Aug. 9, 1966 C. P. LAYARD 3,264,856

HOT STRIP MILL

Filed Sept. 23, 1963 3 Sheets-Sheet 1

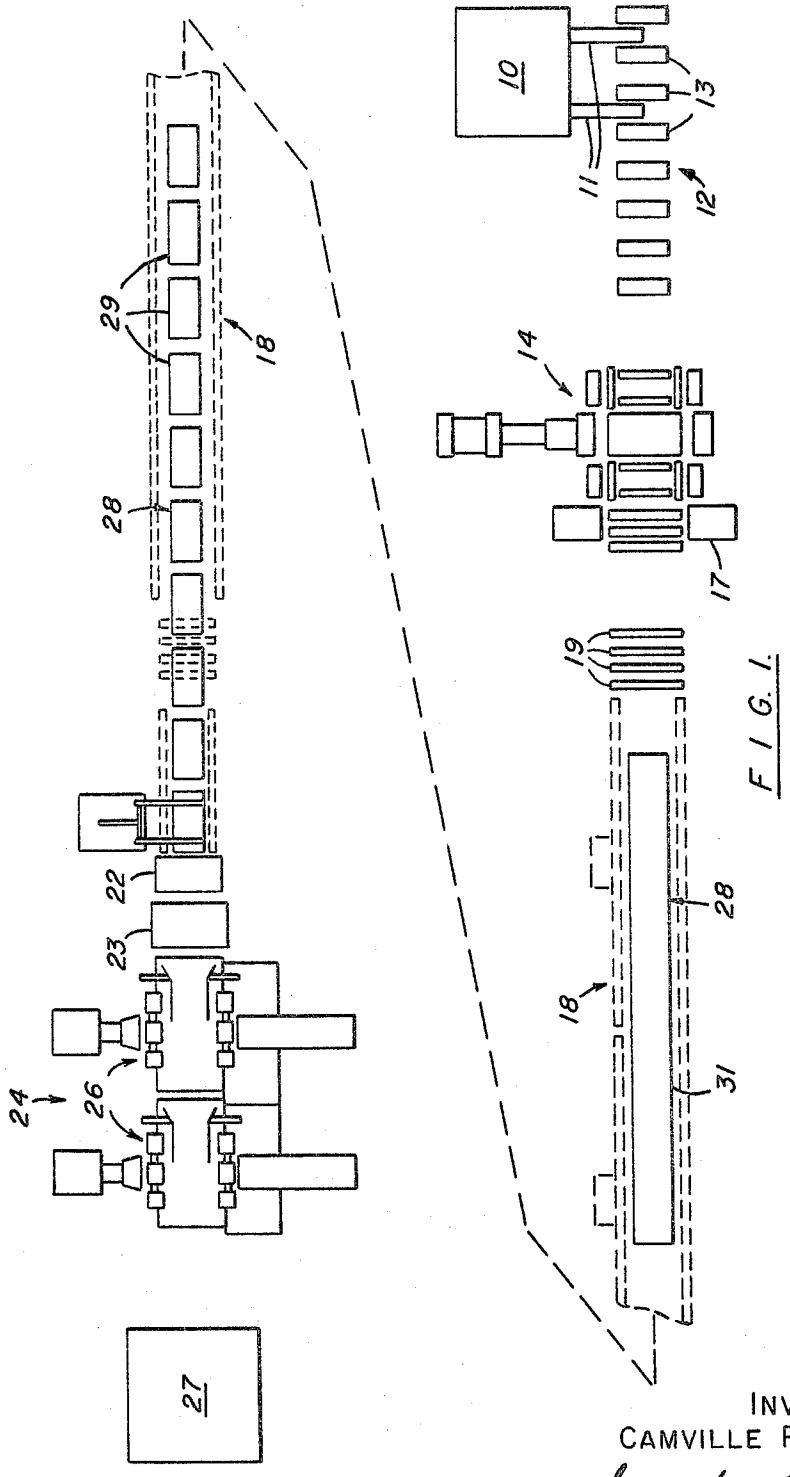


FIG. 1.

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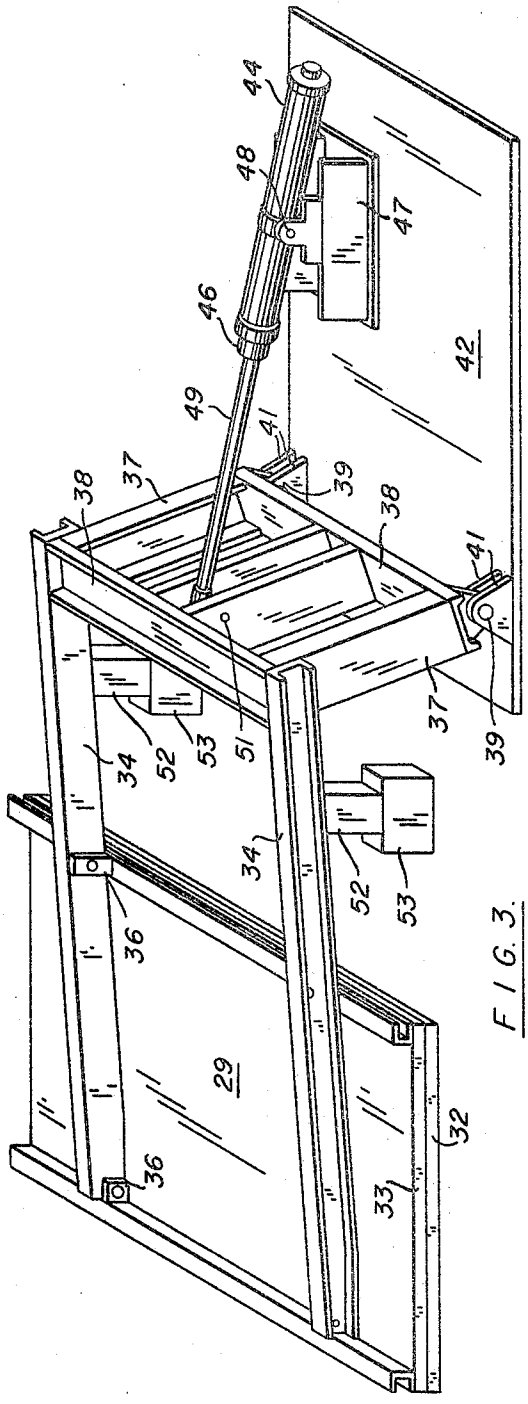


FIG. 3.

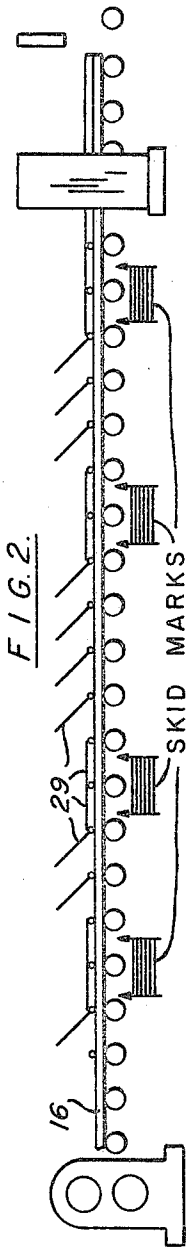


FIG. 2.

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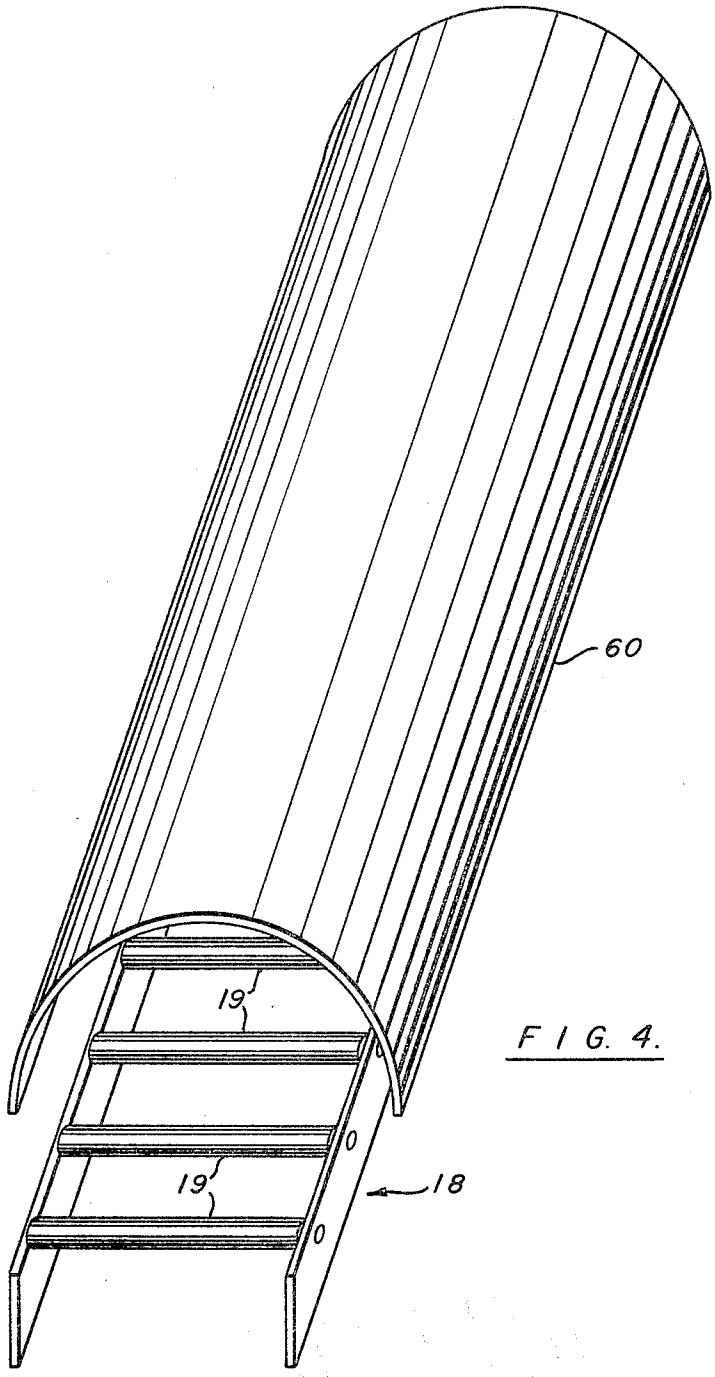


FIG. 4.

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3,264,856

HOT STRIP MILL

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7 Claims. (Cl. 72—202)

This invention relates to a hot strip mill of the type used in the steel industry.

In the making of steel strip, a slab of steel is heated in a furnace to about 2200° F. The slab may be, for example, 5 tons in weight, 10 feet long, 37 inches wide and 6 inches thick, although in some mills the slabs are considerably larger. The hot slab slides out of the furnace on runners or skids to a conveyor where it is conveyed on rollers to a roughing mill. In a semi-continuous hot strip mill the roughing mill consists of a single stand of rollers through which the slab makes 3 to 5 or more passes back and forth to be rolled into a strip about ¾ of an inch thick and 150 to 200 feet long. In a continuous hot strip mill the roughing mill may consist of, for example, six stands of rollers through which the slab passes, one stand after the other, in the same direction. As the strip emerges from the rollers of the roughing mill, the strip is blasted with a jet of water to be de-scaled. The jet of water is directed mainly against the direction of advance of the strip so that most of the bits of scale fly backward, although some of the scale does fly forward. From the roughing mill the strip advances along a delay table on a series of conveyor rollers to the finishing train. The finishing train may consist of six stands of rollers which roll the strip to its final gauge. Located just in front of the finishing train is a crop shear which cuts the crops and squares the end of a strip, and a scale breaker which removes any scale which may have formed while the strip was on the delay table before the strip enters the finishing train. The finished strip which emerges from the finishing train may be 1/10 of an inch thick and 800 to 1800 feet long or longer. The strip is coiled up into a large coil or roll ready for further processing.

There are three main disadvantages associated with a hot strip mill of the type described above, all three of these disadvantages having to do with cooling of the strip before it reaches the finishing train. It is desirable to ensure that the temperature of the strip is greater than about 1550° F. while the strip is in the finishing train to avoid cold working of the metal with corresponding changes in its hardness. It frequently happens in prior art hot strip mills that the temperature of at least the tail end of the strip (which remains on the delay table longer than the head end) falls below the critical value of 1550° F.

It is also desirable to ensure that the temperature of the tail end of the strip as it enters the finishing train approximates as closely as possible to the temperature at which the leading end entered the finishing train. As mentioned above, the tail end of the strip remains on the delay table longer than the head end. The result with the prior art hot strip mills is that the tail end cools for a longer time to a much lower temperature. As metal cools it becomes harder and in order to maintain a reasonably constant thickness of the strip as it cools, more force must be exerted by the rollers in the finishing train. The force exerted by the rollers is controlled by strain gauges which measure the strain in the roller housings and X-ray gauges which monitor the finished product. The strain gauges are responsive to both the thickness and the hardness of the strip passing through the rollers—an increase in either requiring an increase in force by the rollers to keep the thickness constant. The force applied by the

rollers to the strip is exerted on the rollers at their ends. As the force is increased to overcome the increasing resistance of the strip due to the differential cooling of the head and tail ends of the strip, the rollers, which are confined only at their ends, bow outwardly at the middle resulting in crowning along the center of the strip. Crowning in itself is undesirable since it is important that the properties of the strip—including thickness as well as hardness—be constant. Further disadvantages of crowning are that center buckling and edge tear frequently result during subsequent processing of the strip. Thus the second disadvantage associated with prior art hot strip mills is differential cooling of the strip before it enters the finishing train.

The third disadvantage is the occurrence of skid marks in the strip. Skid marks are areas of the strip which are cooler than the adjacent areas on either side. Since the color of a hot strip is determined by its temperature, the skid marks, being cooler, appear as dark patches. Skid marks result from differential heating and are troublesome for the reasons given in the last paragraph. However the differential heating resulting in skid marks is caused quite differently from the continuous differential cooling from head to tail of the strip due to the differential time of exposure of the head and tail before entering the finishing train. Skid marks occur when the hot slab of metal slides through the furnace on water cooled runners or skids to the conveyor which conveys the slab to the roughing mill. The water cooled skids conduct heat away from the areas of the slab in contact with the skids, and these areas remain cooler than their adjacent areas and are visible as skid marks even after passing through the roughing mill. The skid marks are greatly lengthened by the roughing mill, as is the rest of the strip, but the skid marks stay in the strip as it enters the finishing train.

These three difficulties—a temperature of some parts of the strip below 1550° F. in the finishing train, a non-constant temperature in the finishing train, and skid marks—are all very well known in the steel industry, and attempts have been made to overcome at least the first two disadvantages.

One attempt to maintain the temperature of the strip above 1550° F. at the finishing train has been to increase the temperature of the furnace, thereby giving the strip a higher initial temperature. However it has been found that the life of the furnace is greatly reduced if the furnace is operated above about 2400° F.

Another attempt—this one an attempt to solve both the problem of the strip temperature falling below 1550° F. and the problem of differential cooling between the head and the tail of the strip—has been to shorten the time the strip is on the delay table. This has been accomplished by the introduction of Zoom rolling techniques by which the speed of the strip is increased as it travels through the mill. However Zoom rolling requires a considerable increase in the power of the mill in order to achieve effective speeds. Furthermore, Zoom rolling introduces problems in the synchronization of the coilers that coil up the finished strip. The greater the speeds that are attained, the greater the problems in the synchronization.

The present invention overcomes, or at least mitigates, all three of the above disadvantages. The invention in its broadest aspect comprises a method of reducing the cooling of a bar of metal in a hot strip mill comprising the step of reducing the rate of loss of heat due to radiation from at least one surface of the bar. The invention also contemplates apparatus for carrying out the above method. In one embodiment of the apparatus of the present invention, a radiation reflector is provided which is adapted to be positioned in the vicinity of the bar or strip to reflect back at least some of the radiation radiated

from the strip. In this embodiment, the reflector is preferably a sheet of aluminum and forms a concave surface about the upper surface of the strip, thus focussing the reflected radiation more effectively back towards the strip.

In another and more preferred embodiment of the apparatus of the present invention, a heat shield is provided in the vicinity of, and in substantially parallel relation to, the hot strip during at least part of the travel of the strip through the hot strip mill. The heat shield is adapted to quickly absorb some of the heat radiated from the strip and to remain hot from the previous bar thereby resulting in an increased and relatively high temperature of the shield and hence of the surroundings of the strip, so that further radiation from the strip will be reduced in accordance with the Stefan-Boltzmann law:

$$Q=K\ (T_1^4-T_2^4)$$

where

Q is the heat radiated per unit area per unit time
K is a constant
T_1 is the absolute temperature of the strip
T_2 is the absolute temperature of the surroundings.

Without the shield the difference in temperature between the strip and its surroundings is great (of the order of 2000° F. or 1000° K.), and the amount of heat radiated per unit time is considerable. In the time it takes for the strip to reach the finishing train, the total amount of heat lost—and the corresponding decrease in the temperature of the strip—may be quite extensive. However, with the second type of heat shield, the difference between the temperature of the strip and its surroundings is substantially reduced with a corresponding reduction in the radiation and hence in the temperature drop.

The heat shield can be in the form of a tunnel covering the upper suface of the strip. In a semi-continuous hot strip mill the shield can be used over the delay table between the roughing mill and the finishing train; in a continuous mill the shield can also be used between the individual stands of rollers in the roughing mill. The heat shield can advantageously be made of sheet stainless or other steel with a backing layer of insulating asbestos. In normal use the shield might be positioned with its steel surface facing the strip about 4½ inches above it as the strip moves along the conveyor rollers. It has been found that with the shield so positioned, it is very effective for maintaining the heat in the strip thus preventing the temperature of any portion of the strip from falling below 1550° F.

In another aspect of the invention, differential cooling of the bar is substantially reduced by arranging either the reflector or the heat shield in sections along the length of the strip with adjacent sections of the reflector or shield covering adjacent areas of the strip, and by providing means for independently moving the sections into or out of the vicinity of the strip thereby independently controlling the cooling of the various areas of the strip to reduce differential cooling among these areas. The sections are generally moved into the vicinity of the strip in sequence in the same direction as the strip is advancing so that areas towards the tail of the strip are covered for a longer time than areas towards the head. This counteracts the tendency of the tail end to cool more than the head end due to the longer exposure of the tail before entering the finishing train.

In yet another aspect of the invention, skid marks formed in the strip are substantially eliminated. This is accomplished by moving the sections of the reflector or heat shield into the vicinity of the strip over the skid marks as the marks advance along with the strip. Thus the skid marks, which are areas of the strip which are cooler than adjacent areas on either side of the skid marks, cool less than their adjacent areas, thus resulting in substantial equalization of the temperature in the skid mark areas and the adjacent areas so that the skid marks disappear or are at least less pronounced.

This sequence of moving the sections into (and out of) the vicinity of the strip so that the skid marks, but not their adjacent areas, are covered can be superimposed on the general sequence of moving the sections into the vicinity of the strip in the direction of advance of the strip to differentially shield the tail end more than the head end.

To control the movement of the sections into and out of the vicinity of the strip, heat sensing devices can be arranged along the conveyor in the conventional manner to sense the temperature of the strip as it advances past the heat sensing device. Each sensing device controls associated circuitry which is activated according to whether the corresponding area of the strip is above or below the correct temperature at the heat sensing device. If the strip is above the correct temperature at a particular device, the appropriate section will be moved away to allow that area of the strip to cool at a greater rate. If the strip is below the correct temperature at the heat sensing device, the appropriate section will be moved in to cover that area and reduce the rate of cooling.

The means to move the sections of the reflector or heat shield into or out of the vicinity of the strip can conveniently be an air cylinder and piston. The free end of the piston can be attached to the section, and the section hinged along one edge. As the piston moves in or out, the section pivots away from or towards the strip.

In drawings which illustrate embodiments of the invention,

FIGURE 1 is a plan view of a semi-continuous hot strip mill employing a heat shield according to the invention,

FIGURE 2 is a side elevation of part of a hot strip mill employing a different embodiment of a heat shield of the invention,

FIGURE 3 is a perspective of one heat shield section of the type shown in FIGURE 1, and

FIGURE 4 is a perspective view of one section of a reflector according to the invention.

Referring particularly to FIGURE 1, a 5 ton slab of steel (not shown) 10 feet long by 37 inches wide by 6 inches thick, is heated in a furnace **10** to a temperature of about 2200° F. It is supported for part of its travel through the furnace on water cooled skids. The hot slab then slides down the runners or skids **11** from the furnace **10** onto a conveyor **12** having rollers **13**. The slab is moved along the conveyor **12** to a roughing mill **14** through which the slab makes 3 to 5 or more passes back and forth to be rolled into a strip **16** (FIGURE 2) approximately ¾ of an inch thick and **150** feet long. On each pass forward through the roughing mill **14**, the slab is blasted with a jet of water from a de-scaler **17** to remove the continually forming scale from the slab. The jet is directed against the forward direction of the slab so that most of the scale flies off backwards although a certain amount of the scale does fly forward. The strip **16** advances from the roughing mill **14** along a delay table **18** on conveyor rollers **19**. The strip passes through a crop shear **22** located at the end of the delay table. After passing through the crop shear **22**, the strip passes through a scale breaker **23** where scale which formed on the strip while it was on the delay table is removed, and then the strip enters a finishing train **24**. The finishing train **24** consists of six stands of rollers **26** (only the first two of which are shown) where the strip is rolled down to its final gauge, which may be, for example 1/10 of an inch in thickness. The final gauge strip may be 800 to 1800 feet long (or longer in some mills), and is coiled up in coilers **27** into large coils or rolls ready for further use.

A heat shield **28** is formed of 10-foot sections **29** (best shown in FIGURE 3) arranged end to end along the delay table **18**, parallel to the delay table and about 5¼ inches above it so that the shield **28** is about 4½ inches from the upper surface of the hot strip **16** as it moves

along the delay table. Extending back from the crop shear 22 towards the roughing mill 14, the heat shield is in the form of individual sections 29 about 10 feet long and arranged end to end to cover the delay table 18 back a distance from the crop shear 22 equal to the length of the longest strip emerging from the roughing mill. The shield sections 29 move individually into and out of the vicinity of the strip when the hot strip mill is in operation, as will be described later with particular reference to FIGURE 3.

From the point on the delay table where the individually movable sections 29 end—that is, from the point a distance back from the crop shear equal to the length of the longest strip—to a point partway back to the roughing mill, the shield is in the form of a continuous tunnel 31. The tunnel 31 does not extend all the way back to the roughing mill since some of the scale which is blasted off the slab by the de-scaler 17 flies forward and would build up on top of the tunnel. The tunnel 31 can be made up of individual sections 29, but during operation of the mill these sections may not move. However, it is convenient for cleaning of the tunnel and maintenance of the rollers to make it in sections which can be individually moved away from the delay table.

Referring particularly to FIGURE 3, each section 29 has a steel plate 32 which may be stainless steel and corrugated to allow for expansion and contraction, and a backing 33 of asbestos. The plate and backing are cantilevered by two cantilever members 34 secured at one end to the plate 32 by fastening members 36. The other ends of the cantilever members 34 are secured to the upper ends of two outer uprights 37 spaced apart by two cross members 38. The lower ends of the two outer uprights 37 are pivoted on hinge pins 39 journaled in supports 41 secured to a base plate 42. Two inner uprights 43 are fastened to the cross members 38. An air cylinder 44 having a piston 46 is pivotally mounted on a support 47 by pin 48. One end of a connecting rod 49 is fastened to the piston 46, and the other end of the rod 49 is pivotally connected by pin 51 to the two inner uprights 43. Two stops 52 extend downwardly from the plate 32 and rest on abutments 53 when the shield section 29 is in its "down" position, holding the plate 32 substantially horizontal. When the piston 46 is drawn into the cylinder 44, the shield section 29 tilts up about the hinge pins 39. The section is mounted with its tilt axis (i.e. the axis of the hinge pins 39) parallel to the length of the delay table 18, and so that when the section is in its down position, the plate 32 is positioned about 4½ inches above the hot steel strip as the strip moves along the delay table 18.

In the embodiment shown in FIGURE 2, the shield sections 29 are of a slightly different construction which will not be described here in detail, it being obvious to one skilled in the art what sort of construction would be suitable. The essential feature of this embodiment is that the sections tilt about an axis transverse to the length of the delay table 18.

In FIGURE 4 a reflector 60 is shown which is an alternate apparatus to the heat shield described in connection with FIGURES 1 to 3. The reflector 60 is positioned over the delay table 18 so that the strip (not shown) passes under the reflector when advancing along the rollers 19 of the delay table towards the finishing train. The reflector 60 is concave towards the delay table 18 so that heat radiated from the strip as it passes under the reflector will be effectively focussed back towards the strip. The reflector can advantageously be

made of aluminum, in which case care must be taken to ensure that the reflector is placed far enough from the strip so as not to melt. About 40 inches has been found satisfactory.

As was the case with the heat shield, the reflector can be made in the form of a continuous tunnel and also in the form of sections, conveniently about 10 feet in length. The sections can be moved into and out of the vicinity of the strip in the same way as was described in connection with the heat shields of FIGURES 1 to 3.

I claim:

1. In a hot strip mill, wherein a strip is transported along a delay table from a roughing mill to a finishing mill, the method of reducing differential cooling effects on the strip while it is on the delay table which comprises the step of passing the strip below a series of heat shields movably disposed above said delay table and adjusting the height of each of said heat shields above the strip in accordance with the temperature of the strip beneath each said shield.

2. In a hot strip mill; a roughing mill, a finishing mill, and a delay table extending theerbetween, said delay table having first and second parts, a heat reflector disposed above the first part of the delay table; a plurality of heat shield units movably disposed above the second part of the delay table; and means for selectively bringing each of said units into proximity with the surface of said second part.

3. In a hot strip mill, apparatus for equalizing the temperature distribution along a hot strip having relatively hot and relatively cooler regions, comprising means for selectively reducing heat loss due to radiation from the relatively cooler regions of said strip; said means including a heat shield divided into a plurality of sections disposed along the length of the strip; and actuating means for independently moving each of said sections into or out of proximity with said strip.

4. Apparatus as claimed in claim 3, further comprising means for controlling said actuating means in response to the temperature of various areas of the strip.

5. Apparatus as claimed in claim 3, in which the heat shield comprises a steel plate having heat insulating material on a surface thereof remote from said strip.

6. Apparatus as claimed in claim 3 in which said actuating means comprises an air cylinder and piston arrangement for each of said sections.

7. In a hot strip mill wherein a strip is transported along a delay table from a roughing mill to a finishing mill, apparatus for reducing differential cooling effects on said strip while on said delay table, said apparatus comprising a series of heat shields movably disposed above said delay table; a plurality of heat reflectors and means for selectively bringing each of said reflectors into proximity with said strip so as to reduce heat loss by radiation from the region of the strip below said reflector.

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