Nov. 27, 1934. W. R. CLARK 1,982,571

METHOD OF AND APPARATUS FOR ROLLING METAL

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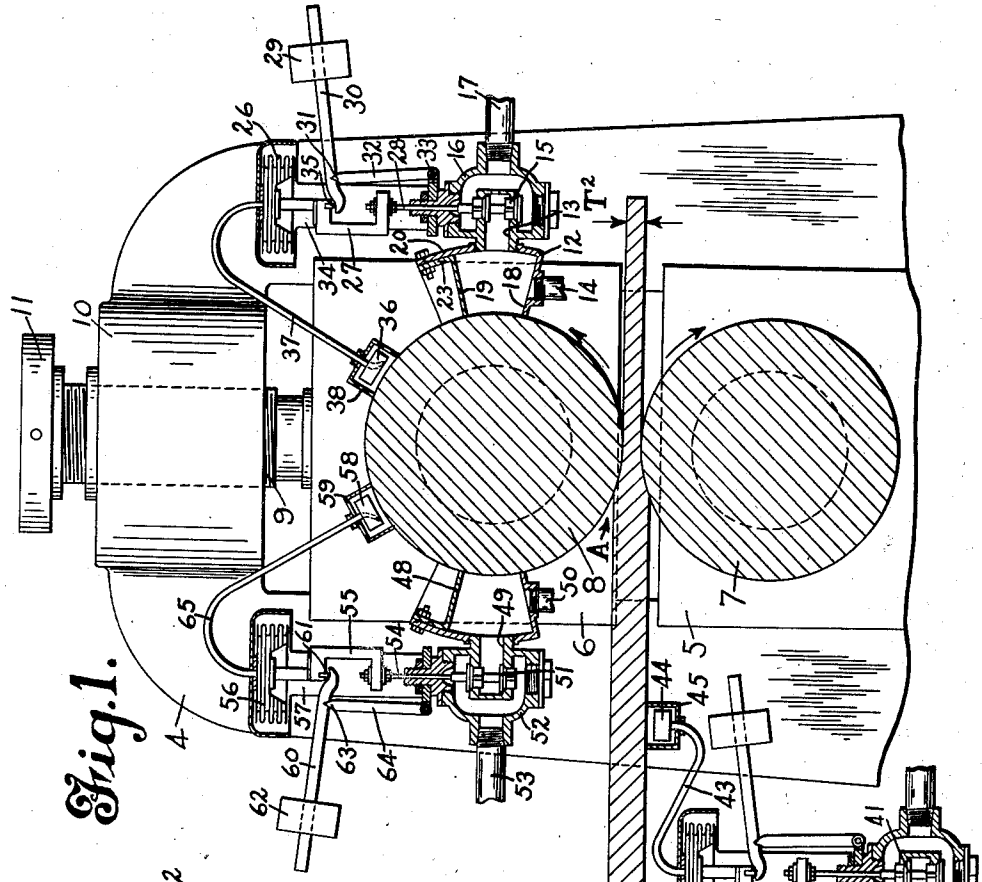


Fig. 1.

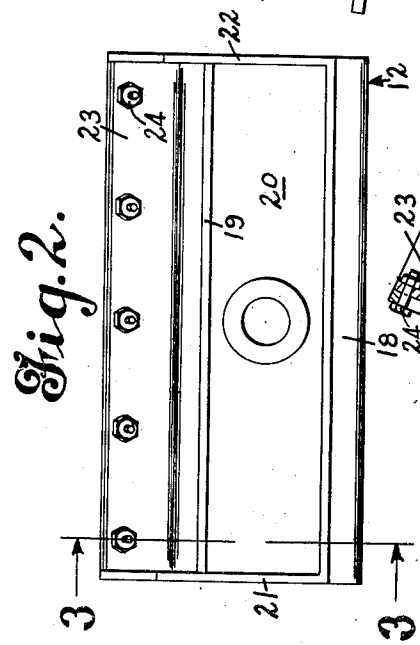


Fig. 2.

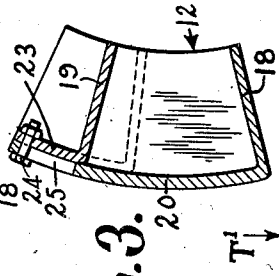


Fig. 3.

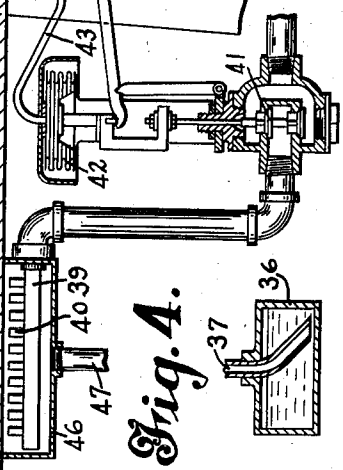


Fig. 4.

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Fig. 5.

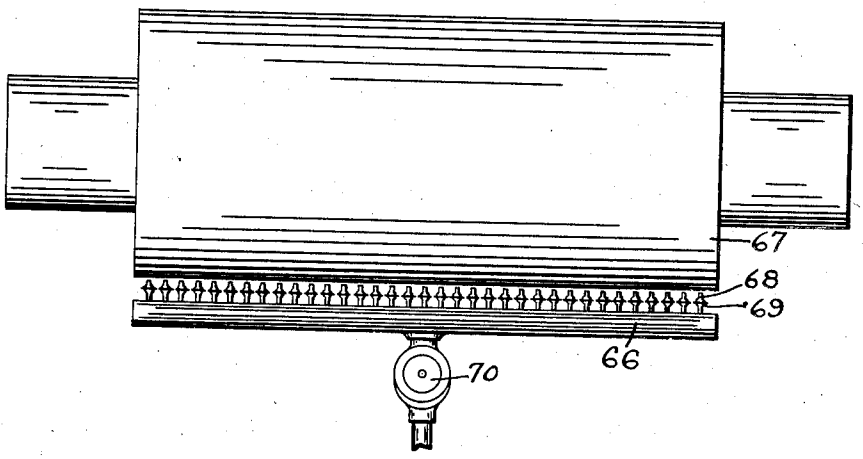


Fig. 6.

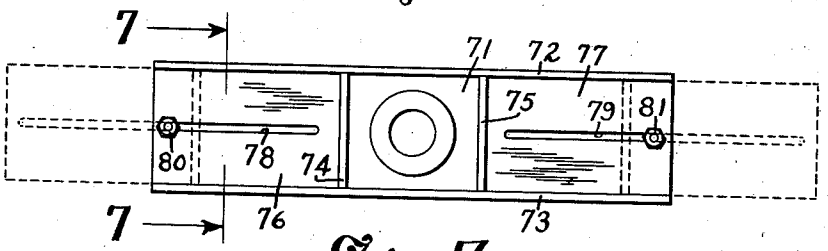


Fig. 7.

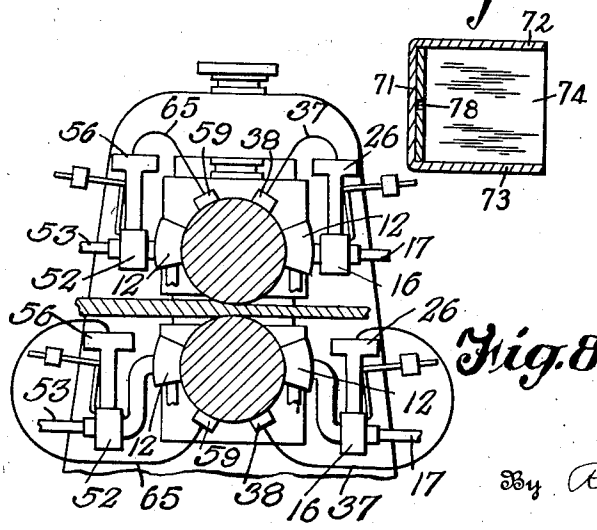


Fig. 8.

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UNITED STATES PATENT OFFICE

1,982,571

METHOD OF AND APPARATUS FOR ROLLING METAL

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Application February 2, 1928, Serial No. 251,430

47 Claims. (Cl. 80—41)

This invention relates to a method of and apparatus for rolling metal, and more especially to a method of and an apparatus for controlling the size of the pass or opening between the rolls of a rolling mill in order to maintain an even or uniform gauge in the material delivered by the rolls from end to end of a given piece of material or from beginning to end of a series of pieces.

In the rolling of material, particularly of sheet material, it is of great importance that the sheets be of uniform gauge from one side to the other and from end to end. If the material delivered to the mill is of substantially even gauge from end to end and the rolls of the mill are properly shaped to give the minimum degree of variation from edge to edge that can be maintained in commercial rolling practice, then the remaining causes of gauge variation will be found to result from variations in the hardness of the material being rolled or from variations in the dimensions or shapes of the rolls of the mill due to changes in the temperatures of the rolls. The present invention relates to the prevention of variations in gauge due to changes in the dimensions of the rolls of the mill, and particularly such variations as are produced by the heating of the rolls.

According to the prior art, it is the usual practice to provide rolls of fairly large diameter which run slowly so that they may be maintained at a normal temperature due to natural air cooling which compensates for any heat that they may absorb during the operation of rolling. It has also been proposed to use hot or cold air blasts which are directed against the faces of the rolls, gas, or electric heaters, or water, or other fluids, which are flowed over the surfaces of the rolls. All of these methods for regulating the temperatures of the rolls to maintain these temperatures as nearly as possible to what are considered normal working temperatures, involve manual control, and require constant attention and considerable skill on the part of the mill operator, and while they are, to a certain extent, effective in the case of large and slowly moving rolls, they are very unsatisfactory when used with small rolls rotating at high speed.

The general object of the invention is to provide a method and means for controlling the size of the pass or opening between the rolls of a rolling mill not only within narrower limits than heretofore possible, but also without the constant care and attention necessary with known methods and means. Another object is to provide a mill in which the size of the opening may be adjusted to deliver the required gauge, before the metal begins to pass through the mill, and in which the size of the opening after this adjustment has been made will be kept constant without further attention on the part of the operator.

The invention is applicable to either hot or cold rolling.

The invention in a broad aspect contemplates the automatic transfer of heat from or to the rolls of a mill according to whether the temperatures are above or below normal working temperatures, and in a more specific aspect, the transfer of heat from or to the rolls by means of fluids which are directed against the faces or journals of the rolls, and the automatic control of the application of these fluids, according to the temperature conditions of the rolls, by a thermo-sensitive element or elements which are constantly subjected to the roll temperatures.

In order to assist in effectively controlling the temperatures of the rolls of the mill, and therefore the size of the pass or opening between the mill rolls, it is desirable to introduce the material to be rolled at a predetermined constant temperature. Accordingly, another object of the invention resides in a novel method and means for controlling the temperature of the material entering the mill.

A further object of the invention is to furnish means for varying the areas of the roll surfaces with which the cooling or heating fluids come in contact in order to more precisely control the effect of these fluids on the temperature of the roll.

To these and other ends the invention consists in the novel features and combination of parts to be hereinafter described and claimed.

In the drawings:

Fig. 1 is a side elevation, partly in section, of a two-roll mill showing a preferred form of my temperature controlling means used in connection therewith;

Fig. 2 is a fragmentary view showing one of the elements used to bring the cooling or heating fluids into contact with the roll surfaces;

Fig. 3 is a sectional view along line 3—3 of Fig. 2;

Fig. 4 is a fragmentary view of one of the heat responsive elements shown in Fig. 1;

Fig. 5 is a view of a mill roll and a different type of element, for bringing the heating or cooling fluids into contact therewith, than that shown in Fig. 1;

Fig. 6 is a view similar to Fig. 2 but showing a modification;

Fig. 7 is a sectional view along line 7—7 of Fig. 6, and Fig. 8 is a somewhat diagrammatic sectional view of a two-roll mill having automatically controlled heat transfer devices associated with the upper and lower rolls.

By way of illustration, I shall now describe my invention in connection with the two-roll metal rolling mill shown in the drawings, which has been chosen for illustrative purposes on account of its simplicity, and it will be understood that the invention is not limited to this particular type of mill, nor to any particular roll or rolls of a mill, but may be applied to a roll or rolls in any of the well known types of mills and is particularly useful in the four-high mills and cluster mills generally in use.

In the drawings, the reference numeral 4 indicates, in general, the frame of a rolling mill of which only one end is shown and in which are mounted bearings 5 and 6, of rolls 7 and 8, bearing 5 being usually fixed, while bearing 6 is adjustable towards and away from bearing 5 by means, such as screw 9, mounted in head 10 of frame 4, and adjusted by means of hand wheel 11.

The material M enters the mill at A with an initial thickness of T^1 and emerges from between the rolls with a final thickness of T^2. The rolls of the usual mill at the start of the rolling operation may have the temperature of the room in which the mill is placed, and the increase in temperature in the rolls may partly be due to the fact that the material being acted on enters the mill at a higher temperature than the room temperature, resulting from the material having been heated; for example, by being previously acted on by another mill, or from the effects of annealing the material. To this is added the heat due to overcoming internal molecular friction during the act of rolling and heat due to the surface friction between the rolls and material at all points in the passage of the material between the rolls where the surfaces of the material and rolls move at different speeds and heat due to friction of the roll necks in their journals. It will be readily understood that as the rolls heat up they expand or increase in diameter, causing a decrease in the bite or amount of clearance between the rolls and thus a decreased thickness or gauge of the material passing therebetween. This expansion of the rolls is apt to be greater where the rolls contact with the material than at points more remote therefrom, and accordingly the contours of the rolls vary as their temperatures vary.

In the present invention, the control of the roll temperatures, and therefore roll contours and gauge variations, is effected by providing means for transferring heat from a roll or rolls when the temperatures thereof are above a predetermined amount, and transferring heat to the roll or rolls when the temperatures thereof are below this predetermined amount, and the transfer of the heat from or to the rolls is controlled by means which is sensitive to changes in the temperatures of the rolls. In the preferred form disclosed herein, the transfer of heat is brought about by bringing hot or cold fluids into contact with the faces of the rolls, according to whether the rolls are to be heated or cooled, and the application of these fluids is controlled by a thermo-sensitive element which responds to changes in the temperatures of the rolls.

A suitable apparatus for the purpose in view may involve a hollow box-like element 12, in contact with the face of roll 8, closely adjacent the point where the material emerges from between rolls 7 and 8, and having an inlet 13 and an outlet 14 for cooling fluid, the passage of which to box 12 is controlled by balanced valve 15 in valve casing 16 having connected thereto a fluid supply pipe 17. Box 12 is open on the side adjacent roll 8 so that the cooling fluid may come into contact with the face of the roll, and is provided with longitudinal walls 18 and 19, which extend radially from the face of the roll 8, and an outer wall 20 which is concentric to roll 8 and which, in the drawings, is shown formed integrally with wall 18 and end walls 21 and 22. Wall 19 is received between the end walls 21 and 22 and adjustably supported on wall 20 by means of flange 23, bolts 24 being provided which pass through flange 23 and wall 20, in order to secure wall 19 in various positions of adjustment, wall 20 being provided with slots 25 through which the bolts 24 pass and which permit the adjustment to take place.

In order to control valve 15, and thereby the flow of cooling fluid through box 12, thermostatic bellows 26 is provided, connected to valve 15 by means of yoke 27 and valve stem 28, valve 15 being constantly urged into closed position by means of weight 29, adjustably mounted on the outer end of lever 30, the latter having a fulcrum point at 31 on lever 32, which is pivoted at 33 to frame 34, the opposite end of lever 30 engaging knife edge 35 on yoke 27. The thermostatic bellows 26 is secured to the upper end of frame 34, the lower end of the latter being mounted in any desired manner on valve casing 16.

Adjacent the surface of roll 8, and beyond box 12 in the direction of rotation of this roll, is a bulb 36 containing a thermo-sensitive fluid, bulb 36 being connected to thermostatic bellows 26 by means of pipe 37 which enters bulb 36 and terminates interiorly of bulb 36 near the bottom thereof. The thermo-sensitive fluid may consist of alcohol, ethyl ether or alcohol mixed with water, depending on the temperature range through which the regulator is to be sensitive. Bulb 36 is partially surrounded by casing 38 formed of heat insulating material, casing 38 having an open side directed toward roll 8 and being supported in or on the mill in any desired manner. The bulb 36 is surrounded in all directions, except in the direction of roll 8, by means of casing 38 so that the thermo-sensitive fluid is acted on by the heat of the roll but substantially unaffected by outside temperature conditions. In the preferred form shown, the bulb 36 is not directly in contact with the roll 8 but is spaced outwardly therefrom a short distance in order that it may not be affected by heat which would otherwise be generated through friction between these parts.

The operation of the device will be readily understood from the above description but will now be briefly described. Assuming that the several parts are in the position shown in Fig. 1, and that the temperature of roll 8 has risen above the normal working temperature, the excessive heat in roll 8 acting on the thermo-sensitive fluid in bulb 36 causes this fluid to vaporize or expand, exerting pressure on thermostatic bellows 26 through pipe 37. The pressure exerted on thermostatic bellows 26 causes the latter to expand, against the constant pressure of weight 29 acting through lever 30, forcing yoke 27 and valve stem 28 downwardly, opening valve 15 and permitting cooling fluid to pass from pipe 17, through valve casing 16, into box 12, where it comes into contact with roll 8 and finally flows

out through pipe 14. Roll 8 will now start to cool and as soon as this occurs the bulb 36 and the thermo-sensitive fluid therein likewise cool, finally causing the condensation of the vapor and the reduction of the pressure in the thermostatic bellows 26. When the temperature of roll 8 is normal the vapor pressure in the thermostatic bellows 26 is such as no longer to support weight 29 on lever 30, and the thermostatic belows contracts, closing valve 15, and stopping the flow of the cooling fluid. The provision of adjustable wall 19 in box 12 permits the cooling fluid to be brought into contact with a variable amount or particular portion of the roll surface in order to more closely control the effect of the cooling fluid on the roll. By adjusting weight 29 on lever 30 the valve 15 can be caused to open at a lower or higher temperature, as will be understood.

In certain cases, it may be desirable to control the temperature of the material entering the mill in order to insure that the material enters the mill at a constant predetermined temperature. A suitable means to this end may be provided by pipe 39, having a series of nozzles 40 through which heating or cooling fluids may be directed against the material M before it enters the mill. The application of these fluids to the material may be controlled in much the same manner as in the case of the fluid which flows through box 12 to roll 8, and may be briefly described as being controlled by valve 41, connected to the thermostatic bellows 42, which is connected by pipe 43, to bulb 44 containing a suitable thermo-sensitive liquid such as one of those mentioned above. Bulb 44 is mounted in any suitable manner closely adjacent to but separated from the lower face of material M, and surrounded on all sides, except in the direction of material M, by means of casing 45 formed of heat insulating material. If desired, trough 46 may be provided to collect the fluids after they have acted on material M, the fluids being carried away from the mill by pipe 47.

Up to this point in the description of my invention, I have been concerned with excessive temperatures which tend to expand the rolls of the mill and to cause decreased thickness in the material passing through the mill. It will be evident, however, that in case the mill rolls cool below their normal working temperatures they will contract, bringing about an increase in the size of the opening or pass between the rolls and increased thickness of the material which may thereafter pass through the mill until such a time as the rolls may regain their normal temperatures. The cooling of the mill rolls may occur through the mill standing idle during the night or during intervals when material is not passing between the rolls. Various attempts have been made to take care of this condition, it being a common expedient to provide an electrically heated jacket which is placed about the mill roll or rolls during the idle periods, but this manner of maintaining temperatures, as well as other expedients which have been proposed, is not very effective and requires skill and constant care and attention on the part of the mill operator.

According to this invention, it is proposed to control decreases in roll temperatures by transferring heat automatically to the roll or rolls of the mill when the temperatures thereof are below normal, and this transfer of heat is controlled by means which is sensitive to changes in the roll temperatures.

In carrying out this part of my invention, I provide a box-like element 48 for the heating medium, this element being substantially similar to box 12 and in contact with roll 8 closely adjacent the point where the material M enters between the rolls of the mill. Box 48 is provided with an inlet 49 and an outlet 50, the passage of the heating fluid, or other medium, being controlled by balanced valve 51, in valve casing 52, having connected thereto supply pipe 53. Connected to valve 51, by means of valve stem 54 and yoke 55, is a thermostatic bellows 56, mounted on frame 57, secured in any desired manner to valve casing 52, and connected to the interior of thermostatic bellows 56, is a pipe 65, leading to bulb 58, containing a suitable thermo-sensitive fluid, as for example one of those mentioned above, the bulb 58 being spaced slightly from the roll 8 and surrounded on all sides, except in the direction of roll 8, by means of casing 59 of heat insulating material. The pipe 65 enters bulb 58 and terminates interiorly near the bottom thereof. It is to be noted that in this case the expansion of the thermo-sensitive fluid in bulb 58, when the temperature of the roll is normal, or above normal, acting through pipe 65, on thermostatic bellows 56, closes valve 51, so that the latter permits heating fluid to flow into box 48 only when the roll temperature, and therefore the pressure on the fluid, is lower than normal. As a suitable means for opening the valve 51 when the thermo-sensitive fluid condenses or contracts during the periods when the roll temperature may be sub-normal, there is provided a lever 60 having one end in contact with knife-edge 61 on yoke 55 having an adjustable weight 62 on its outer end and an intermediate fulcrum point at 63 on lever 64, the latter being pivotally supported on frame 57. When the mill is in operation, the normal temperature of the roll 8 expands or vaporizes the thermo-sensitive fluid in bulb 58 sufficiently so that the pressure exerted thereby acting on thermostatic bellows 56, and against weight 62, keeps valve 51 closed and prevents the flow of hot fluid to box 48. When the temperature of the roll drops below normal, the fluid vapor contracts or condenses reducing the pressure in thermostatic bellows 56, whereupon weight 62, acting through lever 60, yoke 55, and stem 54, opens valve 51 and permits heating fluid to flow into box 48 where it comes into contact with the roll surface to heat the same, and then flows out through outlet 50.

In Fig. 5 I have shown a different type of element for bringing the heat transferring fluids into contact with the roll surfaces in which the boxes are replaced by a longitudinally extending pipe 66 having mounted thereon closely adjacent the roll 67 a series of nozzles 68, each controlled by an individual valve 69, and the flow of fluid to pipe 66 being controlled by a main valve 70 which may be similar to valves 15 and 51 and controlled in much the same manner. The nozzles 68 and valves 69 may be of any preferred type and are not shown herein in detail. With this form, the amount of heat transferring fluid brought into contact with the roll surface or the particular portion thereof to be heated or cooled may be varied by adjusting the individual valves controlling the flow of fluid through the nozzles, and in certain cases, especially where a narrow strip of material is being rolled, the application of heat transferring fluids to the ends of the roll may be dispensed with altogether by closing the valves at the ends of the pipe 66.

In Figs. 6 and 7 I have shown a box-like element somewhat similar to that shown in Fig. 2

of the drawings, but in which means is provided for varying the zone, in which the heat transferring fluids come into contact with the roll, longitudinally of the roll rather than circumferentially thereof. In this form, the box-like element 71 is substantially U-shape in cross-section, and is provided with longitudinally extending side walls 72 and 73, between which are received adjustable end walls 74 and 75, which are mounted on element 71 by means of longitudinally extending walls 76 and 77, which are integrally formed with respect to walls 74 and 75, and provided with slots 78 and 79 through which pass suitable securing means herein shown as bolts 80 and 81.

In the preferred form, the box-like or other element for bringing the heating fluid into contact with the surface of the roll is mounted in a position closely adjacent the point where the material enters between the rolls of the mill, in order that the heat may be transferred to a part of the roll surface immediately before such part engages the material, while the cooling box or other means for bringing the cooling fluid into contact with the roll is mounted closely adjacent the point where the material emerges from between the rolls, in order that the excessive heat may be carried away before it has an opportunity to penetrate into the interior of the roll to any great extent. The thermo-sensitive elements are mounted in contact with the roll surface between the cooling and heating boxes, although this arrangement may be varied to a considerable extent. For instance, in certain cases, it may be found desirable to place the thermo-sensitive element for controlling the heating fluid in a position closely adjacent the point where the material enters between the rolls in order that it may be controlled by the temperature of the roll immediately preceding the engagement of the roll with the material.

In Fig. 8 I have shown apparatus of the kind described in connection with Fig. 1, applied to the lower roll of a mill as well as the upper roll.

The apparatus described herein is capable of maintaining roll temperatures within very narrow limits owing to the flexibility of the controlling means. The weights acting on the thermostatic bellows are adjustable, so that the thermostatic bellows may be brought into operation at various pressures corresponding to different temperatures of the rolls, while the adjustability of the cooling and heating boxes provides a ready means for controlling the effect of these fluids on the rolls.

Although I have shown and described herein a particular form of thermo-sensitive element, it will be readily understood that the valves controlling the transfer of heat from and to the rolls may be controlled by other forms of thermostats.

It will be further understood from the foregoing description of the invention and its mode of operation that my improved method and apparatus, while particularly desirable in controlling the temperatures of the rolls of a rolling mill, is not limited thereto, but may be applied to various situations where it is important to maintain constant temperatures.

While I have shown and described some preferred embodiments of my invention, it will be understood that the same is not limited to the exact details shown but is capable of many modifications and variations which will lie within the spirit of the invention and the scope of the appended claims.

I claim:

1. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising means associated with at least one of said rolls adapted to transfer heat thereto when the temperature of the roll drops below a predetermined normal temperature, and a thermo-sensitive element associated with the roll surface and subjected to the temperature changes in the latter, said thermo-sensitive element controlling the flow of heat to said roll through said heat transferring means.

2. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising means associated with at least one of the rolls at the surface thereof adapted to transfer heat thereto when the temperature of the roll drops below a predetermined normal temperature, and a thermo-sensitive element associated with the roll surface and subjected to the temperature changes in the latter, said thermo-sensitive element controlling the flow of heat to said roll through said heat transferring means.

3. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising means for bringing a cooling fluid into contact with the working surface of at least one of the rolls, a thermo-sensitive element associated with said roll and subjected to the temperature changes at the working surface of the latter, and a connection between said thermo-sensitive element and said means for bringing a cooling fluid into contact with said roll, whereby the flow of the fluid is controlled by said thermo-sensitive element.

4. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising means for bringing a heating fluid into contact with the working surface of at least one of the rolls at one point circumferentially thereof, a thermo-sensitive element associated with the roll surface at another point circumferentially thereof and subjected to the temperature changes in the latter, and a connection between said thermo-sensitive element and said means for bringing a heating fluid into contact with said roll, whereby the flow of the fluid is controlled by said thermo-sensitive element.

5. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising means for bringing heating and means for bringing cooling fluids into contact with at least one of said rolls according to the variations in the temperature of the roll below or above the normal working temperature of the roll, and means associated with said roll and actuated by changes in the temperature conditions in a limited portion of the roll for controlling the flow of cooling and heating fluids.

6. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising a heat transferring element associated with at least one of said rolls, said heat transferring element including adjustable means for varying the size of the zone from which the heat transfer takes place, and a thermo-sensitive element associated with the roll surface and subjected to localized temperature changes in the latter, said thermo-sensitive element controlling the flow of heat through said heat transferring means.

7. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising means associated with at least one of said rolls adapted to transfer heat therefrom when the temperature of the roll rises above a predetermined amount, said means including means for varying the size of the zone from which the heat is transferred, and a thermo-sensitive element associated with said roll within said zone and subjected to the temperature changes in the latter, said thermo-sensitive element controlling the flow of heat from said roll through said heat transferring means.

8. In an apparatus for controlling the temperature of a roll of a rolling mill for strips of metal or the like, means associated with said roll adapted to transfer heat therefrom when the temperature of the roll rises above a predetermined amount, said means including means for varying the size of the zone from which the heat is transferred, and a thermo-sensitive element associated with said roll and subjected to the temperature changes in that portion of the latter which contacts with the strip, said thermo-sensitive element controlling the flow of heat from said roll through said heat transferring means.

9. The method of controlling the temperature of material passing through a rolling mill, which comprises transferring heat from the material when the temperature thereof rises above a predetermined amount, and controlling the transfer of heat from the material by the temperature conditions in the latter.

10. The method of controlling the gauge of material delivered by the rolls of a rolling mill, which comprises delivering the material to the mill at a constant predetermined temperature, transferring heat from a roll of the mill when the temperature thereof rises above a predetermined temperature, and controlling the transfer of heat from the roll by the temperature conditions at the surface of the roll.

11. The method of controlling the gauge of material delivered by the rolls of a rolling mill, which comprises delivering the material to the mill at a constant predetermined temperature, transferring heat to a roll of the mill when the temperature at the surface thereof drops below a predetermined temperature, and controlling the transfer of heat by the temperature conditions at the roll surface.

12. The method of controlling the gauge of material delivered by the rolls of a rolling mill, which comprises delivering the material to the mill at a constant predetermined temperature, transferring heat from or to the rolls according to whether the temperature conditions at the surfaces of the latter are above or below predetermined temperatures, and controlling the transfer of heat by the surface temperature conditions in the rolls.

13. The combination with the rolls of a sheet mill, of a device contacting the roll surface responding to changes of roll temperature during rolling, and heat transfer apparatus controlled by said device to control local variations in the spacing of the opposing working surfaces of the rolls.

14. In an apparatus for controlling the contours of a roll of a rolling mill, heat transferring elements associated with predetermined portions of the roll surface, and thermo-sensitive elements associated with the roll and subjected to the temperature conditions of the predetermined portions of the roll surface, said thermo-sensitive element controlling the transfer of heat through the heat transferring elements to control the roll contours.

15. In an apparatus for controlling the temperature of a roll of a rolling mill for a strip of metal or the like, means for bringing heating and means for bringing cooling fluids into contact with said roll, means associated with said roll for controlling the flow of cooling and heating fluids, said means being actuated by changes in the temperature conditions in that portion of the roll which contacts with the material operated on, and means for varying the areas of the roll surface with which the heating and cooling fluids come into contact.

16. The combination with the rolls of a sheet mill, of a device associated with at least one of said rolls and in contact with the metal-engaging roll surface which is responsive to changes of roll temperature during rolling, and heat transfer apparatus controlled by said device for varying the roll temperature so as to maintain the roll bite within certain dimensional limits during rolling and thereby control the gauge.

17. The combination with the rolls of a strip mill, of devices adjacent the metal-contacting roll surfaces responding to changes of roll temperature during rolling, heat transfer devices for varying the roll surface temperature in both directions by transfer of heat to and from the roll, and operative means of connection between said heat transfer devices and said temperature-responsive devices for controlling said heat transfer devices automatically.

18. The combination with the rolls of a strip mill, of devices responding to changes of roll temperature during rolling, located in proximity to the surface of at least one of said rolls and disposed at different points on said roll, apparatus for varying the surface temperature of said roll by transfer of heat to and from the roll through a fluid applied to the roll face, and operative means of connection between said heat transfer apparatus and said temperature-responsive devices for controlling automatically the gauge being rolled.

19. The combination with the rolls of a strip mill, of means responding to changes of roll surface temperature during rolling, a source of roll heating fluid, a source of roll cooling fluid, and heat transfer apparatus associated with said fluid sources and controlled by said temperature-responsive means for heating at least one of said rolls by the application of heating fluid to its face when the roll temperature falls below a predetermined limit, and for cooling said roll by the application of cooling fluid to its face when the

temperature of the roll rises beyond a predetermined limit.

20. In a mill for rolling metal, the combination with a pair of metal reducing rolls having a bite through which the material passes, of automatic mechanism for counteracting temperature changes in the rolls to maintain the bite at a predetermined size, including devices for applying hot and cold fluids exteriorly to at least one of the rolls as required by changes in the rolling conditions, and thermo-responsive means adjacent the metal-contacting roll surfaces for automatically controlling the application of said fluids to said roll.

21. The combination with a strip mill, of devices associated with said mill adjacent the metal-contacting roll surfaces which are responsive to changes of roll temperature during rolling, a heat transfer device controlled by one of said first-named devices for decreasing the roll temperature when it rises above a predetermined limit, and a heat transfer device controlled by the other of said first-named devices for increasing the temperature of the roll automatically when it falls below a predetermined limit, said devices acting in cooperation with each other automatically to maintain the material being rolled at a substantially uniform gauge.

22. Means for controlling the gauge of strip metal as the same is rolled, comprising, in combination with the rolls of a strip mill, a device for changing the surface temperature of at least one of the rolls by transfer of heat through a fluid medium applied to the roll face, a thermo-responsive device in proximity to the surface of the roll at one point in the periphery thereof and located in line with the metal strip passing through the mill, and an operative connection between said thermo-responsive device and said heat transfer device for effecting a change in the roll temperature automatically through the heat transfer device when the gauge of the material being rolled tends to vary.

23. The combination, with a strip mill, of means for setting the rolls of said mill at a bite of given size, means for decreasing the size of the roll bite by the application of a heating medium to at least one of the rolls, means for increasing the size of the roll bite by the application of a cooling medium to at least one of the rolls, and means responsive to surface temperature changes of the rolls for controlling said bite size changing means automatically so as to maintain the bite size within predetermined limits.

24. The combination with a rolling mill, of apparatus associated with the rolls to vary the temperature of at least one of the rolls in a sense tending to reestablish the initial size of the pass as the temperature of said roll rises or falls beyond a predetermined limit, and roll surface contacting means responsive to changes of roll temperature during rolling to control the operation of said apparatus automatically.

25. The combination with a rolling mill, of apparatus associated with the rolls to vary the temperature of at least one of the rolls by the application of a heating fluid or a cooling fluid to the exterior to reestablish the initial size of the pass as the temperature of said roll rises or falls beyond a predetermined limit, and means adjacent a metal-contacting roll surface responsive to changes of roll temperature during rolling to control the operation of said apparatus automatically.

26. The combination with a rolling mill, of apparatus associated with the rolls to vary the temperature of at least one of the rolls in a sense tending to reestablish the initial size of the pass as the temperature of said roll rises or falls beyond a predetermined limit, roll face contacting means responsive to changes of roll temperature during rolling to control the operation of said apparatus automatically, and means for adjusting the length of that portion of the roll whose temperature is varied by said apparatus.

27. In a rolling mill for metal, the combination of a pair of rotatable rolls between which the metal passes, and means for controlling the size of the pass between the rolls to produce uniform gauges in the metal, comprising a heat-transferring element associated with at least one of said rolls at the surface thereof, and a thermo-sensitive element associated with said roll and subjected to the temperature changes of the latter at the working surface thereof, said thermo-sensitive element controlling the flow of heat through said heat-transferring element.

28. The combination with a rolling mill, of apparatus associated with the rolls to vary the temperature of at least one of the rolls in a sense tending to reestablish the initial size of the pass as the temperature of said roll rises or falls beyond a predetermined limit, and means adjacent the metal-contacting surface of a roll responsive to changes of roll temperature during rolling to control the operation of said apparatus automatically, said apparatus being adjustable to vary the heat of the roll at different points in the length thereof.

29. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating agent externally to the longitudinally central portion of the rolls, means for applying a cooling agent externally to the longitudinally central portion of the rolls, valve means controlling the heating and cooling means, thermostatic means controlling the valve means, and thermal bulb means held adjacent the working surfaces of the rolls and operating the thermostatic means.

30. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating medium to the outer working surfaces of the rolls, means for applying a cooling medium to the outer working surfaces of the rolls, and means controlled by the temperature of the outerworking surfaces of the rolls for operating the means for applying heating and cooling mediums.

31. In combination with a rolling mill for rolling metal and having solid rolls therein, means controlled by the temperature of the outer working surfaces of the rolls for applying a heating agent to said working surfaces when the temperature of the working surfaces drops to a predetermined temperature, and for applying a cooling agent to the outer surfaces when their temperature rises to a predetermined temperature.

32. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating medium to the outer working surfaces of the rolls, valve means controlling said heating means, means for applying a cooling medium to the outer working surfaces of the rolls, valve means controlling said cooling means, thermostat means controlling the valve means, and thermal bulb means operated by the temperature of the outer working surfaces of the rolls and controlling the thermostat means.

33. In combination with a rolling mill for roll-

ing metal and having solid rolls therein, means for applying a heating medium to the outer working surfaces of the rolls, valve means controlling said heating means, means for applying a cooling medium to the outer working surfaces of the rolls, valve means controlling said cooling means, and thermostat means controlled by the temperature of the outer working surfaces of the rolls for controlling the valve means.

34. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a cooling medium to the outer working surfaces of the rolls, and means controlled by the temperature of the outerworking surfaces of the rolls for operating the means for applying the cooling medium.

35. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating medium to the outer working surfaces of the rolls, and means controlled by the temperature of the outer working surfaces of the rolls for operating the means for applying the heating medium.

36. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating agent externally to the longitudinally central portion of one of the rolls, a valve controlling the heating means, means for applying a cooling agent externally to the longitudinally central portion of one of the rolls, a valve controlling the cooling means, thermostatic means controlling the valves, thermal bulb means operating the thermostatic means, and means holding the thermal bulb means in contact with the outer surface of one of the rolls.

37. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating medium to the outer working surface of one of the rolls, means for applying a cooling medium to the outer working surface of one of the rolls, valve means controlling said heating and cooling means, and thermostatic means controlled by the temperature of the outer working surfaces of the rolls for controlling the above-mentioned valve means.

38. In combination with a mill for cold rolling of metal having a pair of rolls, means for applying a heating fluid to the outer working surfaces of the rolls, means for applying a cooling fluid to the outer working surfaces of the rolls, valve means controlling said fluid-applying means, and thermostatic means controlled by the temperature of the outer working surfaces of the rolls for controlling the above-mentioned valve means.

39. In combination with a mill for cold rolling of metal having a pair of rolls therein, means for applying a heating fluid to the outer working surfaces of the rolls, and means controlled by the temperature of the outer working surfaces of the rolls for operating the fluid-applying means.

40. In combination with a mill for rolling metal having a pair of rolls therein, means for applying a heat transfer medium to the material entering said rolls, and means subject to the temperature of said material for controlling the application of such medium.

41. In combination with a mill for rolling metal having a pair of rolls therein, means for applying a heat transfer fluid to the material entering said rolls, and means subject to the temperature of said material for controlling the application of such fluid.

42. The combination with a rolling mill of apparatus associated with the rolls to vary the temperature of at least one of the rolls in a sense tending to reestablish the initial size of the pass as the temperature of said rolls passes a predetermined limit, and means adjacent a roll working surface responsive to changes of roll surface temperature during rolling to control the operation of said apparatus automatically.

43. In combination with a rolling mill for cold rolling metal and having solid rolls therein, means for supplying heat to the outer working surface of one of the rolls, and means adjacent the metal-contacting roll surface for setting said means in operation when the temperature of said roll falls below a predetermined limit.

44. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a cooling medium to the outer working surfaces of the rolls, means controlled by the temperature of the outer working surfaces of the rolls for operating the means for applying the cooling medium, and means for varying the area of the rolls to which the cooling medium is applied.

45. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating medium to the outer working surfaces of the rolls, means controlled by the temperature of the outer working surfaces of the rolls for operating the means for applying the heating medium, and means for varying the area of the rolls to which the heating medium is applied.

46. In combination with a rolling mill for rolling metal and having solid rolls therein, means for applying a heating medium to the outer working surface of one of the rolls, means for applying a cooling medium to the outer working surface of one of the rolls, valve means controlling said heating and cooling means, thermostatic means controlled by the temperature of the outer working roll surface for controlling the above-mentioned valve means, and means for adjusting the length of that portion of the roll surface affected by the heating and cooling mediums.

47. In a rolling mill for the rolling of sheets by a cold process, and in combination with one of the rolls of said mill, means for applying a body of heating fluid to the outer working surface of the roll, means for applying a body of cooling fluid to the outer working surface of the roll, valve means controlling said fluid-applying means, thermostatic means controlled by the roll working surface temperature for operating the above-mentioned valve means automatically so as to maintain the roll bite within predetermined dimensional limits, and adjustable means for varying the length of roll surface affected by the heating and cooling fluids.

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