Jan. 29, 1929. 1,700,267

W. R. KNEELAND

HOT MILL STRUCTURE AND OPERATION

Filed March 17, 1927 2 Sheets-Sheet 1

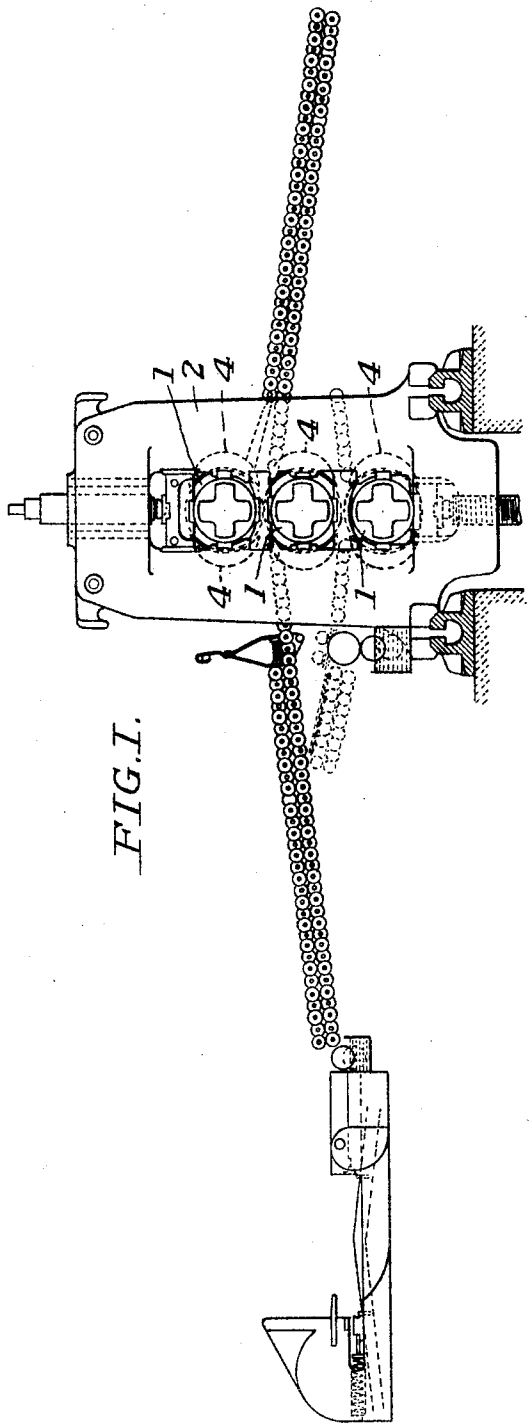


FIG. I.

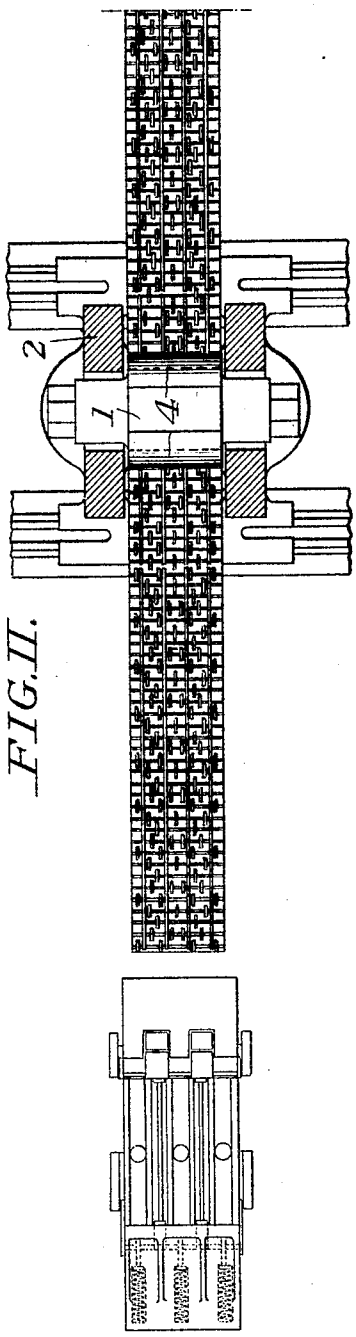


FIG. II.

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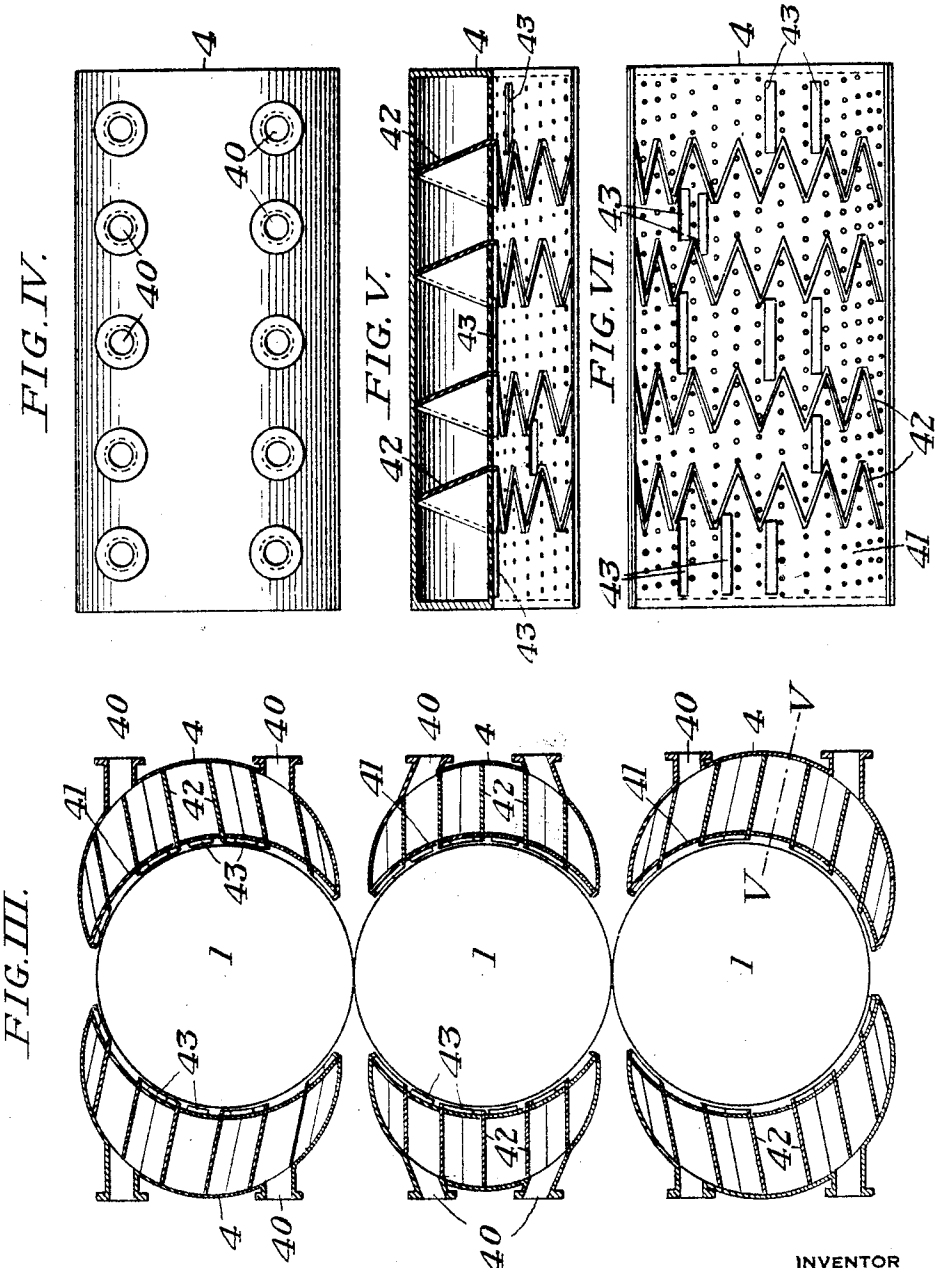
Attys.

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HOT MILL STRUCTURE AND OPERATION

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UNITED STATES PATENT OFFICE.

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HOT-MILL STRUCTURE AND OPERATION.

Application filed March 17, 1927. Serial No. 176,081.

My invention relates to improvements in hot-mill structure and operation. The objects in view are diminution of loss due to the breaking of rolls, improvement in the quality of and particularly in the uniformity in the thickness of the rolled material, and enlarging the practical limits upon the size to which the sheets of material may be rolled. The gaining of these ends effects obvious improvements in product and economies of operation.

In the accompanying drawings Fig. I is a view in elevation and Fig. II a view in plan of a hot-mill in which and in the operation of which my invention is embodied and achieved. Fig. III is a diagrammatic view, in which the rolls of the mill are indicated, in position corresponding to Fig. I, and certain shields in which my present invention is in part embodied are shown in vertical and transverse section. Figs. IV, V, and VI show one of the shields in detail; Fig. IV is a view of the shield in rear elevation, Fig. V a view in approximately horizontal and medial section, (indicated at V—V, Fig. III) and Fig. VI a view in front elevation.

A hot-mill is a steel mill for rolling light plates and sheets of steel. Its characteristic is that during the rolling operation its rolls are not, as are the rolls of a plate mill, cooled by streams of water poured upon them. In preparation for the rolling operation the rolls are heated to a temperature approximating, though somewhat less than, the temperature of the material to be rolled; and the heat which the rolls in the progress of the rolling operation take up, is given off again merely by radiation to the surrounding air. A typical procedure in hot-mill operation as hitherto practiced, is as follows: From forty to fifty bars cut to proper length are charged into a bar heating furnace. These bars are for ordinary sheet rolling for tinning, uniformly 8 inches wide. Their length is that of the width of the ultimate sheet, and this for practical reasons presently to be considered has hitherto been limited to 28 inches. The bars vary in thickness from $\frac{3}{8}$ to $\frac{5}{8}$ of an inch, according to the length desired for the rolled sheet.

The heated bars are taken from the furnace two at a time and are entered singly into the mill. They pass through the mill singly, each from four to six times. These are called the roughing passes. The roughed bars are introduced into a second heating furnace, from which when heated they are taken two by two, matched, and passed twice through the mill. These passes which constitute the second rolling step are called the matching passes or the run-over passes. The two pieces of material thus further attenuated, as they come from the run-over passes are pulled apart, placed together again and doubled. That is to say they are folded on the transverse mid-line, and so are made into a pack of four sheets. This pack is returned to the same furnace in which the roughed bars were reheated, and when brought to rolling temperature again, is taken from the furnace and passed twice through the mill. These passes which constitute the third rolling step are called the fours. After this the pack is again opened, that is to say, the component sheets are pulled apart from their free toward their folded edges and adhesions are broken. The pack then is doubled again and becomes a pack of eight sheets. This pack at one end consists of four free sheets and four sheets with folded edges. The pack at this end then is sheared, so that the edges of all the eight sheets are at this end free. The pack is reheated, and then is passed through the mill from three to five times, and in these passes which constitute the fourth rolling step, called finishing passes, the hot-rolling is completed. The rolled pack is sheared and cut, and the component sheets are torn apart. In the tearing apart the sheets are necessarily more or less mutilated, and many are on account of adhesions and mutilations rejected.

The operation of hot rolling is attended by danger to the rolls; danger of breaking, and danger of the development of small cracks ranging from $\frac{1}{16}$ inch to $\frac{5}{32}$ inch deep. These cracks covering the surface of the roll give to it superficially a crazing on approximately cubically disposed planes of cleavage, the cubes ranging from about ¼ inch to ⅜ inch in size.

When a roll breaks the entire train of mills has to be stopped and considerable time is lost. The value of the roll will be from $400.00 to $700.00, and the loss in production may total one to two hours for six to eight mills, so that it is very costly. In addition, each of such stops endangers every other roll in the other mills. The rolls used range from 28 inches to 32 inches in diameter and from 30 inches to 84 inches long, they are made of cast iron with a chilled surface and are very

hard. The metal has practically little or no elasticity. The high temperature of 750° to 900° or 1000° F. at which they work means considerable expansion, and as the temperature cannot be uniform throughout the casting, the metal is of necessity under considerable stress at all times. As an example, when the rolling operation begins, the surface metal of the roll is expanded both circumferentially and longitudinally, and as the heat penetrates expansion progresses from the surface inward. If such accession of heat be too rapid the roll will be fractured at the center, and due to the inelastic nature of the material the shock will continue the fracture to the surface, and the roll will be broken in two at about its middle. In other words, the roll will be pulled apart at the center when the tension of the expanding outer metal becomes greater than the tensile strength of the unexpanded core.

When a thoroughly heated and equally expanded roll is stopped heat begins to be radiated, and an opposite effect takes place. In this case it is the surface metal which first contracts and its contraction, resisted by the still expanded center, brings about a condition of tension. If the contraction be slow enough, so that the tensile strength of the cooler parts is not exceeded, nothing happens; but if the contraction be a little too fast, numerous fractures deep enough to give relief to strain, appear in the surface. As such contraction and tension involve all of the superficial portions of the roll, so will the small cracks (termed crazing) be distributed; and since the tension is about equal both around and lengthwise of the roll, the crazing takes a cubic form, from cracks running lengthwise caused by tension around its circumference, and cracks running around the roll caused by tension lengthwise of its barrel. Those running around the roll are numerous, and in proportion to the ratio of the length of the barrel of the roll to its diameter. Such crazing occurs when rolls heated to a temperature of about 700° or more are allowed to cool in the open air. When rolls are hotter and are allowed to contract faster, or when some rapid means of conducting away the heat are applied to the face of a roll, the contraction becomes so rapid that one or more cracks are produced of considerable depth and length running around the roll. They may be from a half an inch deep and six or seven inches long up to seven to ten inches deep and include half the circumference. Such a crack may completely fracture the roll at once, but if it does not, the crack soon grows to a complete fracture by being torn deeper and longer each time the roll is subjected to the strains of rolling. These cracks are called fire cracks and are responsible for practically all broken rolls. The exceptions are very few. In actual practice roll breakage is proportionate to roll length. The strains are greater as roll length increases and the strains are greater as the range of temperature increases, and the temperature range increases as thicker and hotter packs are rolled. The matter is further complicated by the greater spring in longer rolls, due to longer distance between bearings, and by such increase in strain as is incident to the rolling of a larger and more cumbersome pack.

In the practice of rolling sheets for tinning, the bars are roughed at a temperature of 1400° to 1450°; the matching passes and the fours are rolled at about 1300°; and the material goes through the finishing passes at about 1200° F. The roughing is done very quickly; all the bars in a heat, say twenty to twenty-four pairs, are put through in eight or ten minutes, and, because of the high temperature of the material, the rolls then reach their maximum temperature. The rolling of the matching passes and of the fours is accomplished with relatively little consumption of time, and with little diminution of roll temperature. In the finishing passes, however, much more time is consumed, because of the greater length which the material has attained. The actual passage through the mill consumes more time, and the material because of the attenuated form which it has assumed requires more careful handling and slower handling by the mill crew. And time is lost in other ways—in measuring the length of the pack, for example. In consequence, there is a greater temperature drop during the finishing step than during any other part of the rolling operation. The material enters the finishing pass at about 1200° F. and is finished at about 1000° F. This fourth or finishing step of the rolling operation is the step during which the rolls are in greatest jeopardy. The pack then is relatively thin and cold, and the rolling pressure is many times greater than at the beginning. Rolls are most frequently broken during the finishing step in the rolling operation, and breakage occurring at other times is often properly attributable to injury which the roll has sustained in the finishing step upon a preceding heat or run of material. When, as often happens, the continuity of mill operation is interrupted for a longer or shorter period of time, the rolls cool and then when rolling is resumed they are peculiarly liable to break, from fire crack caused by contraction during that period.

In practicing my invention I provide a shield covering the roll surface to the greatest possible extent. The shield serves primarily to protect the roll from drafts and currents of outside air. I provide with the shield means for blowing through it and upon the surface of the roll streams of air or other

gaseous fluid of properly regulated temperature. Thus radiation of heat from the roll surface may be controlled and arrested, or even a condition of absorption of heat by the roll may be set up.

In Fig. I of the accompanying drawings the rolls 1 of a three-high mill are shown in end elevation, carried in the housing 2. The shields to which I have alluded are indicated at 4. The arrangement of the shields with respect to the rolls more clearly appears in Fig. III, and in Figs. III–VI the structure of the shields is shown in detail. The shields in cross-section are crescent-shaped, the inner curve conforms to the curvature of the roll surfaces; they are spaced from the roll surfaces at a slight interval, and they extend circumferentially around the roll surfaces. It will be understood that they extend longitudinally of the roll, preferably from end to end. So much of the roll may thus be shielded as is conveniently possible, without interference with other features of structure and operation.

The shields are hollow; they are provided with conduits 40, entering through the rear walls, through which air (or other suitable gas) may be blown, and the shields may be faced with foraminate plates 41, through which the in-blown air may be spread, as it flows out upon the surfaces of the rolls. The shields may be divided interiorly into chambers arranged in succession longitudinally of the roll and the conduits 40 may lead to the several chambers. The dividing partitions 42 between the chambers may at their outer edges and adjacent the roll surfaces be zig-zagged, and as the drawings indicate, the partitions may extend outwardly beyond the face plates 41 of the shields, and to nearer approach to the roll surfaces. By such provision streams of air to effect heating or cooling or retardation of heating or of cooling may be directed upon the surfaces of the rolls. Such streams may be concentrated upon the mid-areas in the length of the roll, or they may alternately be concentrated upon areas toward the ends of the roll bodies. And by virtue of the zig-zag shape of the partitions the localized effect of streams of air upon the roll body may toward the edges of the areas played upon be caused to grade gradually away. Hot or cold air or other gaseous fluid may be supplied to the shields by any well-known and preferred means. Additionally or alternatively the shields themselves may be provided with hot elements such as electrically heated coils 43, arranged adjacent the roll surfaces and constituting roll heating means.

In operation cold air may be blown upon the surface of the roll as it rises from contact with the relatively hot material in the roll pass, and the cold air may be so blown upon the roll surface, in such quantities and at such temperature and during such portion of the path of revolution, that the heat taken up by the roll surface in the roll pass will immediately be taken away, and will not penetrate the roll body more deeply. And of course the play of such a cooling stream upon the roll surface will not be continued beyond the point necessary or for a time greater than that necessary, to carry away the excess heat and to maintain the roll otherwise at substantially the desired normal temperature. The flow of such a cooling stream may obviously be brought under automatic control, so as to act upon the roll during those periods of time only when the roll carries accretions of heat. That is to say, sequent upon the advance of the material from the roll pass and the relief of the strain of rolling, the supply of such cooling streams of air will be cut off.

In contrast to such a cooling stream, streams of hot air may by the means indicated and described flow over the roll surface at such times as may be desired. At times when the rolling operation is intermitted the rolls may by means of the heating elements described be for indefinite lengths of time maintained at rolling temperature, or even by such means they may initially be brought to rolling temperature.

I have already explained that the greatest danger to the rolls is that due to cooling, at the time of the fourth or finishing step of the sheet rolling operation. Having provided the shield of my invention, particularly if it be adapted to deliver a stream of hot air upon the roll surface, I am able to prevent cooling of the roll during this step, and so to relieve the danger. And in addition, the rolls may be maintained hotter at this time, and in consequence the packs under rolling operation may be kept hotter. The working of the material may thus be made easier, and particularly the good end is gained, that the outside sheets of the pack will then be rolled more nearly to the same length as the inside sheets.

The roll of a mill in operation tends to become hottest at the mid-point in its length, and to expand most at that point. It is for this reason that rolls are turned to a diameter which diminishes slightly from ends to middle, so that in operation the roll body will become more perfectly cylindrical. But a chilled roll does not manifest throughout its life an invariable response to thermal conditions; after each successive heating there is less contraction toward the initial dimensions. It is on this account that new and old rolls cannot be successively matched together. When a new pair of rolls goes into service only narrow packs may be rolled, because of the then maximum effect of the turning of the roll, with diminished diameter toward the mid-point in its length. As the rolls grow

hotter, the width of the packs may be increased, until the full width is reached. This maximum width may be maintained for a time, and then the rolls begin to manifest greater wear away toward the middle. This is because of the fact that toward its middle the roll is hottest. The width of the pack rolled must then be reduced again. By the adoption of the shields in which my invention centers, and by operating them in the manner I have described, it is possible to turn the rolls initially to more perfectly cylindrical form and, by control of heating and cooling streams, to maintain through periods of time exceeding earlier possibilities, this substantially perfect cylindrical form. Packs of maximum width may be rolled with a given pair of rolls through longer periods of service, with economy of operation and increase of tonnage. The rolls properly turned may be so mounted as not to touch at any part, and in consequence a better roll surface may be maintained, and this through longer periods of service.

By so controlling and maintaining roll diameter it becomes possible to introduce the bars and packs to the roll passes at somewhat lower temperature than present-day practice requires, and still to operate with such expedition that at the completion of the operation the material is hotter than in the present-day practice it now remains; it becomes possible to roll packs of greater width, and, handling the material mechanically in place of manually, to roll packs of greater length, and packs composed of a greater number of sheets. In place of a pack of eight sheets of the present maximum permissible size of 28 x 72 inches, it becomes entirely practicable to roll a pack of twenty sheets 56 x 144 inches. The consequent gains in speed and mill capacity, in reduction in the number of reheatings, in uniformity of product, in reduction of the number of surface sheets, in reduction in the quantity of waste and scrap and trimmings,—all this, apart from the economies of mechanical as distinguished from manual feeding,—becomes apparent.

In the rolling of high grade sheets it is desirable to roll at as low a temperature as possible, in order to reduce to a minimum the amount of scale formed and also to avoid as completely as possible tearing, slivering, kinking, etc. caused by sticking. With the rolling of relatively cooler packs, as is the case in the practice of my invention, the rolls do not reach so high a temperature, and from the standpoint of reduction and elongation as well as the equal length of the surface sheets it would be more desirable that the rolls be hotter, giving a "keener" mill as operators term it. This desirable end may be attained by using the heating element of my invention, even while rolling packs of low temperature. Such use of the heating element will not interfere with maintenance of the proper shape of the rolls, as that maintenance of shape is governed by the blowing of humid air, as described. The two features of the heater element and the inblown stream of air will then be in operation at the same time.

My invention so far as concerns the thermal condition of the rolls accordingly lends itself to the mechanical handling of the material, and the invention is realized in its perfection in a mill in which the provisions concerning roll temperature are combined with provisions for handling larger and heavier units.

The invention as thus far described centers in the shield, from which air or other gas may be blown, to keep the rolls while in service from becoming too highly heated, a shield composed of compartments, from any one or more of which air may be blown, to keep the roll in certain portions from expanding too greatly and to maintain a particular optimum contour; a shield which screens the roll and protects it from outside drafts or currents of air, and which, enclosing the roll and confining an envelope of air next to the roll surface, prevents rapid radiation of heat and consequent too rapid contraction of the exterior portions of the roll body upon a still relatively hot and expanding interior portion; a shield equipped with heating means arranged adjacent the roll surface, for the purpose, first, of initially heating the roll before the rolling operation begins; second, of heating differentially one portion of the roll body relatively to another while the rolling operation is in progress, and so maintaining a desired roll contour; third, of raising the body of the roll to a temperature higher than that to which it otherwise would be brought; fourth, of keeping the roll hot and of maintaining it in proper shape during intervals when the rolling operation is interrupted; and, finally, of helping to effect gradual contraction when the rolling operation has been completed.

In Fig. I, I show associated with the rolls of the rolling mill conveyor tables for the mechanical handling of the material in course of rolling. Such mechanical handling apparatus is in its general features known. Particular features of the apparatus shown are made the subject-matter of a companion application for Letters Patent, filed March 17, 1927, Serial No. 176,082. It suffices here to indicate that by the use of such mechanical material-handling apparatus the economies consequent upon the control of roll temperature as described above may be realized in largest measure.

I claim as my invention:

1. The method of rolling herein described comprising maintaining within the body of a roll of a hot-mill a condition of better uniformity of temperature by causing a stream of cooling fluid to play upon the surface of

the roll as the surface recedes from the surface of the article being rolled and cutting off the flow of the stream when the article being rolled passes from beneath the action of the roll, and passing the article to be rolled through said rolls the temperature of which has been thus regulated.

2. The method of rolling herein described comprising maintaining within the bodies of the cooperating rolls of a hot-mill conditions of better uniformity of temperature by causing streams of cooling fluid to play simultaneously upon the surfaces of the rolls as the surfaces recede from the surfaces of the article being rolled and cutting off the flow of the streams when the article being rolled passes from the roll pass, and passing the article to be rolled through said rolls the temperature of which has been thus regulated.

3. In a rolling mill and in combination with a roll body of an elongate box crescent-shaped in cross-section and including inner and outer curved walls different in radius of curvature, the inner wall of the crescent-shaped box corresponding in curvature to the roll surface, and being perforate, and the box being arranged with the said inner wall in proximity to the roll surface, and means for maintaining within the box a supply of temperature-controlling fluid.

4. The structure of claim 3, together with a heating element arranged between the inner wall of the box and the roll surface.

5. The structure of claim 3, together with a partition extending transversely and in zigzag course within the box.

6. In a rolling mill and in combination with a roll body of a shield extending circumferentially of and longitudinally of and adjacent to the roll body, the shield being box-like in structure opening toward the surface of the roll, a partition extending in devious course within the shield and dividing the space within into independent chambers arranged in succession longitudinally of the roll, and means for causing gaseous streams to flow through the said chambers and over the outer surface of the roll body.

7. In a rolling mill and in combination with a roll body, two elongate boxes extending longitudinally of and circumferentially of the roll and arranged on opposite sides of the roll, each box being divided internally into a succession of chambers longitudinally of the roll, the wall of the box adjacent the roll surface being perforate, and means for supplying streams of temperature controlling fluid through the box and to the roll surface.

In testimony whereof I have hereunto set my hand.

WALTER R. KNEELAND.