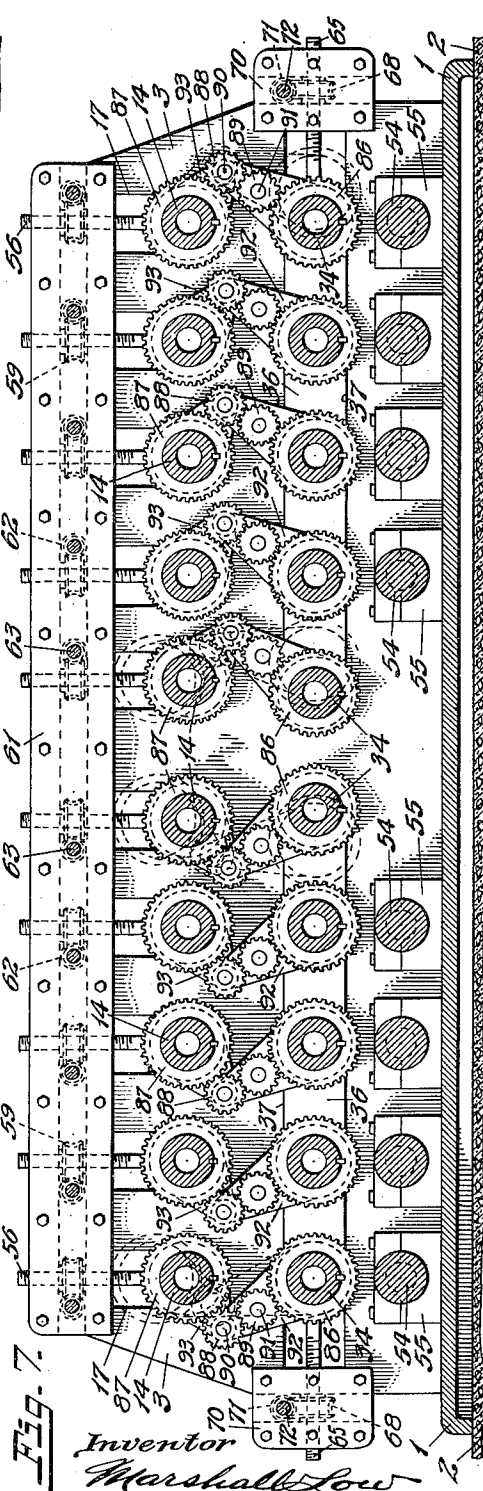
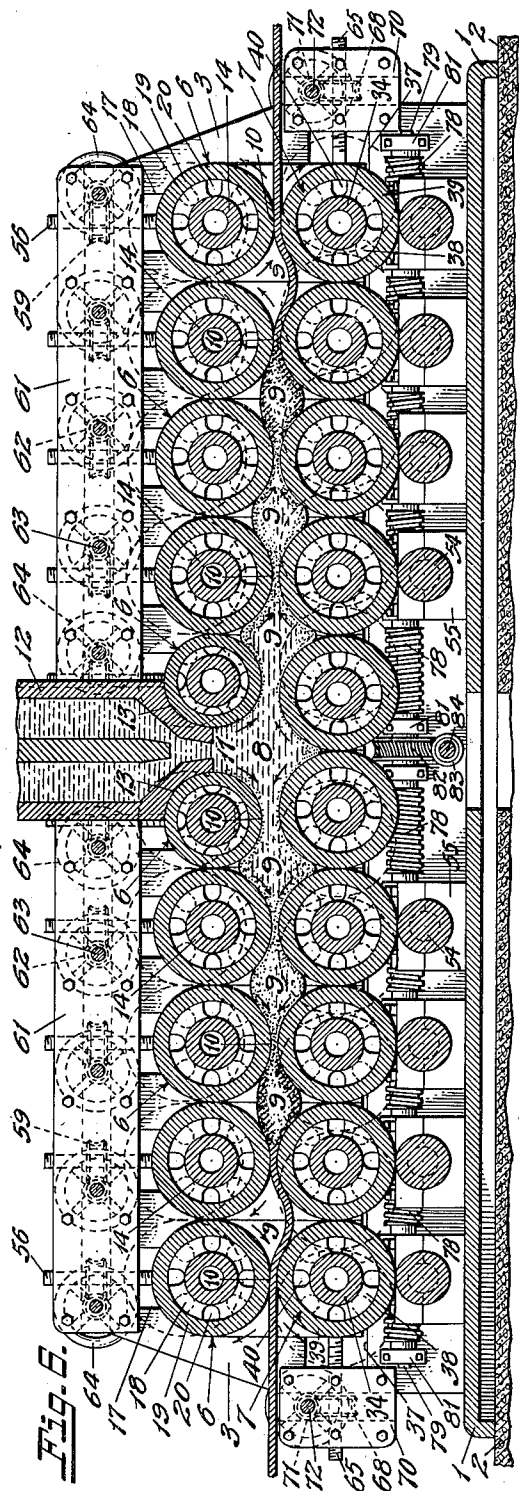
M. LOW

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METHOD OF AND APPARATUS FOR SHAPING METAL DELIVERED IN A MOLTEN CONDITION

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6 Sheets-Sheet 4



Inventor
Marshall Low

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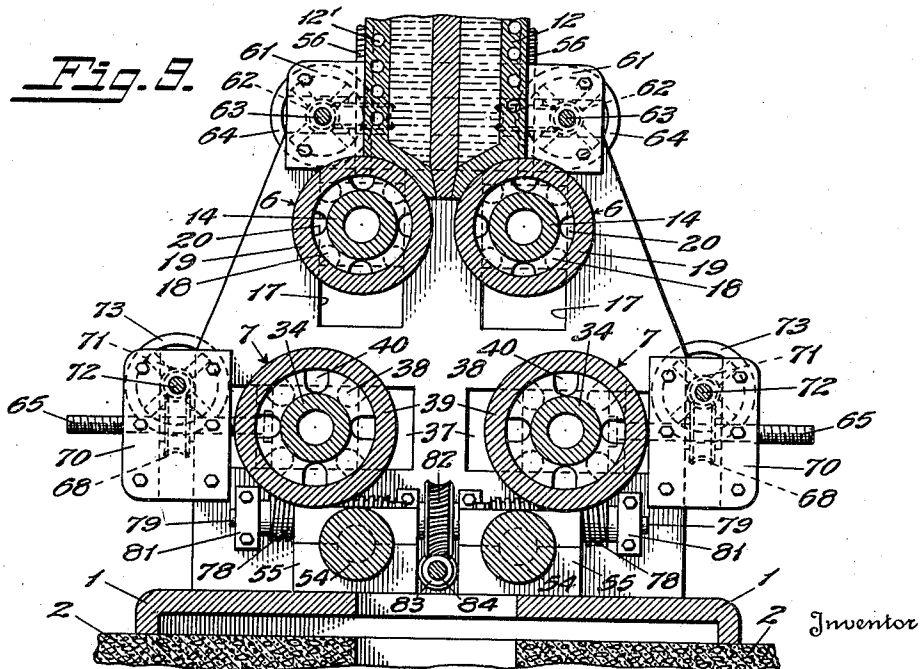
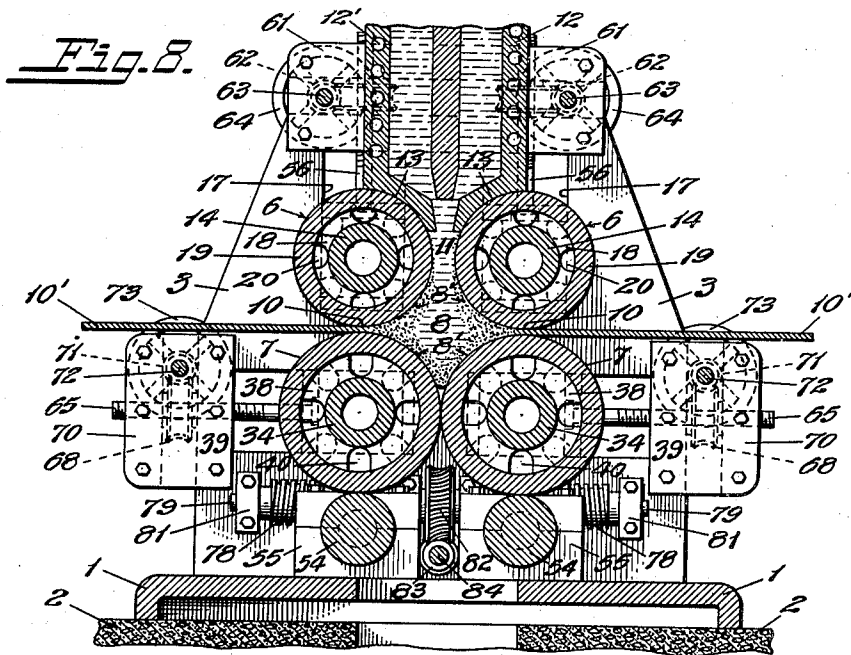
M. LOW

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METHOD OF AND APPARATUS FOR SHAPING METAL DELIVERED IN A MOLTEN CONDITION

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6 Sheets-Sheet 5



Inventor

Marshall Low

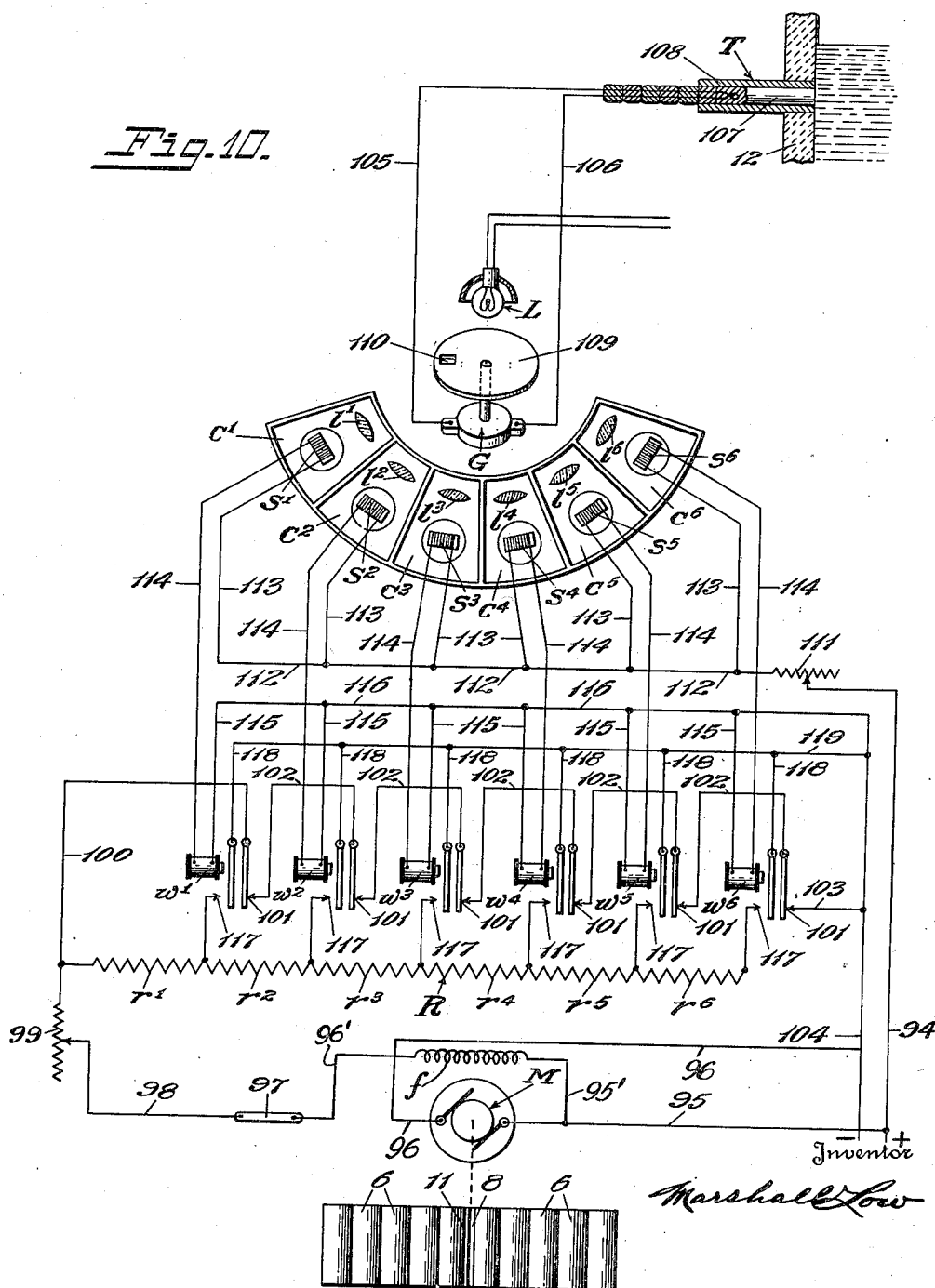
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M. LOW

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METHOD OF AND APPARATUS FOR SHAPING METAL DELIVERED IN A MOLTEN CONDITION

Original Filed July 9, 1934 6 Sheets-Sheet 6



UNITED STATES PATENT OFFICE

2,108,753

METHOD OF AND APPARATUS FOR SHAPING METAL DELIVERED IN A MOLTEN CONDITION

Marshall Low, Washington, D. C.

Application July 9, 1934, Serial No. 734,350
Renewed January 17, 1938

25 Claims. (Cl. 22—57.5)

This invention relates to a method of and apparatus for shaping plastic material and it has particular relation to a method of and apparatus for continuously solidifying and shaping material which is fluid when subjected to heat, such as is disclosed in applicant's copending continuing application, Serial No. 636,080, filed October 3, 1932, of which this application is a continuation in part.

One of the objects of the present invention is to provide a method of and apparatus for continuously rolling sheets, bars and the like from metal having a relatively high melting point such as iron and steel and delivered in a molten condition.

Another object of the invention is to provide a method of and apparatus for rendering the metal relatively plastic prior to its contact with the sheet forming rolls by controllably reducing the temperature of the metal at intervals and according to a temperature gradient determined by the temperature and characteristics of the metal.

A further object of the present invention is to provide a method of and apparatus for automatically controlling the rate of flow of the metal to the shaping rolls in accordance with the temperature of the metal.

Still another object of the present invention is to provide an apparatus of the character described in which the molten metal is rendered plastic and supplied to the shaping rolls in an inert or relatively non-oxidizing atmosphere.

A still further object of the invention is to provide an apparatus of the character described in which the metal may be rolled to the desired form at a plurality of points or locations along its path of travel through the apparatus thus insuring that the rolling operation occurs when the metal reaches the proper degree of plasticity.

Still another object of the present invention is to provide an apparatus of the character described which is not only capable of producing a plurality of sheets or bars simultaneously but which may be employed to produce but a single sheet if so desired.

A still further object of the invention is to provide an apparatus of the character described which may quickly and easily be adjusted to fabricate sheets or bars of different thickness and in which the cooling and shaping rolls may be separated to discharge the metal therefrom and to provide access thereto when the operation of the apparatus is discontinued.

With such objects in view, as well as other ad-

vantages which may be incident to the use of the improvements, the invention consists of the parts and combinations thereof hereinafter set forth and claimed with the understanding that the several necessary elements constituting the same may be varied in proportions and arrangement without departing from the nature and scope of the invention as defined in the appended claims.

In order to make the invention more clearly understood there are shown in the accompanying drawings, means for carrying the invention into practical effect, without limiting the improvements in their useful application to the particular constructions and arrangements which, for the purpose of explanation, have been made the subject of illustration.

In the accompanying drawings:

Figure 1 is a plan view of an apparatus constructed in accordance with the present invention.

Figure 2 is a side elevational view of the structure illustrated in Fig. 1.

Figure 3 is a vertical longitudinal sectional view taken on line 3—3 of Fig. 1.

Figure 4 is a front elevational view of the structure shown in Fig. 1.

Figure 5 is a vertical transverse sectional view taken on line 5—5 of Fig. 1, and illustrating the movable end members and operating means therefor.

Figure 6 is a vertical transverse sectional view taken on line 6—6 of Fig. 1, and illustrating the metal being passed through the several conditioning chambers and being finally rolled into sheet form.

Figure 7 is a vertical transverse sectional view taken on line 7—7 of Fig. 1 and illustrating the mechanism for rotating the upper rolls in their various positions of adjustment.

Figure 8 is a vertical transverse sectional view of another embodiment of the invention for rolling plastic materials and metals having a relatively low melting point.

Figure 9 is a view similar to Fig. 8 but with the rolls separated to discharge material from the chamber defined thereby, and

Figure 10 is a diagrammatic view of the thermo-responsive means for automatically varying the speed of rotation of the rolls in accordance with the temperature of the metal.

Referring to the drawings, an apparatus embodying the present invention is shown as comprising a base 1, preferably of cast construction, suitably anchored upon a concrete foundation 2, and having a pair of parallel frame

members 3 secured thereto along its edges, at what may be termed the front and rear of the apparatus, by bolts 4 passing through flanges 5 formed on the lower edges of the frame members. The frame members 3 may be suitably tied together adjacent to their upper edges to provide a rigid structure and support a plurality of pairs of upper and lower cooling and shaping rolls 6 and 7 respectively arranged in side-by-side contiguous relation and together defining a centrally disposed receiving chamber 8 and a series of conditioning chambers 9 communicating therewith and with one another through spaces or sheet forming passes 10 between the rolls 6 and 7 of each pair of rolls (Fig. 6).

The upper rolls 6 at the center of the apparatus are of slightly less diameter than the rolls located outwardly therefrom so as to define a restricted opening or throat 11 through which molten metal or other material is adapted to be introduced downwardly into the receiving chamber 8, from a feeding device 12, such as a forehearth or ladle located above the rolls. This feeding device may constitute a part of the apparatus and is formed with arcuate lower surfaces 13 conforming with the radius of curvature of the central rolls 6. When the feeding device 12 occupies its operative position the faces 13 are disposed in intimate contact with the central rolls 6, thus preventing air from the outer atmosphere from entering the several conditioning chambers 9 through the throat 11 and receiving chamber 8.

The upper rolls 6 comprise tubular shafts 14 the ends of which are journaled in bushings 15 carried by slide bearings 16 which are mounted for vertical adjustment in ways 17 formed in the frame members 3. The bushings 15 may be of the eccentric type so as to enable the rolls 7 to be accurately adjusted relative to one another and to provide for any reduction in the diameter of these rolls due to wear. The intermediate portions of the shafts 14 are formed with spaced collars 18 upon which outer cylindrical shells 19 are fixed, preferably by shrinking. The collars 18 are formed with a plurality of circumferentially spaced openings 20, the openings in each of the collars being angularly staggered or offset relative to those of the adjacent collars so as to cause a temperature controlling medium to traverse a tortuous path in passing through the rolls from end to end, as will presently be described. The tubular shafts 14 are provided with partitions 21 intermediate their ends and also with radial openings 22 adjacent to the ends of the rolls 6 for establishing communication between the shafts and the interior of the rolls (Fig. 3).

A temperature controlling medium which may be live steam, air or water refrigerated or otherwise, according to the nature and characteristics of the material being shaped by the rolls, is directed through the upper rolls 6 from end to end, from flexible inlet pipes 23, the upper ends of which are secured by means of clamping straps 24 to tubular flanged nipples 25 which are bolted to the outer surfaces of the slide bearings 16 at the front of the apparatus and in axial alignment with the tubular shafts 14. The lower ends of the pipes 23 are secured by means of clamping straps 26 to flanged nipples 27 mounted on inlet valves 28 which control communication between the inlet pipes 23 and a supply main or conduit (not shown) also located at the front of the apparatus.

After passing through the upper rolls 6, the temperature controlling medium escapes from these rolls through flexible outlet pipes 29 the upper ends of which are secured by means of clamping straps 30 to flanged nipples 31 which are bolted to the slide bearings 16 at the rear of the apparatus and in axial alignment with the tubular shafts 14. The lower ends of the pipes 29 are secured by means of clamping straps 32 to flanged nipples 33 which communicate with a common discharge main or conduit (not shown) also located at the rear of the apparatus.

The lower rolls 7 of the several pairs of rolls are of substantially the same construction as the upper rolls just described in that they also comprise tubular shafts 34 the ends of which are journaled in bushings 35, which may also be of the eccentric type, carried by horizontally movable elongated slide bearings 36 mounted in ways 37 formed in the frame members 3. The intermediate portions of the shafts 34 are formed with spaced collars 38 upon which outer cylindrical shells 39 are fixed, preferably by shrinking. The collars 38 are provided with spaced openings 40 similar to those described in connection with the upper rolls 6. The tubular shafts 34 are also provided with partitions 41 intermediate their ends and also with radial openings 42 for establishing communication between the shafts 34 and the interior of the lower rolls 7 at the ends thereof.

A temperature controlling medium is also directed through the lower rolls 7 in opposite directions with respect to that of the flow of the medium through the associated upper rolls 6, from flexible inlet pipes 43 the upper ends of which are secured by means of clamping straps 44 to tubular flanged nipples 45 bolted to the outer surfaces of the slide bearings 36 at the rear of the apparatus. The lower ends of the inlet pipes 43 are secured by means of clamping straps 46 to flanged nipples 47 mounted on inlet valves 48 which control communication between the inlet pipes 43 and a supply main or conduit (not shown) located at the rear of the apparatus.

After passing through the lower rolls 7 the temperature controlling medium escapes from these rolls through flexible outlet pipes 49, the upper ends of which are secured by clamping straps 50 to flanged nipples 51 which are bolted to the outer faces of the slide bearings 36 at the front of the apparatus. The lower ends of the outlet pipes 49 are secured by means of clamping straps 52 to flanged nipples 53 which communicate with a common discharge main or conduit (not shown) also located at the front of the apparatus. It will be observed that the cooling medium is thus directed through the upper and lower rolls 6 and 7 in opposite directions, thus equalizing the dissipation of heat from the metal transversely of its path of travel.

The lower rolls 7 are additionally supported by back-up rolls 54 of solid construction which are journaled in bearings 55 carried by the base 1.

The upper rolls 6 may be raised and lowered independently of one another in order to adjust the size of the spaces 10 or to transform these spaces into sheet forming passes of equal size or into passes decreasing progressively in size outwardly according to the temperature, nature, rate of heat dissipation, or other characteristics of the particular metal or material being rolled, by means of adjusting screws 56 having heads 57 at their lower ends which are rotatably confined within keepers 58 bolted to the upper surfaces of

the slide bearings 16. The upper portions of the adjusting screws 56 are threaded into worm nuts 59 which are confined between the upper ends of the frame members 3 and bars 60 secured to the frame members by side plates 61. The worm nuts 59 are rotated in order to raise or lower the adjusting screws 56 and the parts carried thereby, by means of worms 62 which are fixed to shafts 63 extending between the frame members 3 and journaled in the plates 61 and are provided at their forward ends with hand wheels 64 by means of which both ends of the upper rolls 6 may be raised or lowered simultaneously between the positions shown in full and broken lines in Fig. 6.

The lower cooling and shaping rolls 7 may be separated at the middle of the apparatus, that is to say the rolls 7 on opposite sides of a vertical medial plane are moved in unison away from one another, as indicated by broken lines in Fig. 7, so as to provide a space between the two central rolls 7 through which the apparatus may be emptied of material when operation is discontinued. This is accomplished by means of jack screws 65 having heads 66 at their inner ends which are rotatably confined within keepers 67 bolted to the outer ends of the slide bearings 36. The outer portions of the jack screws 65 are threaded into worm nuts 68 which are confined between the outer edges of the frame members 3 and bars 69 secured to the frame members 3 by side plates 70. The worm nuts 68 are rotated by means of worms 71 which are fixed to shafts 72 extending between the frame members 3 and journaled in the side plates 70, and are provided at their forward ends with hand wheels 73 by means of which the opposite ends of the lower rolls may be moved in unison from the front of the apparatus.

Mounted contiguous with the ends of the upper rolls 6 and with the lower rolls 7 of each of the pairs of rolls, is an end member 74. When the rolls occupy their operative positions these end members abut one another and prevent the escape of material from the chambers 8 and 9 and the spaces 10 in a direction longitudinally of the rolls. These end members may be constructed of any suitable refractory material, such as fire brick or lava rock, or they may be of hollow cast metal construction, in which case a temperature controlling medium may also be circulated there-through by providing suitable pipes for such purpose. The end members 74 are supported by hangers 75 which are pivotally connected thereto at their lower ends and which are provided with strap portions 76 at their upper ends for engagement with eccentrics 77 fixed to the shafts 14 of the upper rolls 6. By means of this construction the end members 74 are reciprocated vertically as the rolls 6 are rotated, thus exerting a shearing action against the ends of the rolls such as will prevent material from adhering to the end members during its passage through the chambers. The end members are prevented from end-wise displacement by the eccentrics 77 and hangers 75.

The lower rolls 7 of the several pairs of rolls are rotated in the directions indicated by the arrows in Fig. 6 in order to fabricate two sheets simultaneously when the rolls occupy their operative positions, and also to free them from material when they occupy their inoperative or separated positions, as shown by broken lines in Fig. 6; by means of a plurality of elongated worms 78 which are fixed to a jack shaft 79 and which

mesh with worm gears 80 keyed to the tubular shafts 34 of the lower rolls 7. The jack shaft 79 is journaled in bearings 81 fixed to the front frame members 3 and carries a worm wheel 82 for intermeshing engagement with a worm 83 fixed to a transversely extending drive shaft 84. The drive shaft 84 is journaled in the front frame member 3 and in a bearing 85 carried by the base 1 and is suitably driven by a variable speed electric motor M (Fig. 10) in a manner hereinafter to be described.

The upper cooling and shaping rolls 6 of the several pairs of rolls are rotated in the directions indicated by the arrows in Fig. 6, by means of spur gears 86 which are fixed to the lower tubular shafts 34 at the rear of the apparatus (Fig. 7) and which drive gears 87 fixed to the upper shafts 14 through the medium of intermeshing upper and lower pinions 88 and 89 respectively. These pinions are journaled on stud shafts 90 and 91 carried by arms 92 which are mounted on the lower shafts 34 for swinging movement thereon. The stud shafts 90 upon which the upper pinions 88 are journaled, are pivotally connected to arms 93 which are mounted on the upper shafts 14 for swinging movement thereon. This construction insures that the pinions 88 will traverse paths concentric or planetary with respect to both the gears 86 and 87 and thus maintain driving connections between the rolls 6 and 7 when either the former are adjusted vertically or the latter are adjusted horizontally, as is shown by broken lines in Fig. 7.

It will be apparent from the foregoing that the molten metal introduced into the receiving chamber 8 is moved laterally outwardly therefrom in opposite directions through the chambers 8 and spaces 9 until it reaches a plastic condition and is rolled into sheet form by the rolls 6 and 7. The particular point where the sheet forming operation occurs depends upon the initial temperature of the metal, rate of heat dissipation and the speed of the rolls. If the metal reaches a plastic condition at an early stage and is shaped into a sheet by certain of the intermediate rolls, the rolls disposed outwardly from such rolls merely function as supporting and as additional cooling and smoothing means. On the other hand, if the metal does not become plastic until it reaches the outermost rolls these outermost rolls perform the shaping function and the rolls located inwardly therefrom act as cooling and feeding means. Obviously the particular number of pairs of rolls employed depends upon operating conditions, and may be reduced in number or added to according to requirements.

For example, there is shown in Figures 8 and 9 an embodiment of the invention in which only two pairs of rolls are employed. This construction may be preferable in rolling plastic materials and metals having relatively low melting points. Inasmuch as this construction is practically the same as that hereinbefore described and is the subject of applicant's co-pending application hereinabove referred to, a detailed description thereof is believed to be unnecessary.

As in the rolling operations hereinbefore described, the metal within the chamber 8 is rendered plastic in zones 8' of substantially equal area above and below the passes 10. The rotation of the rolls carries the metal of these zones outwardly through the passes where they are united by the pressure of the rolls to form sheets 10' having skins on opposite sides of substantially uniform thickness.

Also, it will be apparent that the surfaces of the corresponding rolls of the several pairs of rolls move in opposite directions at the lines of contact therebetween and consequently exert a scraping or scouring action against one another such as will not only prevent the metal from escaping therebetween but will free the metal from the rolls in the event of any tendency to adhere thereto during its passage through the apparatus. In this respect the assembly may be termed a "continuous self-stripping ingot mold". This contiguous relation of the upper and lower rolls also tends to exclude air from the outer atmosphere from the several chambers, thus preventing undue oxidation of the metal during its conditioning stages.

Obviously if the cooling and shaping rolls 6 and 7 are rotated too rapidly with respect to the rate at which the metal dissipates its heat, the metal will not become sufficiently solidified to retain its sheet form after passing between the outermost pairs of rolls. On the other hand, if the rolls are rotated too slowly the metal may reach such a degree of solidity as to subject the rolls to excessive strain if not actually "freezing" while in contact therewith. Also, the temperature of the metal as well as that of the cooling medium flowing through the rolls may fluctuate to such an extent and so frequently as to render any constant roll speed impractical.

According to the present invention these difficulties and uncertainties are avoided by the provision of thermo-responsive means for automatically varying the speed of the motor M and that of the rolls 6 and 7 in accordance with the temperature of the metal and any fluctuations therein.

With particular reference to Fig. 10 of the drawings, the armature winding of the motor M is shown as being energized by direct current which traverses a circuit from a suitable source, such as positive bus wire 94, through wire 95, armature winding of motor M, and wire 96, to negative bus wire 104. The field winding of motor M is also energized by current which traverses a circuit from positive bus wire 94, through wires 95, and 95', field winding f of motor M, wire 96, manually operable switch 97, wire 98, manually adjustable rheostat 99, wire 100, back contacts 101 and connecting wires 102 of a series of relays, indicated by the letter w with exponents according to their order of energizing, and wire 103 to negative bus wire 104. Under these conditions the motor M will drive the cooling and shaping rolls 6 and 7 at a maximum speed determined by the manual adjustment of the rheostat 99 and the rolls will fabricate sheets, as previously described, if the metal dissipates its heat the proper rate at such roll speed.

The speed of the motor M and the rolls 6 and 7 driven thereby is automatically controlled by a thermocouple T which is positioned adjacent to the molten metal within the feeding device 12 or within certain of the chambers 8 and 9 or both, so that the temperature of the metal will generate an electric current, in the well known manner, in a circuit including wires 105, and 106, connecting the terminals of the thermocouple T with those of a galvanometer G. The hot end of the thermocouple T is suitably connected with the outer end of a metal bar 107 the inner end of which is exposed to the hot metal and which is provided with a suitable heat insulating covering 108 so as to insure a uniform drop in temperature from end to end. The temperature of

the inner end of the bar 107 is that of the metal with which it is in contact but the drop in temperature longitudinally of the bar is such as to prevent the thermocouple from being damaged by being subjected to excessive heat. However, sufficient heat is transmitted to the thermocouple T by conduction to insure that the same will operate properly in accordance with fluctuations in the temperature of the metal within the feeding device or chamber.

The galvanometer G operates a disk or shutter 109 provided with an aperture 110 through which light rays emanating from a source of light, such as an electric lamp L, may progressively be admitted into a series of chambers c. Located within each of the chambers c is a selenium cell or resistor s and also a lens l for focusing the light rays admitted through the aperture 110 upon the light sensitive element of the cells s.

When the temperature of the metal in the vicinity of the thermocouple T reaches a predetermined degree, the galvanometer G will swing the shutter 109 to a position in which its aperture 110 registers with the first chamber c¹ of the series so that light from the lamp L will be focused upon the selenium cell s¹ thus rendering the light sensitive element thereof sufficiently conductive to effect the energizing of relay w¹ by current traversing a circuit from positive bus wire 94, through a manually adjustable resistance element 111, wires 112, and 113, light sensitive element of the selenium cell s¹, wire 114, winding of relay w¹, and wires 115 and 116 to the negative bus wire 104. The energizing of the relay w¹ by current flowing in the circuit just traced causes it to open its back contact 101 and to close a front contact 117 thereof. This opens the circuit previously traced for the motor M but establishes an auxiliary circuit therefor through the first section r¹ of a resistance R, front contact 117 of relay w¹ and wires 118 and 119 to the negative bus wire 104. The introduction of this additional resistance r¹ into the motor circuit causes the speed of the motor and that of the rolls 6 and 7 to decrease a predetermined amount so as to allow a greater period of time for the metal to dissipate its heat and reach the desired degree of plasticity before passing between the rolls performing the shaping function.

If the speed of the rolls is still too high to permit the metal to become sufficiently plastic to retain its sheet form after passing between the shaping rolls, the galvanometer G will swing the shutter 109 until the aperture 110 therein registers with the next adjacent chamber c² of the series so that light from the lamp L will render the next succeeding selenium cell s² electrically conductive and cause the energizing of the relay w². The energizing of the relay w² introduces the next section r² of the resistance R into the motor circuit so as to cause the motor M to rotate at a still further reduced speed. It will be understood that when the front contact 117 of one of the succeeding relays w is closed, as above described, the front contact 117 of the preceding relay w is opened so that the current in the motor circuit will be compelled to traverse all of the sections r of the resistance R which are introduced into this circuit by the closing of the front contact 117 of the relay last energized. The above described operations are repeated successively until the desired amount of resistance is included in the circuit of the motor M.

It will be understood that the chambers c are

impervious to light except when the aperture 110 in the shutter 109 is moved into registry therewith. Also, it will be understood that suitable amplifying means may be provided in the circuits of the several selenium cells if so desired.

For the purpose of illustration, the current is schematically shown as passing directly through the contacts 101 and 117 of the relays *w*, but it will be appreciated by those skilled in the art that the contacts of these relays may be employed to energize auxiliary circuits including circuit makers and breakers of a type particularly adopted to carry the current employed, especially where normally high current values are to be dealt with.

The hereinabove described control system is given by way of example only, it not being intended to limit the instant improvements to any particular circuit or circuits.

From the foregoing it will be apparent that an apparatus is provided in which the metal is not only rolled to sheet form but in which the metal is also conditioned prior to the rolling operation. By regulating properly the rate of flow of the cooling medium through the several rolls, or by regulating the speed of the rolls, or both, the rate of dissipation of heat from the metal may be adjusted in accordance with a temperature gradient determined by the initial temperature of the metal or the characteristics of the particular metal being rolled. This gradient may be uniform in character or it may be shaped according to requirements.

The sheets of metal issue from the apparatus in a relatively hot condition and may immediately be fed to other instrumentalities for further shaping or conditioning operations. For example, the sheets may be fed directly to drop hammers to be forged thereby into articles of appropriate shape while the metal is still hot from its original heat. Also the sheets may be fed to other rolls for further reduction in thickness, or they may immediately be introduced into annealing ovens or subjected to tempering, carburizing, or other heat treating processes or operations.

The apparatus hereinabove described may be employed to roll a single sheet by disconnecting or entirely dispensing with the outer roll or rolls at one side of the apparatus and by altering the gearing so that the innermost lower roll 7 on the side where such disconnection is effected, will rotate in a direction opposite to that shown. In such event the upper roll 6 associated with said innermost lower roll 7 should be adjusted downwardly so as to close the space 10 between these rolls. When these slight changes are made a single sheet will be fabricated by the rolls on the opposite side of the apparatus. An apparatus of this type which is specifically designed to fabricate a single sheet only is disclosed in applicant's copending application, Serial No. 734,349, filed July 10, 1934.

If desired the entire series of rolls on both sides of the apparatus may be enclosed within a casing or housing through which an inert or non-oxidizing atmosphere may either be circulated or maintained.

Also, instead of mounting the lower rolls on each side of the center line of the apparatus in single slide bearings 36 as shown, these rolls may be journaled in separate slide bearings having loose or lost motion connections therebetween.

When thus mounted the jack screws 65 will

separate the rolls 7 progressively inwardly so as to provide discharge openings between each of the lower rolls. In such an arrangement the ways 37 may be inclined slightly downwardly toward the center of the apparatus so that the rolls 7 will frictionally engage one another under the influence of gravity.

Other modifications and changes in proportion and arrangement of the several necessary elements constituting the invention may be made by those skilled in the art without departing from the nature and scope of the invention as defined in the appended claims.

What I claim is:

1. The method of rolling sheets or bars from material delivered in a molten condition which comprises the steps of passing the molten material through a series of chambers defined by a plurality of pairs of rolls arranged in side by side relation; rendering the material relatively plastic by progressively reducing the temperature of the material during its passage through said chambers in accordance with a predetermined temperature gradient; rolling the plastic material into sheet or bar form while it is still hot from its original heat; and automatically controlling the speed of rotation of said rolls by and in accordance with the temperature and characteristics of the material.

2. The method of rolling sheets or bars from material delivered in a molten condition which comprises the steps of passing the molten material in two streams from a single source of supply in opposite directions through a series of chambers defined by a plurality of pairs of rolls arranged in side by side relation; rendering the material relatively plastic by progressively reducing the temperature of the material during its passage through said chambers in accordance with a predetermined temperature gradient; simultaneously rolling the plastic material of each of said streams into sheet or bar form while it is still hot from its original heat; and automatically controlling the speed of rotation of said rolls by and in accordance with the temperature and characteristics of the material.

3. The method of rolling sheets or bars from oxidizable metal such as iron or steel delivered in a molten condition which comprises the steps of passing the molten metal through a series of chambers defined by a plurality of pairs of rolls arranged in side-by-side contiguous relation, said chambers being substantially closed to the outer atmosphere, by rotating said rolls; rendering the metal relatively plastic by progressively reducing the temperature of the metal during its passage through said chambers in accordance with a predetermined temperature gradient; and finally rolling the plastic metal into sheet or bar form while it is still hot from its original heat.

4. The method of rolling sheets or bars from oxidizable metal such as iron or steel delivered in a molten condition which comprises the steps of passing the molten metal in two streams from a single source of supply in opposite directions through a series of chambers defined by a plurality of pairs of rolls arranged in side-by-side contiguous relation, said chambers being substantially closed to the outer atmosphere, by rotating said rolls; rendering the metal relatively plastic by progressively reducing the temperature of the metal during its passage through said chambers in accordance with a predetermined temperature gradient to render the same relatively plastic; and finally simultaneously rolling

the plastic metal of each of said streams into sheet or bar form while it is still hot from its original heat.

5 5. Apparatus of the character described comprising a pair of shaping rolls; a series of chambers communicating with one another and with
10 said rolls for receiving a supply of molten metal, means for moving a wall of each of said chambers to move the metal in said chambers toward
10 said rolls; and means for reducing the temperature of the metal moving through said chambers to render the metal relatively plastic prior to its contact with said rolls.

15 6. Apparatus of the character described comprising a pair of shaping rolls; a series of chambers communicating with one another and with
15 said rolls for receiving a supply of molten metal; means for moving a wall of each of said chambers to move the metal in said chambers toward
20 said rolls, means for reducing the temperature of the metal moving through said chambers to render the metal relatively plastic prior to its contact with said rolls; and means responsive
25 to the temperature of said metal for controlling the rate of movement of said walls and the resulting movement of said metal.

7. Apparatus of the character described comprising two pairs of laterally spaced shaping rolls; a series of chambers located between said pairs
30 of rolls and communicating with one another and with said rolls for receiving a supply of molten metal from a single source and directing the same in opposite directions towards said
35 rolls; means for moving a wall of each of said chambers to move the metal in said chambers toward said rolls; means for reducing the temperature of the metal in said chambers to render the metal relatively plastic prior to its contact with
40 said rolls; and means responsive to the temperature of the metal for automatically controlling the rate of movement of said metal toward said rolls.

8. Apparatus of the character described comprising a plurality of pairs of relatively closely
45 spaced rolls arranged in side-by-side relation and together defining a series of chambers communicating with one another through the relatively narrow spaces between the rolls of the several pairs of rolls, said rolls being operable
50 when rotated to move molten metal introduced into one of said chambers through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic, and finally to impart to the plastic metal
55 a predetermined configuration.

9. Apparatus of the character described comprising a plurality of pairs of relatively closely
55 spaced rolls arranged in side-by-side relation and together defining a series of chambers communicating with one another through the relatively narrow spaces between the rolls of the several
60 pairs of rolls, said rolls being operable when rotated to move molten metal introduced into one of said chambers through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic, and
65 finally to impart to the plastic metal a predetermined configuration; and means for independently varying the size of the spaces between the rolls of the several pairs of rolls in accordance
70 with the degree of plasticity of the metal.

10. Apparatus of the character described comprising a plurality of pairs of relatively closely
75 spaced rolls arranged in side-by-side contiguous relation and together defining a series of cham-

bers substantially closed with respect to the outer atmosphere and communicating with one another through the relatively narrow spaces between the rolls of the several pairs of rolls, said rolls being operable when rotated to move molten metal introduced into one of said chambers through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic, and finally to impart to the plastic metal a predetermined configuration.

11. Apparatus of the character described comprising a plurality of pairs of relatively closely spaced rolls arranged in side-by-side relation and together defining a series of chambers communicating with one another through sheet forming passes defined by the rolls of the several pairs of rolls, said rolls being operable when rotated to move molten metal introduced into said chamber through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic and finally to roll the plastic metal into sheet or bar form.

12. Apparatus of the character described comprising a plurality of pairs of relatively closely spaced rolls arranged in side-by-side relation and together defining a plurality of chambers communicating with one another through the relatively narrow spaces between the rolls of the several pairs of rolls, said rolls being operable when rotated to move molten metal introduced into an intermediate chamber in opposite directions through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic, and finally to impart to the plastic metal predetermined configurations at opposite sides of the apparatus.

13. Apparatus of the character described comprising a plurality of pairs of relatively closely spaced rolls arranged in side-by-side relation and together defining a plurality of chambers communicating with one another through the relatively narrow spaces between the rolls of the several pairs of rolls, said rolls being operable when rotated to move molten metal introduced into an intermediate chamber in opposite directions through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic, and finally to impart to the plastic metal predetermined configurations at opposite sides of the apparatus; and means for independently varying the size of the spaces between the rolls of the several pairs of rolls in accordance with the plasticity of the metal.

14. Apparatus of the character described comprising a plurality of pairs of relatively closely spaced rolls arranged in side-by-side contiguous relation and together defining a plurality of chambers substantially closed with respect to the outer atmosphere and communicating with one another through the relatively narrow spaces between the rolls of the several pairs of rolls, said rolls being operable when rotated to move molten metal introduced into an intermediate chamber in opposite directions through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic, and finally to impart to the plastic metal predetermined configurations at opposite sides of the apparatus.

15. Apparatus of the character described comprising a plurality of pairs of relatively closely spaced rolls arranged in side-by-side relation and together defining a plurality of chambers communicating with one another through sheet forming

ing passes defined by the rolls of the several pairs of rolls, said rolls being operable when rotated to move molten metal introduced into an intermediate chamber in opposite directions through successive chambers, to reduce progressively the temperature of the metal and render the same relatively plastic, and finally to roll the plastic metal into sheet or bar form at opposite sides of the apparatus.

16. Apparatus of the character described comprising a pair of shaping rolls; metal conditioning means communicating with said rolls for receiving a supply of molten metal and directing the same toward the rolls, said conditioning means including a plurality of chambers communicating with one another through restricted passages; means for reducing the temperature of the metal passing along said conditioning means, controllable as to its temperature reducing effects and applicable at intervals along said conditioning means to render the metal relatively plastic prior to its contact with the said rolls, and means responsive to the temperature of the metal for automatically controlling the rate of movement of said metal toward said rolls.

17. Apparatus of the character described comprising two pairs of laterally spaced shaping rolls; a series of chambers located between said pairs of rolls and communicating with one another and with said rolls for receiving a supply of molten metal from a single source and directing the same in opposite directions towards said rolls; means for moving a wall of each of said chambers to move the metal in said chambers towards said rolls to be simultaneously shaped thereby into two sheets; and means for reducing the temperature of the metal in said chambers to render the same relatively plastic prior to its contact with said rolls.

18. Apparatus of the character described comprising two pairs of superposed rolls arranged in side-by-side relation and cooperating to define a substantially closed chamber for receiving the supply of molten metal, a restricted throat through which metal is adapted to be introduced into said chamber and a sheet forming pass communicating with said chamber; means for cooling said rolls to extract heat from the metal in said chamber and render the same relatively plastic; means for rotating said rolls to move the plastic metal from said chamber outwardly through said pass to form a sheet; and a receptacle removably seated upon the upper rolls of said pairs of rolls and communicating with said throat for supplying molten metal to said chamber, said receptacle having arcuate surfaces corresponding in curvature to that of said rolls to provide intimate contact therewith, thus to exclude air from the outer atmosphere from said throat and said chamber.

19. Apparatus of the character described comprising two pairs of superposed rolls arranged in side-by-side relation and cooperating to define a substantially closed chamber for receiving the supply of molten metal, a restricted throat through which metal is adapted to be introduced into said chamber and a sheet forming pass communicating with said chamber; means for cooling said rolls to extract heat from the metal in said chamber and render the same relatively plastic; means for rotating said rolls to move the plastic metal from said chamber outwardly through said pass to form a sheet; a receptacle removably seated upon the upper rolls of said pairs of rolls and communicating with said throat

for supplying molten metal to said chamber, said receptacle having arcuate surfaces corresponding in curvature to that of said roll to provide intimate contact therewith, thus to exclude air from the outer atmosphere from said throat and chamber; and means for circulating a cooling medium adjacent to the metal in said receptacle to extract excess heat therefrom prior to its introduction into said chamber.

20. Apparatus of the character described comprising two pairs of superposed rolls arranged in side-by-side relation and cooperating to define a substantially closed chamber for receiving the supply of molten metal, a restricted throat through which metal is adapted to be introduced into said chamber and a sheet forming pass communicating with said chamber; means for cooling said rolls to extract heat from the metal in said chamber and render the same relatively plastic; means for rotating said rolls to move the plastic metal from said chamber outwardly through said pass to form a sheet; a receptacle removably seated upon the upper rolls of said pairs of rolls and communicating with said throat for supplying molten metal to said chamber, said receptacle having arcuate surfaces corresponding in curvature to that of said roll to provide intimate contact therewith, thus to exclude air from the outer atmosphere from said throat and chamber; and means for separating the lower rolls of said pairs of rolls to discharge metal from said chamber.

21. Apparatus of the character described comprising two pairs of superposed rolls arranged in side-by-side relation and cooperating to define a substantially closed chamber for receiving the supply of molten metal, a restricted throat through which metal is adapted to be introduced into said chamber and a sheet forming pass communicating with said chamber; means for cooling said rolls to extract heat from the metal in said chamber and render the same relatively plastic; means for rotating said rolls to move the plastic metal from said chamber outwardly through said pass to form a sheet; a receptacle removably seated upon the upper rolls of said pairs of rolls and communicating with said throat for supplying molten metal to said chamber, said receptacle having arcuate surfaces corresponding in curvature to that of said roll to provide intimate contact therewith, thus to exclude air from the outer atmosphere from said throat and chamber; means for separating the lower rolls of said pairs of rolls to discharge metal from said chamber; and means for rotating said lower rolls when separated to free metal therefrom.

22. Apparatus of the character described comprising two pairs of superposed rolls arranged in side-by-side relation and cooperating to define a substantially closed chamber for receiving the supply of molten metal, a restricted throat through which metal is adapted to be introduced into said chamber and a sheet forming pass communicating with said chamber; means for cooling said rolls to extract heat from the metal in said chamber and render the same relatively plastic; means for rotating said rolls to move the plastic metal from said chamber outwardly through said pass to form a sheet; a receptacle removably seated upon the upper rolls of said pairs of rolls and communicating with said throat for supplying molten metal to said chamber, said receptacle having arcuate surfaces corresponding in curvature to that of said roll to provide intimate contact therewith, thus to exclude air

from the outer atmosphere from said throat and chamber; means for separating the lower rolls of said pairs of rolls to discharge metal from said chamber; means for separating the rolls of said pairs of rolls to facilitate access to said rolls and chambers; and means for rotating the upper and lower rolls of said pairs of rolls when thus separated to free metal therefrom.

23. Apparatus of the character described comprising two pairs of superposed rolls arranged in side-by-side relation and cooperating to define a substantially closed chamber for receiving the supply of molten metal, a restricted throat through which metal is adapted to be introduced into said chamber and a sheet forming pass communicating with said chamber; means for cooling said rolls to extract heat from the metal in said chamber and render the same relatively plastic; means for rotating said rolls to move the plastic metal from said chamber outwardly through said pass to form a sheet; a receptacle removably seated upon the upper rolls of said pairs of rolls and communicating with said throat for supplying molten metal to said chamber, said receptacle having arcuate surfaces corresponding in curvature to that of said roll to provide intimate contact therewith, thus to exclude air from the outer atmosphere from said throat and chamber; and means responsive to the temperature of the metal for controlling the speed of rotation of said rolls.

24. The method of rolling sheets or bars from

material delivered in a molten condition which comprises the following steps: delivering the molten material to an initial receiving chamber; causing the material to move from the said initial receiving chamber through a series of chambers successively connected by restricted passes, wherein heat is abstracted from the material rendering it relatively plastic by progressively reducing the temperature thereof during its passage through said chambers, in accordance with a predetermined temperature gradient; subjecting the material to progressive forward feeding action between successive chambers, and finally rolling the plastic material into sheet or bar form while it is still hot from its original heat.

25. The herein described method of rolling sheets or bars from oxidizable metal such as iron or steel, delivered in a molten condition, which comprises the following steps: delivering the molten metal into an initial receiving chamber; passing it therefrom through a series of chambers connected successively with each other by passes of reduced dimensions, the said chambers being substantially closed against the admission of atmospheric air, rendering the metal relatively plastic by progressively reducing the temperature thereof during its passage through the said chambers in accordance with a predetermined temperature gradient, and finally rolling the plastic metal into sheet or bar form while it is still hot from its original heat.

MARSHALL LOW.