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TREATING STRIP

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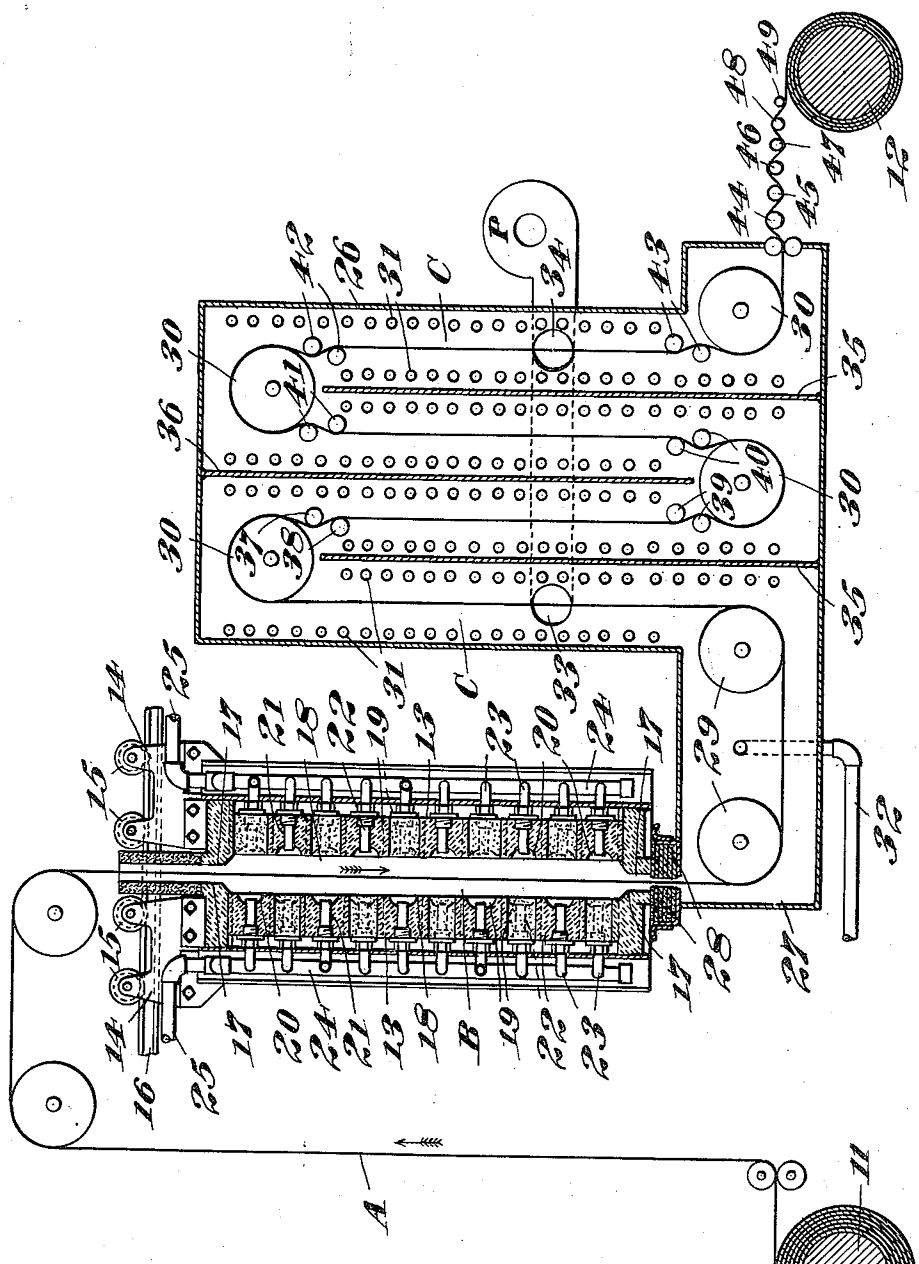

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TREATING STRIP

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Our invention relates to the heat treatment of steel strip, particularly cold rolled steel strip, and it is directed to a method and to an apparatus for continuously heat treating strip.

As is well known, when steel strip is produced by rolling, particularly by cold rolling, the strip is objectionably hard and is in a severely strained condition. The usual process to overcome these effects of rolling is by means of what is commonly designated as "annealing." This operation comprises enclosing the strip, in the form of rolls of strip, and heating the strip to a temperature of from 1100° F. to 1300° F., and then allowing the strip to cool slowly to atmospheric temperature, the total time of this annealing operation taking something of the order of 72 hours. As a consequence of this treatment the strip is rendered considerably softer and the strains are removed. Moreover, the steel of the strip is considerably modified metallurgically since the long time that the steel is maintained at elevated temperature permits of a substantial amount of carbon migration and other metallurgical changes of the metal.

Our invention likewise is directed to the removal of the strains produced in steel strip by rolling, particularly by cold rolling, but we do not subject the strip to the slow, batch system of annealing but we employ a continuous heat treatment involving a rapid heating of the strip to the desired temperature and then cooling as quickly as practicable. This heat treatment of our invention does not affect the steel as profoundly as does the usual annealing treatment. Except for recrystallization the steel is metallographically much the same as before the heat treatment and there is little if any carbon migration. This heat treatment, however, does remove the strains and the steel is softened although not as much so as with the prior annealing operation.

Our invention comprises the idea of feeding strip rapidly and continuously through a heating zone which is heated by the combustion of fuel to a temperature considerably higher than the temperature to which the strip is to be heated in its passage through the heating zone whereby the strip is rapidly heated to the necessary annealing temperature in its rapid passage through the zone. Our invention also comprises the idea of rapidly and continuously passing the strip from the heating zone through a cooling zone to cool the strip as quickly as practicable. It also comprises the idea of drastically flexing the strip at intervals over a considerable range of temperature while it is cooling, and also preferably,

after it has cooled to or near atmospheric temperature to obviate the fluting tendencies of the heat treated strip.

To illustrate the principles of our invention, we will first give a more or less specific example of its application, it being understood that this example is for illustrative purposes and is not intended to limit the scope of the actual invention. In this specific example, the strip being treated is of cold rolled steel of low carbon content (less than 0.10%). The drawing, which forms a part of this specification, diagrammatically shows a vertical longitudinal section of equipment suitable for carrying out the operation of the invention.

Strip A is unwound from the supply reel 11 and is fed successively through heating zone B to heat the strip to the necessary temperature and then through cooling zone C to cool the strip, the strip passing ultimately to take-up reel 12.

Panels 13 constitute the walls of heating zone B. These two panels are supported at their upper ends by brackets 14 having rollers 15 adapted to slide on a runway 16. By means of this arrangement the two panels may be separated from each other to permit access to their inner surfaces for repair and for other purposes, which will later appear in the specification, and may be brought close together in the normal operation for the heating of the strip.

Each of the two panels 13 is provided with a peripheral portion 17 which projects somewhat out of the plane of the main heating portion 18 so that the opening face of the two panels are somewhat dished, thus providing the necessary space between the panels to constitute the heating zone B. The space between the opposing faces 18 of the panels should be as narrow as practicable to get the most efficient heating of the strip as it passes through the heating zone. The main heating portions 18 of the panels are made up of a multiplicity of burner blocks 19 of refractory material. Each block is provided on its inner side with a concave depression 20. Each block has a central opening 21 which contains a burner tube 22 adapted to terminate centrally of the concave depression 20. The burner tubes 22 receive a mixture of air and combustible gas from pipe 23 which connects with manifold 24, the manifold receiving the gas mixture through supply pipes 25.

Cooling zone C comprises tank 26 having an extension 27 which serves to connect tank 26 with heating zone B. Between extension 27 and the heating zone B is a slot type seal 28 through which the strip passes.

Rolls 29 in extension 27 and rolls 30 in tank 26 serve to guide the strip through cooling zone C, rolls 30 being disposed alternately near the bottom and top of tank 26 so as to give an alternate upward and downward path of travel to the strip. Disposed to each side of the path of the strip and as close as practicable thereto are water-cooled coils 31. Non-oxidizing gas is introduced into the cooling zone C through pipe 32. The non-oxidizing atmosphere in zone C is rapidly circulated through tank C by means of pump P, the gas being withdrawn from the tank through opening 33 near the beginning of the path of travel of the strip and returns to the tank through opening 34 near the end of the travel of the strip in the tank. Any suitable means may be employed for cooling the gas. Tank 26 is provided with plates 35 extending clear across the tank and extending from the bottom of the tank but terminating short of the top thereof. These plates alternate with plates 36 extending from the top of the tank but terminating short of the bottom. By this arrangement the gas which enters through opening 34 takes a course of travel along the path of the strip but in a counter direction.

Just after the strip leaves upper guide roll 30 in cooling chamber 26 it passes over small roll 37 and then over small roll 38 disposed near roll 37. Roll 37 is so placed as to deflect the course of the strip to the left and roll 38 brings the strip back into what might be called the normal course of the strip. It will be evident that the strip will be flexed by roll 37 in one direction and then be flexed in a reverse direction by roll 38, the strip wrappingly engaging an arc of roll 37 and wrappingly engaging an arc of roll 38 as the strip passes over these two rolls. These two rolls are of sufficiently small diameters so that the strip is flexed beyond the elastic limit of the steel at the temperature of the strip when it reaches these two rolls. When, hereafter in this specification and in the claims, we refer to "drastic" flexing of the strip we intend to signify this flexing beyond the elastic limit of the steel at the temperature at which the flexing occurs. Rolls 39, 40, 41, 42 and 43 act similarly to rolls 37 and 38 in effecting drastic flexing of the strip.

After the strip emerges from cooling tank 26 it passes over a series of small rolls 44, 45, 46, 47, 48 and 49 placed relatively close together, these rolls being progressively smaller. It will be evident that these rolls also flex the strip drastically in progressively greater amounts.

Having given a brief description of the equipment we will now describe the operation of our invention when using such equipment.

A mixture of gaseous fuel and air is fed through pipes 25 to manifolds 24 and thence through pipes 23 to burner tubes 22 and burned at the ends of the tubes to produce flames in a concave depression 20, the gas being fed at such velocity in accordance with well known principles and practices as to prevent the combustion taking place before it leaves the exit of tubes 22. The burning is effected in accordance with well known practices in such a way as to practically confine the flame to the concave depression areas 20 so that no direct flame impinges on the strip.

By means of this system of heating we are able to heat the panels to very high temperatures. When using coke oven gas and air, for example,

we are able to heat the panels to a temperature of about 2500° F. The strip to be annealed is heated to a temperature of from 1200° F. to 1700° F. We consider a temperature range of from 1350° F. to 1400° F. to be the most practical range as this temperature range is high enough to effect the desired change in the strip and higher temperatures would be less economical.

It will be noted that the temperature to which the strip is heated is markedly less than the temperature of the heating zone. When, for example, the strip is heated to a temperature of from 1300° F. to 1400° F. and the panels are at a temperature of 2500° F. there is a temperature differential of some 1100° F. This provision of a temperature of the heating zone much higher than the temperature to which the strip is heated permits of the strip being heated rapidly to the desired temperature.

This rapid heating of the strip greatly reduces the length of time the strip must be in the heating zone, thus permitting the strip to be fed rapidly through the heating zone. In practice we feed the strip at from fifty to five hundred feet per minute or at even greater speeds. Several important advantages are thereby obtained. The output of the strip annealed is greatly increased and the length of the heating zone necessary for a given output is reduced. Moreover, the rapidity of movement through the heating zone limits the time that any particular portion of strip is in the heating zone and thereby enables us to avoid any deleterious oxidation of the strip while it is passing through the heating zone even though the heating zone contains the products of combustion which are oxidizing at the elevated temperatures of the strip.

Preferably the mixture of coke oven gas and air is such as to give a small amount of reducing gas in the products of combustion, this being effected by having a slight deficiency of air. When using coke oven gas we employ this gas in the ratio of about 1 part of coke oven gas to 4 parts of air and the resulting products of combustion contain approximately 1% of hydrogen and 1% of carbon monoxide. It is to be understood that this small percentage of uncombined combustibles would not prevent serious oxidation of the strip if any portion of the strip were to remain in the atmosphere of combustion gases for any substantial period of time, since the atmosphere of the heating zone contains large amounts of water vapor and carbon dioxide which have considerable oxidizing power at the high temperatures of the strip. Because of the rapid movement of the strip through the heating zone, however, there is insufficient time for any substantial oxidation. The presence of the small amounts of reducing constituents in the atmosphere, however, does assist in avoiding any detectable oxidation of the strip and we are able to secure "bright" strip.

When, in the operation of our equipment, it is necessary to stop the feed of the strip through the heating zone the two panels 13 may be separated as already described above, thereby allowing the strip to cool and not to become excessively heated as would otherwise happen.

As the strip is at a high temperature when it leaves the heating zone it must be protected from the air until the strip has been cooled to a sufficiently low temperature not to be oxidized by the air. Accordingly the strip is fed directly from the heating zone B into the cooling zone C in which the strip is cooled as rapidly as practicable in a non-oxidizing atmosphere. As a cheap non-oxidizing gas for use in the cooling zone we have employed a mixture of nitrogen with small amounts of hydrogen and carbon monoxide prepared by burning coke oven gas with a deficiency of air and then removing carbon dioxide and water vapor. This non-oxidizing gas consists mostly of nitrogen with about 2% of both carbon monoxide and hydrogen.

The cooling in zone C is accelerated by various means and conditions within such zone. The course of the strip is in proximity to the water-cooled coils **31**. The cooled non-oxidizing gas is rapidly circulated over the strip. An important factor in accelerating the cooling of the strip is the cooling effect of feed rolls **29** and **30** over which the strip passes, this being particularly true when one or more of the feed rolls are water-cooled.

An important feature of our invention is the prevention of fluting of the strip. Heretofore fluting of the strip has been most commonly prevented by subjecting strip to a "skin pass" operation after the completion of the annealing operation. We avoid the necessity of skin passing and obviate the fluting characteristics of the strip by drastically flexing the strip while it is passing through the cooling zone and preferably we also drastically flex the strip after it has left the cooling zone and when its temperature is at or not far from atmospheric temperature.

We have already pointed out above the means for drastically flexing the strip which we employ with the particular embodiment of our apparatus given in the drawing, namely by means of rolls **37**, **38**, **39**, **40**, **41**, **42** and **43** in the cooling chamber, and rolls **44** to **49**, inclusive, outside the cooling chamber.

For the most effective elimination of the tendency to flute we find that the strip should be drastically flexed before it has cooled below 650° F. and then drastically flexed at different temperatures below 650° F. while the strip is cooling. The first drastic flexing should not be at too high a temperature, since with the temperature substantially higher than 900° F. or thereabouts, the material is so plastic that flexing the strip has no appreciable effect in the prevention of fluting tendencies. In general, the first drastic flexing of the strip should be at a temperature between 650° F. and 850° F. Accordingly, in the illustrative embodiment herein given the first flexing rolls **37** and **38** are disposed in that part of the cooling zone where they flex the strip beyond its elastic limit at a temperature between 650° F. and 850° F. or thereabouts.

In the illustrative embodiment of our invention the first drastic flexing of the strip, namely that by rolls **37** and **38** are when the strip is at a temperature of about 700° F., the next drastic flexing, that by rolls **39**, being at a somewhat lower temperature. Rolls **40** drastically flex the strip while it is at a temperature of about 455° F. and rolls **41** drastically flex the strip at a somewhat lower temperature. Rolls **42** drastically flex the strip at a temperature of about 170° F. and rolls **43** drastically flex the strip at a somewhat lower temperature.

As we have already indicated above, it is desirable to drastically flex the strip after it has left the cooling chamber and when the strip is at or comparatively near atmospheric temperature. While the drastic flexing in the cooling chamber greatly reduces the tendency of the strip to flute we have found that additional drastic flexing after leaving the cooling chamber renders the strip still more resistant to fluting.

The strip leaves the cooling chamber sufficiently cool so that it will not be oxidized in the air. We prefer to have the temperature of the strip when it leaves the cooling chamber not over about 200° F. In the embodiment of our invention here illustrated the strip emerges from the cooling chamber at a temperature not much above atmospheric temperature. Under this condition the strip passes over rolls **44** to **49**, inclusive, which drastically flex the strip. As these rolls progressively decrease in diameter the strip is drastically flexed progressively in greater amounts.

We claim:

1. In a process for treating steel strip, the steps of continuously feeding the strip through a heating zone to heat the strip to a temperature not less than 1200° F., continuously feeding the strip thus heated through a cooling zone having a non-oxidizing atmosphere, flexing the strip beyond its elastic limit in the cooling zone while it is at a temperature not lower than 650° F. but at a temperature lower than the critical range, and flexing the strip beyond its elastic limit in the cooling zone after it is cooled below 650° F.

2. In a process for treating steel strip, the steps of continuously feeding the strip through a heating zone to heat the strip to a temperature of at least 1200° F., continuously feeding the strip thus heated through a cooling zone having a non-oxidizing atmosphere, flexing the strip beyond its elastic limit in the cooling zone while it is at a temperature not lower than 650° F., flexing the strip beyond its elastic limit at intervals in the cooling zone after it is cooled below 650° F., and flexing the strip beyond its elastic limit after it has left such cooling zone.

3. In a process for treating steel strip, the steps of continuously feeding the strip through a heating zone to heat the strip to a temperature above 1200° F., continuously feeding the strip thus heated through a cooling zone having a non-oxidizing atmosphere, flexing the strip beyond its elastic limit in the cooling zone while it is at a temperature not lower than 650° F., flexing the strip beyond its elastic limit in the cooling zone after it is cooled below 650° F., and flexing the strip beyond its elastic limit after it has left such cooling zone in gradually increasing amounts.

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