Dec. 6, 1938. S. BADLAM 2,139,483

METHOD OF ROLLING FLAT MATERIAL

Filed July 2, 1935 3 Sheets-Sheet 1

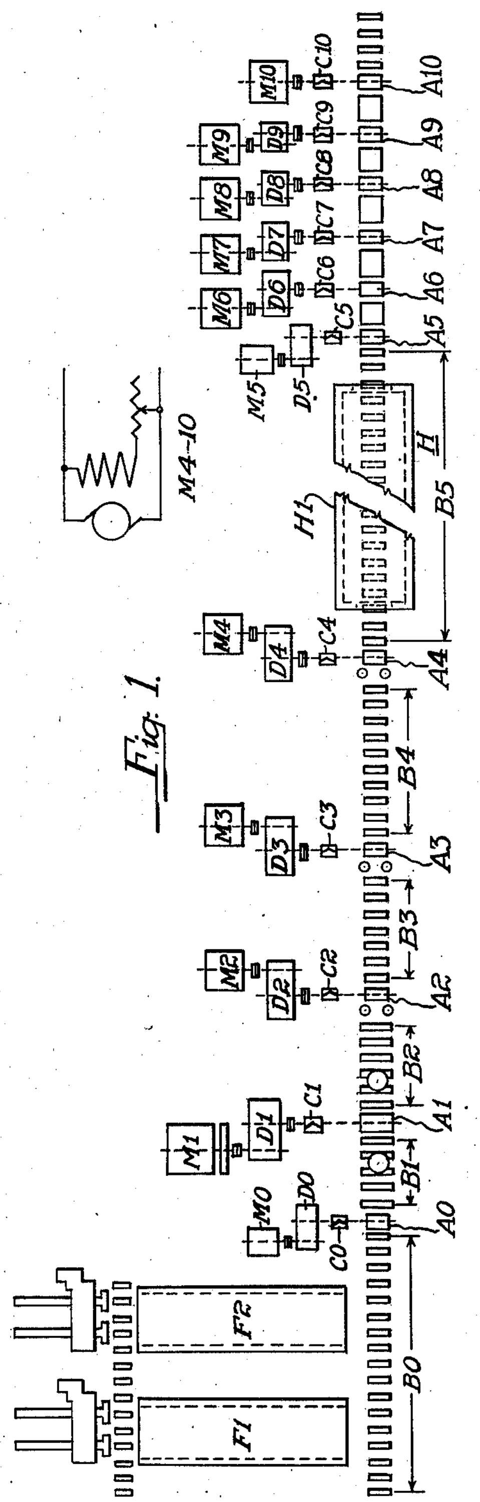

Fig. 1.

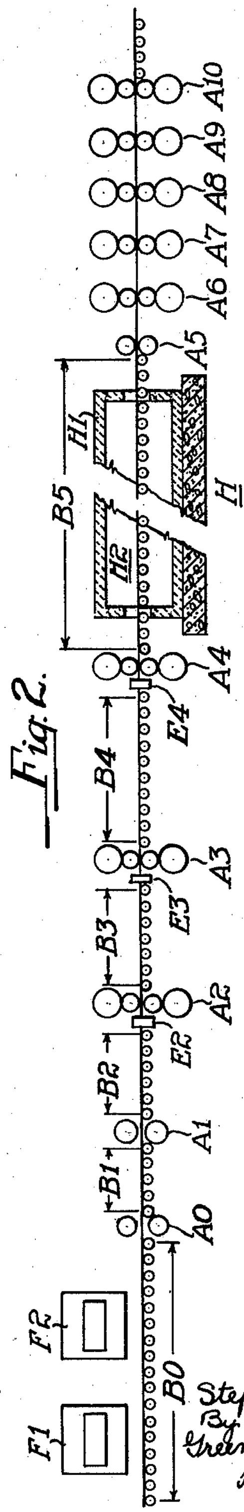

Fig. 2.

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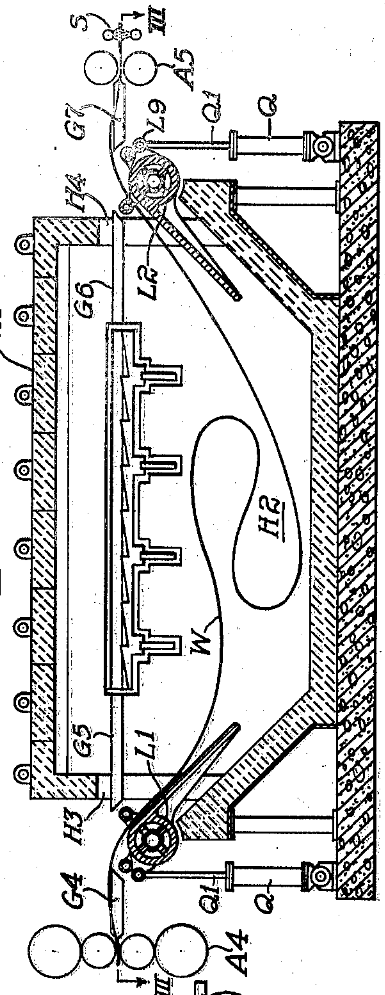

Fig. 4.

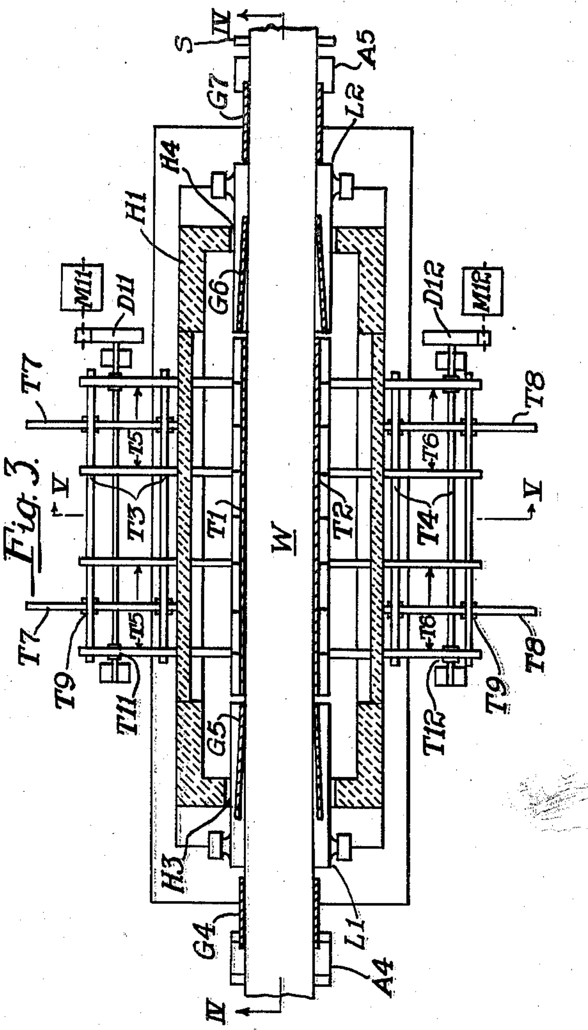

Fig. 3

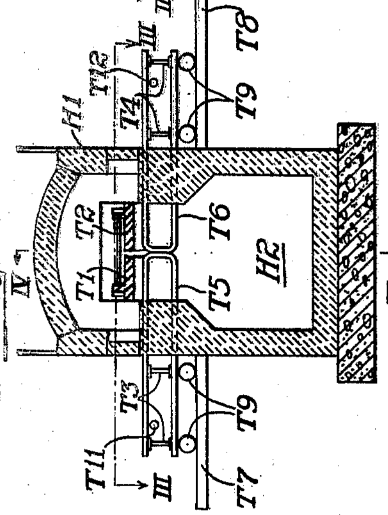

Fig. 5.

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Fig. 6.

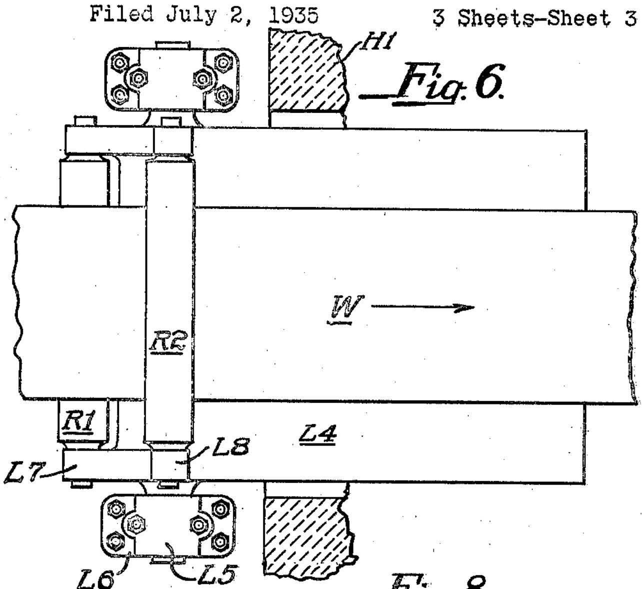


Fig. 7.

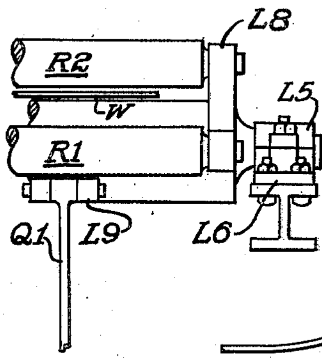


Fig. 8.

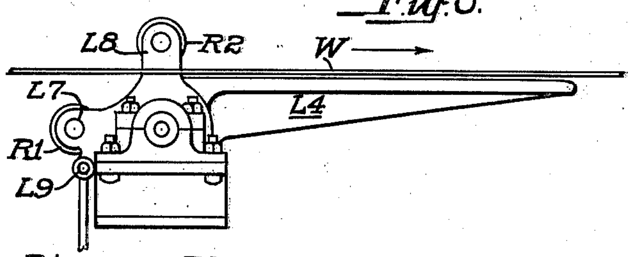
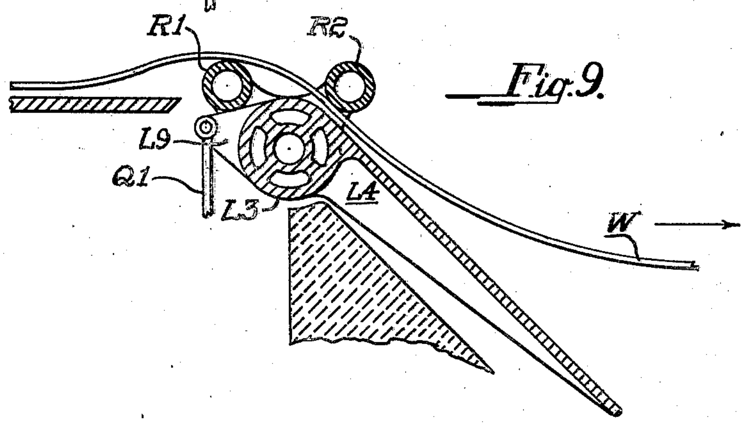


Fig. 9.



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Patented Dec. 6, 1938

2,139,483

UNITED STATES PATENT OFFICE

2,139,483

METHOD OF ROLLING FLAT MATERIAL

Stephen Badlam, Rosslyn Farms, Pa.

Application July 2, 1935, Serial No. 29,480

16 Claims. (Cl. 80—2)

This invention relates to metal rolling, and more particularly to the hot rolling of metal to form thin flat sections such as strip, and is herein specifically described as applied to the rolling of wide thin flat steel in the form known as wide, or broad strip.

The term strip is not to be construed as limiting the product to the class commercially known as "strip steel", that is to say 24" wide and under, and less than ¼" in thickness, but is intended to apply equally to other classes of thin flat rolled products, without limitation as to width and gage.

One difficulty encountered in hot rolling is due to a variation in temperature between the front, or leading end, and the back, or trailing end, of the piece rolled, at the time each is subjected to its last substantial reduction.

It is, of course, apparent that, where the conditions of rolling are such that the piece moves in the same direction from stand to stand, as in the continuous mill, this temperature variation is progressive from end to end, and the rear end of the piece is substantially colder than the forward end at the time it is subjected to the reducing forces, and there is an appreciable difference in the response of successive elements of the piece to the rolling pressures encountered.

The difference in temperature is a function of the time each successive element of the piece is exposed to cooling influences during the rolling operation and this is true even though the piece to be rolled is of uniform temperature, from end to end at the initiation of the rolling operation. In hot rolling the reduction of the piece is quite marked, at least in the earlier passes where the piece is thick and quite hot and responds readily to the rolling pressures encountered. During these early passes such variations in the heat content, and temperature of the metal as may exist from end to end of the piece being rolled, are not of material importance, but as the piece is elongated and reduced in thickness its exposed area is increased, thus increasing the rate at which it gives off heat. Then too, as the piece increases in length, there is an increasing difference between the time that the forward end, and the rear end of the piece, each enters a roll stand and is subjected to the rolling pressure. Thus it will be apparent that as the reduction of the piece continues, its rate of giving off heat increases and because of this and its increasing length, the difference in temperature, at the instant of rolling, between the front and rear end becomes more marked.

The difference in temperature occasions variations in physical and dimensional properties from end to end of the rolled piece, and these variations become more marked as the piece is elongated by the rolling operation. For example, where a relatively long piece is traversing the pass between the rolls of a stand, the forward or leading end of the piece may be at such a temperature at the time it is subjected to the distorting pressures as to readily respond to those pressures, but the rear end of the piece will not arrive at the pass until some time has elapsed, consequently the rear end of the piece will respond less readily to the rolling pressures, and there will be a difference, from end to end, in the dimensional and physical properties of the piece on leaving the pass.

The most easily discernible result of this response to the rolling pressure is in the thickness of the piece on leaving the pass, that is to say, where the rear end of the piece is appreciably colder than the front end at the time it arrives at the pass, the rear end will not be reduced to the same extent as the front end, consequently on leaving the pass there will be a variation in the thickness of the piece from the front to the rear end, and this variation will be progressive. The temperature difference also occasions variations in the physical properties, such as hardness, ductility and grain structure, and here again the variations will be progressive from the front end to the rear end of the piece.

The difference in the above mentioned properties follow directly from the difference in temperature of successive elements of length of the piece, at the time each is subjected to the rolling pressure. These differences are of little practical importance during the earlier passes of a hot rolling operation, or during the final passes when the finished section is heavy, because then, the piece is comparatively short, its volume as compared to its exposed surface is relatively great; and consequently, the rate of cooling is relatively small and the time difference at which each element of the piece arrives in the pass of the stand is likewise small. However, as the piece is diminished in cross section, and increased in length, by the rolling operation, the rate of cooling increases, and the time difference also increases, consequently the variations in physical properties, from end to end of the piece, becomes more marked and of greater practical importance.

When any of these variations in dimensional and physical properties exceed the permissible tolerances for the particular product being rolled;

it constitutes an effective limitation as to the gage and length to which a piece may be rolled in commercial hot rolling procedure.

In order to eliminate the most important cause for the variation in cross section and physical properties, from end to end of the piece being rolled, it is essential that the successive length elements of the piece shall be of substantially the same temperature at the time they are subjected to the last distorting forces, i. e., in general, at the time each enters the finishing pass.

Various expedients have been adopted for the purpose of diminishing the difference in temperature, and the resulting difference in cross section, physical properties, and in grain structure here commented upon. Probably the simplest, as well as the earliest to be adopted, was to reduce the length of the piece to one that could be easily and rapidly handled in the type of mill available, thus reducing the variations above noted so that the thickness and other physical properties, from end to end of the piece, all came within acceptable tolerances.

In the rolling of material having a high ratio of width to thickness, as in sheets, pack rolling was resorted to and in this way the thickness of the work piece was, in effect, increased and the rate of heat dissipation decreased. The pack is made up of two or more pieces, laid one upon the other and then passed through the rolls as if it were a single piece. After the rolling operation the separate components of the pack are separated into the resulting sheets. Pack rolling operations are, and have been, extensively employed and by such procedure, sheets have been produced having a ratio of width to gage of 1,000, 2,000, and even 3,000 to 1. Such high ratios of width to gage, however, are accompanied by a limitation of the length obtainable, ranging from as low as four feet, in the thinnest gages, up to not over 16 or 20 feet, in the heavier gages.

There has, however, been a demand for thin material in long lengths and this, among other requirements, has resulted in the development of the so-called continuous mill wherein the finishing stands, at least, are located in tandem, are placed close together, and are so speeded that there is little or no looping between them. That is to say, at least the last several stands are continuous and receive a piece of such length that it is simultaneously acted upon by the rolls of two or more stands. The first stand of the finishing mill receives a relatively thick piece from the last roughing stand, and the final, or finishing, stand is run at a high speed in an endeavor to reduce, as much as possible, the temperature difference between the leading and trailing ends of the piece here commented upon. Mills of this kind have limitations particularly where wide flat material is rolled. The heavy reductions and the speed requirements necessitate the expenditure of a large amount of power and this, in the wider widths, at least, effectively limits the gage, and the length of strip, which may be rolled in commercial operations.

In strip rolling, the question of hot finishing at a definite and predetermined temperature is particularly important. In the lighter gages, e. g., 12 gage or under, it is usually desirable that the strip be delivered from the last finishing pass at a temperature sufficiently high to permit of "self annealing", either in the coil, or if cut by flying shears, in piles. In the heavier gages, however, there is a tendency towards finishing at too high a temperature, with the resulting grain growth during cooling. Where such a tendency exists, it has been found desirable to hold the piece prior to its entry into the finishing train, and thus either to permit it to cool naturally, or to accelerate the cooling by means of water spray or a similar expedient. Thus, the importance of completing the hot rolling operation at a definite temperature, is well understood, particularly in connection with the rolling of thin flat material, such as ferrous strip.

It has been proposed, at least for such gages as would normally be finished at temperatures above those required to insure desirable grain structure, to cool the leading end of the piece, more than the trailing end while at an intermediate stage of rolling, so that the two ends are of substantially equal temperatures when subjected to the reducing forces in the succeeding passes. This procedure tends towards an improvement in the gage and physical properties of the finished product, but it is difficult to obtain a uniform condition throughout the length of the piece, since several variables are involved in such cooling operation, and, in any event, this procedure is undesirable in the rolling of the lighter gage material.

In the hot rolling of strip, the difference in gage and physical properties between the front and the rear ends of the piece being rolled, becomes particularly important in connection with thicknesses below 16 gage and has heretofore constituted an effective limitation to the ratio of width to gage capable of being produced commercially. It has been, in fact, the principal limitation to the commercial rolling of strip, in thin gages, and in sheet widths.

The maximum ratio of width to gage hitherto produced, in long lengths, has been of the order of 960 to 1, or about 16 gage, (.0625″) in 60″ widths. Below 16 gage, it has been of the order of 48″ in 17 gage, down to 27″ in 20 gage, and even within these limits undesirable variations are encountered. In rolling it has been found necessary to form a relatively thick piece, (½″ to 1″) as the entering piece for the finishing stands, in order to keep the variations in gage, hardness, etc., from end to end of the finished piece within allowable tolerances. This makes it necessary to have available on the several stands of the finishing train, sufficient horsepower to effect the necessary heavy reductions to produce the desired finished gage, and to maintain the speed of rolling so as to minimize the effect of the time factor mentioned.

Strip of a greater ratio of width to gage has commonly been produced by hot rolling to such heavier gages as may be economically produced on the hot mill and then in effecting a further reduction either by cold rolling and coiling, or by cutting the hot rolled product into short lengths, (strip mill breakdowns) reheating and finishing on sheet mills of the conventional type. Either of these methods adds considerably to the cost of the product.

The foregoing relates generally to ordinary soft steel. In the case of the hard, carbon or alloy steels, and particularly the chrome, and chrome nickel steels, of the stainless type, the resistance to the rolling pressure is greatly increased, and the response of the metal thereto is decreased, and this is particularly marked as the temperature falls.

The method of hot rolling here disclosed is particularly advantageous in connection with hard steel and such alloys as above mentioned.

At present there is a substantial demand for a hot rolled product, having a ratio of width to gage greater than is now obtainable in long lengths, for example soft steel 20 gage in widths of 36" and over and alloy steels in comparable widths and gages, and it is to such products that the aim of the present invention is particularly directed.

This involves not only a procedure for eliminating the difference in temperature between the front and rear ends of the piece, heretofore commented upon, in the finishing passes, but also the accomplishment of this result while maintaining a rate of output necessary for economical commercial operation.

An object of my invention is, therefore, to provide a commercially economical process for producing hot rolled material, in long lengths and thin gages, wherein the finished material produced is of substantially uniform cross section physical properties and grain structure throughout its length.

A further object is to provide new and improved apparatus for carrying forward a process having the characteristics outlined in the previously noted object.

A further and more specific object is to provide a new procedure of hot rolling ferrous material in long lengths and to sheet gages having a width to thickness ratio of about 1000 to 1, or over, and substantially uniform cross section, physical properties and grain structure throughout the length of the piece produced.

These and other objects, as will be made more apparent throughout the further description of my invention, are attained by means of the procedure herein outlined in connection with the apparatus illustrated in the drawings accompanying and forming a part hereof.

Figure 1 is a diagrammatic plan view of a mill installation including apparatus such as enables the installation to be employed in carrying forward my improved process.

Fig. 2 is a diagrammatic view of the apparatus illustrated in Figure 1, partly in elevation and partly in vertical section.

Fig. 3 is a horizontal sectional view taken along the line III—III of Figs. 4 and 5, with the loopers in the horizontal position, and illustrates an embodiment of improved apparatus constituting a part of my invention and which may be employed in a mill installation, for the purpose of carrying forward my improved process.

Fig. 4 is a vertical sectional view along the line IV—IV of Figs. 3 and 5 with the loopers in the lowered position.

Fig. 5 is a transverse vertical sectional view along the line V—V of Fig. 3.

Fig. 6 is a fragmentary plan view of a structural detail included in the furnace illustrated in Figs. 3, 4, and 5.

Fig. 7 is a fragmentary elevation; and

Fig. 8 is a fragmentary side view of the same.

Fig. 9 is a fragmentary sectional view of apparatus illustrated in Fig. 6, with the looper in the lowered position.

The mill diagrammatically illustrated in Figures 1 and 2, is to a large extent a conventional continuous hot strip mill, but as will be made apparent by the further description, is employed in such a way as to adapt it for use in carrying forward my improved process of rolling. As illustrated, the mill includes the usual furnaces F1, F2, for heating the initial piece, such as the slab or ingot. The heated piece, either from the furnaces, F1, or F2, or from a previous operation, is delivered by any convenient means to a conveyor diagrammatically illustrated as a roller table, B0. The heated piece is first delivered to a scale breaker, A0, which may be of conventional form, and equipped with water spray, and the function of which is to loosen and remove furnace scale from the piece. The piece is then passed successively through the roll stands A1, A2, A3, and A4, which constitute the roughing train and which may be so spaced that the piece is in only one stand at a time. The space intervening between successive stands is bridged by conveying means such as the usual roller tables diagrammatically shown at B1—B4. It will be noted that at least some of the roughing stands are provided with, or supplemented by edging rolls, E2—E4, and these edging rolls may, if desired, be supplemented by hydraulic or similar scale removing means, all as is well known practice in connection with hot mill procedure.

The piece, after having been reduced in thickness and elongated by the action of the roll stands A1 to A4 inclusive, is delivered directly into a furnace H, thence to a secondary scale breaker, A5, and from thence to the finishing train of roll stands which, as illustrated, includes four high stands A6 to A10, inclusive. These stands constitute a continuous finishing train and they are preferably so located that the piece is simultaneously acted on by the rolls of two or more stands as it traverses the train.

The usual loopers may be employed between the individual stands, as A6 to A10, and, as is ordinary practice, each stand may also be driven at such a speed, with relation to the other stands of the train, as to apply a slight tension to the strip between some of the stands.

In the drawings, I have diagrammatically illustrated the driving mechanism for each pair of opposed rolls as an electric motor and I have marked these motors with the reference character M, followed by a numeral corresponding to the number of the stand in question. It will, of course, be understood that any suitable driving mechanism may be employed, but individual electric motors are preferred because they admit of more flexible speed control of the individual stands and this question of speed control is important, at least in connection with some of the stands, as will be made apparent throughout the further description.

I have also diagrammatically illustrated gear reductions D0—D9, for reducing the R. P. M. of the motors to speeds suitable for the pinion stands C1—C9, which drive the working rolls. It will also be noted that I have indicated the roughing stands A2, A3, A4, as four high stands and in this connection it will be understood that I am not placing any limitation on the type of stands employed in the roughing stands, so long as each is sufficiently rugged to satisfactorily accomplish the reductions contemplated. I have illustrated all the finishing stands as four high stands, but I do not contemplate thus limiting the application of my invention as it will be apparent that any form of rugged mill is suitable and I have therefore merely illustrated this form of backed-up mill as desirable for each of the finishing stands.

The furnace H, intermediate the roughing train and the finishing train has a double function, viz., to supply heat to the piece as it leaves the last roughing stand and enters the first pair of rolls of the finishing train, and also to so supply heat to the piece as to avoid the detrimental effects of temperature difference heretofore commented upon.

This furnace is shown as of the tunnel type and is preferably of such length as to be able to receive the entire length of the piece delivered from the stand A4. As diagrammatically illustrated, the furnace includes an enclosing housing H1, open at both ends to receive and deliver the piece or strip issuing from the stand A4, and moving toward the scale breaker stand A5, of the finishing train, and a heating chamber H2. The furnace is also shown as provided with heat resisting rollers which constitutes the means not only for conveying the piece from the stand A4 into the furnace, but also for conveying the piece through the furnace and to the scale breaker A5.

It will be noted that, in a straight continuous mill, as illustrated, the rear end of the piece, when it arrives at stand A4, will be somewhat colder than the front end when it arrived at the same stand. Also, when the piece arrives at stand A5, unless corrective means are provided, this condition will be greatly accentuated, on account of the piece being thinner, and having a greatly extended surface, and also because its length, and the time intervening between the approach of the front and back ends to that stand have been increased.

In order to accomplish the desired differential heating from end to end of the piece, under the conditions illustrated, it is necessary, either that the trailing end of the piece be exposed to heating for a period appreciably longer than the period during which the leading end is so exposed, or that the trailing end of the piece be exposed to a higher temperature than the leading end for the same length of time or a combination of the two. From these considerations it will be apparent that the desired heat input to successive length elements of the piece may be accomplished by employing a uniform distribution of temperature throughout the length of the heating chamber and by so controlling the delivery to, and withdrawal from that chamber that the successive length elements of the piece are differentially heated so as to produce an increase in temperature of the successive elements from the leading to the trailing end of the piece, or, by employing a higher temperature at one end of the chamber than the other, and so controlling the time of exposure to the temperature within the chamber, that the piece is differentially heated as above described. I prefer, however, to employ substantially uniform heat throughout the chamber, and then so deliver the piece to, and withdraw it from the chamber, that the piece is progressively heated from the leading to the trailing end, with the result that as each length element of the piece approaches stand A10, it is as hot as the preceding elements, and therefore the trailing end of the piece arrives at stand A10, at substantially the same temperature as the leading end of the piece when it arrived at that stand.

That is to say, the function of the furnace H, is not only to supply heat to the previously roughed piece, as that piece is delivered from the last stand of the roughing train and to the first stand of the finishing train, but to supply the heat differentially along the piece so that all length elements thereof will be of substantially equal temperature as they are acted upon by each of the finishing stands A6, to A10. It will, of course, be apparent that the leading end of the piece may be colder when it arrives at the stand A10, than when it arrived at the stand A6, due to the cooling effect occasioned by the necessary lapse of time, but by properly applying heat to the successive length elements of the piece, while it is in, or is passing through, the furnace H, each successive length element is of approximately the same temperature as every other length element of the piece at the time it receives its last substantial amount of work, i. e., when it is acted upon by the final stand, A10, of the finishing train.

In order to accomplish this result, I prefer to deliver the piece from the stand A4, into the furnace at a higher speed than the piece is withdrawn therefrom and delivered to the first stand, A5, of the finishing train. While driven pinch rollers may be employed on the entrance and exit sides of the furnace for accomplishing this result, I contemplate that the roll table B5, acting in conjunction with the rolls of the stand A4, and the rolls of the stand A5, will accomplish the desired result. More specifically stated, I contemplate driving the final stand of the roughing train at a higher speed than the initial stand of the finishing train, and so proportioning the speeds of these two stands that the difference in speed will provide the necessary interval at which each length element of the piece is retained within the furnace, or is absorbing heat.

With this in mind, it will be apparent that it is not necessary to stop the piece within the furnace provided the furnace is of such length and temperature as to impart the desired degree of heat to the leading end of the piece as it traverses the furnace chamber. It will be noted that under conditions such as described, the leading end of the piece moves through substantially the entire length of the furnace at the speed of delivery from the roughing stand A4. In other words, the progress of the leading end of the piece into and through a substantial portion of the furnace is controlled by the speed of the reducing rolls constituting a part of the last roughing stand A4. As the trailing end of the piece leaves the stand A4, the further progress of the piece toward the stand A5 of the finishing train must depend upon other motivating means, but in any event, such means as are here employed for withdrawing the piece from the furnace must be so controlled that the speed of the piece on leaving the furnace is not only less than the speed of entrance, but in such relation to the speed of entrance that each length element of the piece is differentially heated and that the degree of such differential heating is such as to secure the desired results.

To employ figures, but for illustrative purposes only, it may be assumed that the piece on leaving the last roughing stand A4, is 80 feet long and the speed of delivery from that stand is 400 feet per minute. The entire piece will then be delivered to the heating chamber of the furnace H, in 12 seconds. Inasmuch as the piece will be in all of the finishing stands A5—A10 at the same time, it is essential, in order to avoid excessive stretching or excessive looping between stands, that the volume of the metal simultaneously passing these stands shall be the same and consequently that the speed of the stands shall be increased from the first to the last stand. Again, for illustration, assume that the piece enters the stand A5, secondary scale breaker, at a speed of 100 feet per minute, and leaves the last finishing stand A10, at a speed of 1000 feet per minute. Under such conditions the piece will be withdrawn from the furnace in 48 seconds and the rear end of the piece will be exposed to the temperature of the heating chamber for a period of 36 seconds longer than the front end. This difference in temperature is necessarily progressive from the leading to the trailing end of the piece, with the result that the length elements of the piece are incrementally heated, and the rise in temperature is progressively increased from the front to the rear end of the piece on leaving the furnace.

For a given length of piece and a given speed of entry into the stand A5, the time that the rear end of the piece will be exposed to the elevated temperature may be varied by changing the speed of the stand A4, or with a constant speed of delivery of that stand the same result may be obtained by varying the speed of the stand A5, and necessarily, of the succeeding stands of the finishing train.

For a given time of exposure to the temperature of the heating chamber, the rise in temperature of any length element of the piece is determined by the amount that the temperature of the furnace is above the temperature of that length element at the time it enters the furnace and thus by properly adjusting the speed of entrance to, and withdrawal from the furnace and also properly adjusting the furnace temperature, the piece may be so heated as to obtain the desired results in its passage through the final stand of the finishing train.

One factor to be considered in carrying out my process is the character of the atmosphere surrounding each piece at the time it is subjected to intermediate heating, i. e., to the heating as above specified between the stand A4 or A5. Ordinarily this atmosphere will range from a somewhat oxidizing through neutral to a somewhat reducing atmosphere. Under all conditions the scale existing on the piece as it enters the finishing train should be readily removable by the scale breaker A5 and its associated scale removing devices. The character of this scale will depend, to some extent, upon the atmosphere surrounding the piece at the time of its last heating and may therefore be affected by varying the characteristics of this atmosphere. The conditions of this final heating, including the temperature and also the character of the atmosphere in which the heating is accomplished, should be controlled so as to secure the final surface condition best suited to the use to which the product is to be put.

From the foregoing it will be apparent that nine factors are involved in determining the necessary thermal condition of the piece at the time it enters the finishing stand, viz.:

(1) The temperature of the piece, or of each length element of the piece, as it leaves stand A4.

(2) The speed of delivery of stand A4.

(3) The thickness and length of the piece as it leaves stand A4.

(4) The temperature to which the piece is subjected between the stands A4, and A5.

(5) The character of the atmosphere surrounding the piece during this heating.

(6) The speed of entry into stand A5.

(7) The time elapsing between the withdrawal of the piece from the heating influences, and its passage through the stand in which it receives its last substantial hot reduction.

(8) The amount of sensible heat added to the piece, after its removal from the heating chamber, due to the mechanical work imposed upon it, i. e., by the drafts in the several stands A5 to A10.

(9) The length and thickness of the piece after each pass, i. e., the relation between the exposed surface and the volume at successive stages of reduction.

By taking account of all these factors my improved process may be so employed that each length element of the piece receives its last substantial reduction at a predetermined and proper temperature, which, within close limits, is equal to the temperature at which every other length element of the piece receives its last substantial reduction. This, of course, involves a speed control of either stand A4, or A5, or both; a control of the heat input to the partially reduced piece; and a control of the drafts in the several stands A5 to A10, inclusive.

The regulation of the speed of the various stands may be accomplished by any one of numerous well known means but, as before stated, the use of separate electric motors to drive the individual roll stands is indicated because such a drive contributes to a more ready and accurate regulation, which may be accomplished by one of several known devices such as shunt field control, Ward-Leonard, Scherbius or Kraemer controls.

As before intimated this speed control may be applied to one, A4, or more of the stands of the roughing train, or to the finishing train, or to both, as may be necessary or desirable, and, in order to promote maximum production it is desirable to so co-relate the speeds of the two trains that both the heating furnace H, and the roughing and the finishing trains will be effectively and efficiently employed. It is of course, apparent that with apparatus such as illustrated where several stands follow the furnace H, and the piece is in two or more stands at the same time, it is essential that the speed of all such stands be varied in the proper relationship in order to avoid undue stretching or looping between stands. This statement relates with equal force to the roughing train if the stands of that train are so spaced that the piece is in more than one stand at a time. For the reasons above stated I have diagrammatically indicated each of the motors, M4—M10, as adjustable speed motors equipped with means for regulating its speed; there is no intent however to designate either the type of motor, or the type or kind of control therefor, to be employed.

Any one of various means may be employed for supplying heat to the material passing through the space between stands A4 and A5, i. e., a heating chamber may be employed which is heated by gaseous, liquid or solid fuel, or which is electrically heated, or the metal itself may be heated electrically as it traverses this space. Temperature regulating means are well known, and it is consequently only necessary to say that some such means be provided as to insure the proper heating of each length element of each piece. When the operating conditions are such that it is desirable to vary the character of the furnace atmosphere, means for accomplishing this result are also well known and may be employed.

When the same mill is operated to produce a wide range of thickness of product, e. g., both thin sheet gages and heavier plate and skelp gages, in the latter case it may be desirable to pass the piece between the stands A4, and A5, without exposing it to the heat of the chamber, H2. This may be readily accomplished by providing the furnace with removable roof sections which may be lifted off when it is desired that the furnace be rendered non-operative both as a heat supplying and a heat conserving means. It would also be desirable since it facilitates the removal of cobbles from the furnace in case any are formed therein.

It will, of course, be apparent that the setting of each successive pair of reducing rolls throughout the two trains will vary from the setting of every other pair and that, in order to obtain the best results, it is essential that these settings be adjustable. Such means are usual and well known in connection with roll stands, and therefore, need not be further commented upon.

Any one of several means may be employed for delivering each piece to, and withdrawing it from, the heating chamber of the furnace H, and also for introducing it into the first stand of the finishing train. All such means are generally well known and a specific selection of one or another forms no part of this invention in its broadest aspect.

In Figures 3 to 9, inclusive, I have illustrated a modified form of furnace which may be employed, in connection with rolling equipment, for carrying out my improved process and which also forms a part of my present invention. One of the features of this furnace is that it is adapted for handling pieces having a greater length than the distance between the final roughing stand, A4, and the first stand, A5, of the finishing train. This feature results in a saving of floor space and at the same time provides effective apparatus for accomplishing the purpose intended.

The modified furnace, illustrated in Figs. 3–5, includes a housing, H1, which, like the furnace disclosed in Figs. 1–2, encloses a heating chamber H2, which extends above and below the plane generally defined by the pass line of the stands A4—A5. In its broader aspects this modified form of furnace is of the tunnel type in that it is provided at one end with an aperture H3, through which the piece delivered from the stand A4, enters the furnace, and it is provided with a similar aperture, H4, at the other end through which the piece emerges as it moves toward the stand A5, of the finishing train.

In order that the leading end of the piece, W, issuing from the stand A4 may be conveniently passed through the furnace and then presented to the first stand of the finishing train, I employ what may be termed a conveyor table assembly which is located within the heating chamber, H2, and which is conveniently formed of four distinct parts, each of which is movable. As illustrated it consists of two oppositely disposed loopers, L1, and L2, and a table proper which is formed in halves T1 and T2. Each half of the table proper is movable from the center line of the furnace heating chamber, i. e., from a work supporting position, shown in Fig. 3, to a position out of the line of travel through the furnace, and each looper is movable from a horizontal position, as shown in Figs. 3 and 8 to an inclined position as shown in Figs. 4 and 9. Thus the parts described may either occupy positions such that they, in effect, bridge the gap between the passes of the stands A4 and A5, and provide a substantially horizontal and uninterrupted conveying surface over which the leading end of each piece may be guided from the entrance aperture, H3, to the exit aperture, H4, of the heating chamber; or the halves of the table proper may be retracted, and the looper arms dropped to the inclined position thus permitting intermediate portions of each strip to fall below the entrance and exit plane of the chamber and loop within the lower portion thereof. It will be understood that one or both the loopers may be omitted, or the two loopers, in themselves, may be of sufficient length to bridge the gap, thus obviating the necessity for the table proper and all without affecting the method of operation as here set forth.

Each half, T1, and T2, of the central portion, or table proper, is carried by a separate, movable frame which is more or less diagrammatically illustrated as being fabricated from structural sections T3 and T4, and pipe sections, T5 and T6, which latter may be protected against the heat of the furnace by causing water to flow through them. Each frame, T3 and T4, is in turn mounted upon support rails, T7 and T8, which extend transversely of the longitudinal center line of the furnace and, like the structural frame, are located wholly without the furnace chamber. The arrangement is such that each frame is movable along its supporting rails so as to move its corresponding table half, T1, or T2, laterally to and from the position shown in Figures 3 and 5. Each frame is preferably provided with flanged wheels, T9, for facilitating this movement. Electric motors, M11 and M12, may be employed for actuating each frame, and reduction gearing D11 and D12, and rack and pinions, T11 and T12, may be employed between each motor and its corresponding table half. As shown in Fig. 5, the inner, heat resisting wall of the furnace is provided with inwardly extending shoulders which may aid in protecting the table halves, T1 and T2, particularly when they are in their outermost positions, and not actively engaged in guiding the front end of the strip from stand A4, to stand A5.

The side wall above the shoulder may also be in part removable to permit withdrawing the table halves T1 and T2 to a position entirely outside the furnace for repairs or other purposes.

Each looper, L1 or L2, consists essentially of a body or hub portion, L3, and an integrally formed projecting arm, L4. The hub, L3, is provided at each end with trunnions, L5, adapted to be supported in suitable bearings carried by pedestals, L6, located on either side of the furnace. In addition, each hub portion, L3, is provided at each end with two radially extending lugs, L7, and L8, in which rollers, R1 and R2, are respectively journalled. A lug or crank L9 is provided on, or formed from the hub portion, L3, and is adapted to be pivotally connected to an actuating motor, Q, Fig. 4, by means of a link, Q1. The motor Q, may be a solenoid, or a thrustor, or a pressure cylinder and its piston, in which case the link, Q1, would, in effect, constitute the piston rod. It may, equally, well, be a rotating crank linkage.

The motivating means, Q, for each looper is adapted to move the arm, L4, to and from a position in which the surface thereof is substantially horizontal, and as shown in Figs. 6 and 8, or to and from the position shown in Figs. 4 and 9. In the upper, or horizontal position, the arm L4, of each looper cooperates with guide members, G5 and G6, which extend into the furnace and which constitute adjustable lateral guides for the piece moving into the heating chamber over the corresponding looper, L1 or L2. It will, of course, be apparent that all operating parts within the furnace, or exposed to the heat of the furnace are formed of heat resisting material, or are water cooled.

The operation of the modified form of heating chamber is as follows: As a piece, W, is delivered from the stand A4, it is guided by the delivery guides, G4, of that stand onto the looper, L1, which is then in elevated position with its arm, L4, horizontal and cooperating with the guides, G5. As the piece, W, enters the furnace, its leading end moves under the roller, R2, and then continues its travel over the table proper, the halves, L1 and L2, of which are in their innermost position, as shown in Fig. 3. The looper, L2, is also in the elevated position and thus is, in effect, an extension of the table proper, consequently the leading end continues over the arm, L4, of the looper, L2, and moves beneath the roller, R2, of that looper. This movement of the strip is occasioned by the strip impelling means at the inlet end of the furnace, e. g. the reducing rolls of the stand A4, and continues until the leading end is engaged by the withdrawal means, e. g., the gripping and propelling rolls of the stand A5, at which time the loopers, L1 and L2, are dropped to the position shown in Fig. 4 and the table halves, T1 and T2, are withdrawn laterally from the center line of the furnace so that they no longer support the intermediate portion of the work piece, W. Under such conditions the intermediate portion of the oncoming piece drops towards, or to, the bottom of the furnace chamber, H2, and its further withdrawal from the furnace is controlled by the gripping rolls on the exit side of the furnace, e. g., the rolls of stand A5.

The roller, R1, of each looper, L1 and L2, is elevated, as shown in Figs. 4 and 9, by the dropping of the looper arm, and these rollers, in connection with the rollers R2, of the loopers guide the strip as it moves into, and as it moves out of the furnace when the loopers are lowered.

In this furnace, as in the furnace previously described, the rate of delivery of the piece, W, into the heating chamber exceeds the rate of withdrawal from the chamber, consequently looping of the strip will occur within the chamber, and the form of the loop may be controlled by manipulating the looper, L1, i. e. by raising and lowering so as to cause oncoming portions of the piece to overlap preceding portions.

In the arrangement of apparatus described, the leading end of the work piece, W, moves through the chamber at the entrance rate. As soon as this end is engaged by the withdrawal means, e. g., by the rolls of the scale breaker, A5, the rate of withdrawal of the piece is controlled by the rate at which the strip passes through these rolls. It will, therefore, be apparent that the intermediate length elements of the strip are retained in the furnace for a period of time which corresponds to the difference between the entrance and withdrawal rates, even though the entire piece is never located wholly within the furnace. As the trailing end of the piece is withdrawn from the furnace by the action of the gripping rolls at the exit end of the furnace, e. g., the rolls of the stand A5, the loopers are again raised, and the table is again moved inwardly so that its halves, L1 and L2, cooperate with the loopers to provide a continuous surface over which the leading end of the next succeeding piece, W, may move. It is, of course, apparent that the looper, L1, may be elevated, and the table halves T1 and T2, may be moved inwardly, i. e., to a strip supporting position, prior to the elevation of the looper, L2, and for this reason a strip may be entering the furnace while the trailing end of the next preceding piece is leaving it. The rate of feeding pieces to the stand A4, however, must be so timed as to avoid having the leading end of any piece overlap the trailing end of the preceding piece.

The gripping rolls at the exit end of the furnace, e. g., the rolls of stand A5, should be so located, and all moving parts L1 and L2, T1 and T2, so manipulated, as to avoid forming excessive loops in the strip on the exit end of the furnace, and between the guiding roll, R2, of the looper, L2, and such gripping rolls. It is, of course, apparent that with a furnace having the structural details illustrated in Figs. 3 to 9, the leading end, and a small but appreciable portion of the strip immediately adjacent thereto will only be subjected to the direct heat of the furnace as they are propelled through the furnace at the speed of delivery from stand A4, but even so, the major portion, and in fact substantially all, of the strip will be differentially heated, as described in connection with the furnace H of Figs. 1 and 2, and the heat input into the piece, and each length element thereof may be so controlled by varying the temperature of the furnace, the rate of delivery into, and the rate of withdrawal from the furnace, as to insure a predetermined heating of each such element, such that all length elements of the piece arrive at the last reducing stand, A10, of the finishing train, at the same temperature, within close limits.

When it is desired to accomplish this differential heating from end to end of the piece, pinch rolls of heat resisting metal, or other withdrawal means, may be located within the confines of the heating chamber, on the exit side thereof, and immediately adjacent the exit opening, H4. Such means as are employed will, of course, so propel the leading end of the strip to the first stand of the finishing train that there will be no excessive looping, or stretching of the strip as it is withdrawn from the furnace.

In Fig. 4 I have shown the stand A5, as including scale breaking rolls, and associated with them water sprays, S, and it will be apparent that here I have merely conventionally illustrated a well known form of hydraulic scale remover. It might be here stated that while I have indicated edging rolls associated with some of the stands of the roughing train, such rolls may likewise cooperate with scale loosening and removing devices as may be desirable to employ during the roughing operation.

It will be apparent that by so heating a piece that all the length elements are at substantially the same predetermined temperature at the time they are acted upon by the finishing stand, or by the final stand in which they receive substantial deformation, I am able to produce long lengths of flat material, in thin gages and wide widths, which is uniform from end to end, from the standpoint of cross section, physical properties, and grain structure, and that I am able to do this with a saving in power and a consequent saving in cost of equipment, maintenance, and labor. In addition by being able to subject each length element of the piece to final hot working at substantially the proper temperature I am able to produce commercially a materially improved product.

While I have described my improved process in connection with a specific disclosure of rolling apparatus and in connection with but two forms of furnace, and for one class of product, it will be apparent to those skilled in the art that various changes, substitutions, modifications, additions to and omissions from the apparatus illustrated may be made, and various other products may be rolled, without departing from the spirit and scope of my invention as defined by the appended claims.

What I claim as new and desire to secure by Letters Patent is:

1. A continuous method of hot reducing ferrous material, which consists in heating a ferrous piece, hot reducing such piece to strip form, in immediately subjecting the strip so formed to reheating while continuously moving the leading end thereof and while so controlling such reheating that the strip is differentially heated from end to end, then subjecting the successive length elements of such strip to further hot reduction while so timing the application of hot reducing force to each such length element that all length elements of the strip are subjected to final hot reduction at a temperature such as to produce a finished piece of substantially uniform gauge and physical properties from end to end.

2. A method of hot reducing ferrous material to strip form having a width to gauge ratio of at least 1000:1, which consists in heating a ferrous piece, hot reducing the same to strip form, reheating the strip so formed while portions thereof are continuously propelled and other portions thereof are propelled during only a portion of such reheating, subjecting the successive length elements of the strip so reheated to further hot reduction and so timing the application of reducing force to each length element of the strip that all length elements thereof are subjected to final hot reduction at substantially the same temperature.

3. A method of producing metal strip, which consists in heating a metal piece to rolling temperature, in hot rolling the same to strip form, in reheating the strip from end to end by subjecting all length elements thereof to substantially the same temperature for progressively increasing periods of time from the leading to the trailing end thereof, in subjecting the so heated strip to further hot reduction and in so timing the application of reducing force to each length element thereof that the final hot reduction of all length elements is completed at substantially the same temperature.

4. A method of producing metal strip, which consists in heating a ferrous piece to rolling temperature, in hot rolling the same to strip of intermediate gauge, in retarding the travel of the strip and during such retardation in reheating the same to rolling temperature by subjecting all length elements thereof to substantially the same temperature for progressively increasing periods of time from the leading to the trailing end thereof and then in hot rolling the reheated strip to final gauge.

5. A method of producing ferrous metal strip, which consists in heating a ferrous piece to rolling temperature, in hot rolling the same to strip form, in reheating the strip to rolling temperature by subjecting all length elements thereof to substantially the same temperature for progressively increasing periods of time from the leading to the trailing end thereof, in removing scale from the strip and in hot rolling the reheated strip to gauge.

6. In a method of hot rolling ferrous strip in a multi-stand continuous mill, the steps which consist in retarding the strip in its travel from one intermediate stand to the next succeeding stand and during such retardation in heating the strip from end to end by subjecting all length elements thereof to substantially the same temperature for progressively increasing periods of time from the leading to the trailing end thereof and then in completing the hot rolling in the succeeding stands.

7. A method of producing metal strip, which consists in heating a metal piece to rolling temperature, in hot rolling the same to strip form, in reheating the strip while so controlling the application of heat thereto that the strip is differentially heated from end to end with the trailing end hotter than the leading end, subjecting the so reheated strip to further hot reductions and in so timing the application of reducing force to each length element thereof that the final substantial hot reduction of all length elements is completed at substantially the same temperature.

8. A method of continuously rolling ferrous material to strip form having a width to gauge ratio of at least 1000:1, which consists in heating a ferrous piece to hot rolling temperature, roll reducing the same to an intermediate gauge and length and to substantially the final width, reheating the elongated piece so formed while so controlling the delivery of heat thereto that the piece is differentially heated from end to end, then subjecting the piece so reheated to further hot reduction while so timing the application of hot reducing force to each length element thereof that the final hot reduction of all length elements thereof is accomplished at substantially the same temperature.

9. A method of continuously rolling strip material, which consists in heating a metal piece to a rolling temperature, roll reducing such piece while hot to an elongated piece of intermediate gauge and of such length that the end elements thereof are of substantially different temperatures, immediately reheating the piece so formed while so controlling the application of heat thereto that such piece is differentially heated from end to end, then hot reducing the piece so reheated by subjecting it to the reducing action of a plurality of successive roll passes while so timing the application of reducing force to each length element thereof that the final substantial hot reduction of all length elements is accomplished at substantially the same temperature.

10. A method of producing strip material, which consists in heating a metal piece to rolling temperature, roll reducing the piece so heated by subjecting it to the reducing action of a plurality of successive roll passes, immediately reheating the piece so formed while so controlling the application of heat thereto that such piece is differentially heated from end to end, then hot reducing the piece so reheated by subjecting it to the reducing action of a plurality of successive roll passes while so timing the application of reducing force to each length element thereof that the final substantial hot reduction of all length elements is completed at substantially the same temperature.

11. A method of producing strip material, which consists in heating a ferrous piece to a rolling temperature, hot rolling such piece to intermediate gauge and a length such that the trailing end thereof was substantially colder than the leading end when subjected to final intermediate reducing force, immediately subjecting the piece so formed to reheating while continuously moving

the leading edge thereof and while so controlling the application of heat to the successive length elements thereof that the piece is differentially heated from end to end, then subjecting such piece so reheated to further hot reduction while so timing the application of the reducing force to each length element thereof that all length elements of such strip are subjected to final substantial hot reduction at substantially the same temperature.

12. A method of continuously producing ferrous strip, which consists in heating a ferrous piece to a rolling temperature, roll reducing the piece so heated by subjecting it to the reducing action of successive roll stands, subjecting the piece so formed to reheating while continuously moving the leading end thereof and while so controlling the delivery of heat to each length element thereof that the piece is differentially heated from end to end, then subjecting the piece so reheated to further hot reduction and so regulating the speed of the piece that all length elements thereof are subjected to final hot reduction at substantially the same temperature.

13. A method of forming hot rolled strip, which consists in heating a piece of ferrous material to hot rolling temperature, hot reducing said piece to strip form of intermediate gauge and length, checking the travel of the piece so formed, subjecting the piece while so checked to reheating under conditions such that the trailing end thereof is subjected to a higher temperature than the leading end, controlling such reheating so that the trailing end of such piece is raised to a higher temperature than the leading end and then completing the hot reduction of such piece.

14. A method of forming hot rolled strip, which consists in heating a ferrous piece to hot rolling temperature, hot reducing said piece to strip form of intermediate gauge and length, checking the movement of the piece so formed while differentially heating it from end to end, then subjecting the piece so reheated to further hot reduction and so regulating the speed of the piece that all length elements thereof are subjected to final substantial hot reduction at substantially the same temperature.

15. A method of forming hot rolled strip which includes the steps of heating a piece of ferrous material to hot rolling temperature, passing the piece so heated through a reheating furnace as it leaves an intermediate roll stand and moves toward a following roll stand, operating such following stand at a lower speed than the intermediate stand delivering to such furnace, whereby successive length elements of the piece are heated for progressively increasing periods of time from the leading to the trailing end of the piece, and the piece is then subjected to further hot reduction as it moves through said following stand.

16. A method of forming hot rolled strip, which includes the steps of heating a piece of ferrous material to hot rolling temperature, passing the piece so heated through a reheating furnace as it leaves one roll stand and moves toward a succeeding roll stand, so controlling the reheating within such furnace that the piece is differentially heated from end to end and then so controlling the delivery of said piece to said succeeding roll stand that all length elements of the final product are of substantially uniform gauge.

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