

July 12, 1932.

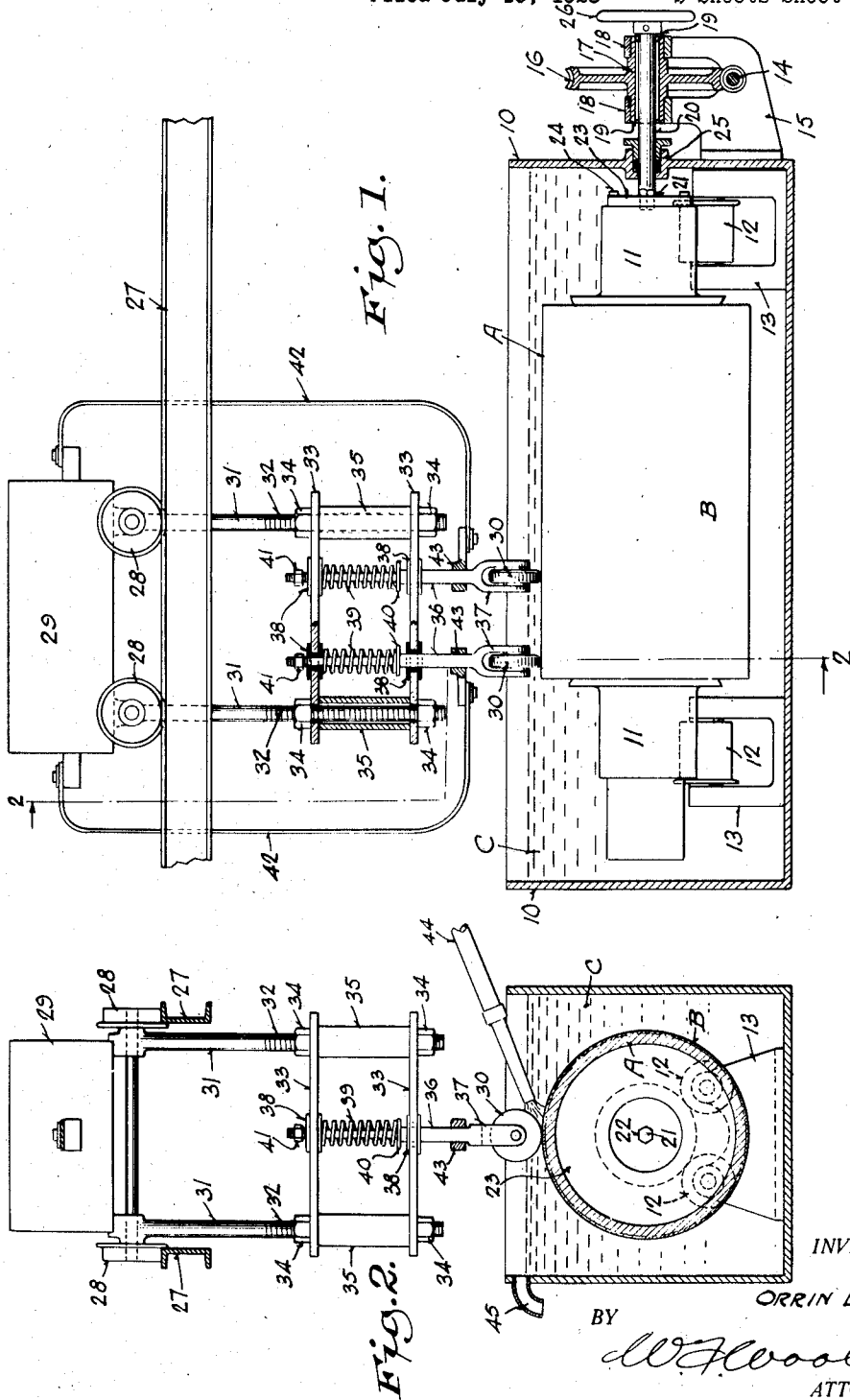
O. E. ANDRUS

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METHOD OF STRUCTURALLY MODIFYING THE SURFACES OF METAL BODIES

Filed July 13, 1928

2 Sheets-Sheet 1



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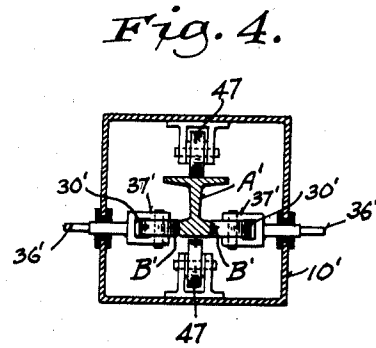
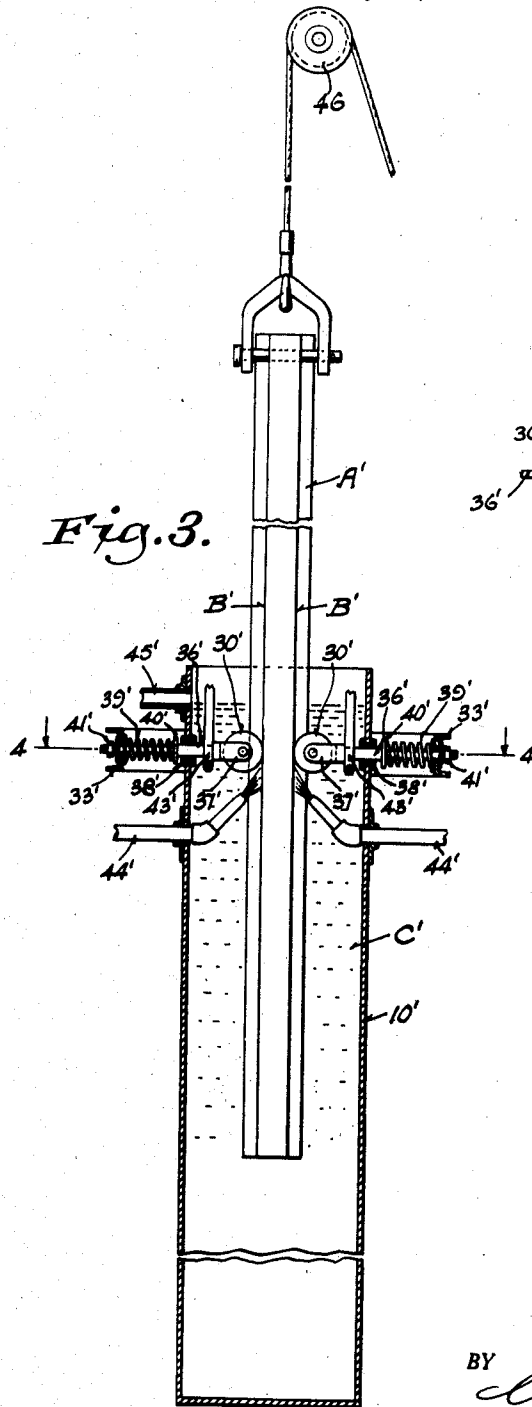
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2 Sheets-Sheet 2



INVENTOR.

ORRIN E. ANDRUS

BY

W. F. Hoosier
ATTORNEY.

UNITED STATES PATENT OFFICE

ORRIN E. ANDRUS, OF MILWAUKEE, WISCONSIN, ASSIGNOR TO A. O. SMITH CORPORATION, OF MILWAUKEE, WISCONSIN, A CORPORATION OF NEW YORK

METHOD OF STRUCTURALLY MODIFYING THE SURFACES OF METAL BODIES

Application filed July 13, 1928. Serial No. 292,377.

My invention relates to a method of structurally modifying a surface of a metal body by applying thereto an electric current having sufficient intensity to raise the temperature of a portion of said metal body above transformation temperature by reason of the natural resistance of the metal of said body to the flow of the said electric current.

Some of the various purposes for which the invention is suitable may be stated as follows: (a) to surface harden high carbon steel; (b) to surface harden carburized steel; (c) to surface toughen low carbon steel; and (d) to surface harden cast iron.

Heretofore, the surfaces of metal bodies have been structurally modified in a number of different manners, but usually by subjecting the bodies to a high temperature, as, for example, in a furnace, to raise the temperature of the whole of their surfaces above transformation temperature, and then quenching the bodies. Such procedure, obviously, changes the entire structure of the bodies and has tendency toward developing stresses and warping in the bodies. To obviate stresses and warping and changes in the entire structure, attempts have been made to structurally modify the surfaces of metal bodies by the external application of localized heat to the said surfaces. But, so far as I am aware, satisfactory structural modification of the surfaces of metal bodies has not been attained by the external application to the surfaces of localized heat, for the reason that all attempts to make the methods continuous, by the external application of localized heat to portions of a surface adjacent portions already modified by externally applied localized heat, have either resulted in further modification, of a substantial part at least, of the said already modified portions, so that the surfaces have been of greatly varied structure throughout their areas, and not of a substantially uniform and predetermined modified structure, or have resulted in the melting or burning of the surface because of a too intense localized heat.

By way of example, it may be said that should it be desired to acquire a modified surface of a uniform and predetermined struc-

ture upon a carbon steel, such as would result from heating the whole of the surface of the steel to critical temperature and quickly quenching, there would be a failure in the attempts to accomplish this result by repeated external applications of localized heat, necessarily insufficient to melt or burn the surface, to different and contiguous portions of the said surface. It is well known that portions of a steel heated to critical temperature and quenched, to be thus tempered, will have their temper greatly altered if the said portions are again materially heated to a temperature less than critical, and that the extent of alteration of the temper will depend upon the time interval the portions remain so materially heated. The external application of localized heat to a surface of a metal body, as, for example, carbon steel, to raise a portion thereof above transformation temperature, and without melting or burning the metal, of necessity causes a considerable spreading of the heat to surrounding areas of the surface, so that portions of the metal directly surrounding portions raised above transformation temperature are just below transformation temperature, while surrounding portions further removed are but little cooler. In fact, a surrounding area of considerable dimensions is materially heated when a portion of a metal surface is raised above transformation temperature by the external application of localized heat, and the temperature of the said surrounding area varies about uniformly from the perimeter of the area above transformation temperature, where said surrounding area is hottest, to a perimeter remote from the transformation temperature area, where said surrounding area is coolest. Thus, as will be evident, when a repeated external application of localized heat is made upon a portion of the surface of a metal body adjacent a portion thereof already heat treated, there is considerable heat lap-over which results in material alteration of the structure of practically all, if not all, of the said portion already heat treated, and the structure of the already treated portion is affected, to an ever varying

degree, practically throughout its whole area.

An object of the present invention is the provision of a method for structurally modifying a surface of a metal body by applying thereto an electric current adapted to raise substantially instantaneously the temperature of a portion of the surface of said metal body above transformation temperature, by reason of the natural resistance of the metal of said body to the flow of the current, without materially heating other portions of said surface which are adjacent the said portion raised above transformation temperature, whereby applications of localized heat to different and contiguous portions of the said surface can suffice to produce upon said metal body a modified surface of practically uniform and predetermined structure.

A further object is the provision of a method for structurally modifying a surface of a metal body by applying thereto an electric current adapted to locally and practically instantaneously heat a portion of the surface, and a localized region of said metal body contiguous with the heated portion of the surface and substantially surrounded by unheated metal of said body, above the transformation temperature of the metal, in such manner that the heat applied to the said surface and localized region will not spread to any material extent, but will be concentrated substantially within the said localized heated region, whereby unheated metal of the said body surrounding the said localized heated region can materially assist in the quenching operation.

A further object is the provision of a method as stated, wherein the application of the localized heat to the surface of a metal body is accomplished by the utilization of one or more resistance heating electrodes, and in such manner that the portion of the surface heated above transformation temperature is engaged by a resistance heating electrode while the localized heated region is situated within and is substantially surrounded by the mass of the unheated metal of the body.

A still further object is the provision of a method as stated, wherein the practically instantaneous application of the localized heat to the surface of a metal body is accomplished by causing a resistance heating electrode to but momentarily engage each portion of the said surface to practically instantaneously raise the temperature of the said portion above the transformation temperature of the metal, whereby the concentrated action of the current can be applied to a portion of the said surface and in overlapping relation to a contiguous portion already modified without altering the structure of the said already modified portion.

And another object is the provision of a method as stated, wherein the resistance heat-

ing electrodes utilized are preferably, but not necessarily, roller electrodes adapted to ride over the surface of the body of metal.

With the above objects in view, as well as others which will appear as the specification proceeds, the invention will now be fully described and will hereinafter be specifically claimed.

In the accompanying drawings forming a part of this specification,

Fig. 1 is an elevational view, partially sectioned of an apparatus by utilization of which the improved method can be practiced, the disclosure also including a metal cylinder, having a surface to be hardened, as when acted upon by the apparatus;

Fig. 2 is a sectional view taken as on line 2—2 in Fig. 1;

Fig. 3 is an elevational view, partially sectioned, of a modified type of apparatus for practicing the novel method, the disclosure also including a metal rail, having a surface to be hardened, as when acted upon by the modified apparatus; and

Fig. 4 is a sectional view taken as on line 4—4 in Fig. 3.

With respect to Figs. 1 and 2 of the drawings, A represents a metal cylinder having an external surface B which is to be structurally modified. The cylinder A may be composed of any one of a variety of different metals. For example, it may be high carbon steel, carburized steel, low carbon steel, or cast iron.

As disclosed, the cylinder A is situated in cooling liquid C of any suitable nature contained in a vessel 10, and the said cylinder is rotatably supported in the vessel, in spaced relation to its walls, by means of studs 11 upon the cylinder which rest upon rollers 12 conveniently mounted in brackets 13 supported upon the base of the vessel.

Any suitable mechanism may be utilized to rotate the cylinder. As shown, a worm 14 supported by a bracket 15 upon the vessel meshes with a worm wheel 16 having a hub 17 mounted in a bifurcated part 18 of said bracket 15, as at 19, and a short shaft 20 splined to the hub has an hexagonal end portion 21 adapted to fit an hexagonal opening 22 in a plate 23 secured as at 24 to the adjacent stud 11 upon the cylinder. The short shaft 20 is slidably situated in a gland 25 of the adjacent wall of the vessel, and a hand piece 26 upon the outer end of said short shaft is for the purpose of manipulating the hexagonal end portion 21 into and out of the opening 22 of the plate 23. Clearly, when the hexagonal end portion 21 of the short shaft 20 is situated within the opening of the plate 23, turning of the worm 14 will cause the cylinder A to be rotated upon its bearings, or the cylinder can be rotated by turning the hand piece 26.

A double track 27, above and parallel with the vessel 10, supports wheels 28 mounted upon a source of electric current supply, rep-

resented generally at 29, which may be a transformer. The element 29 is thus made rideable along the track 27, and may be propelled in any convenient manner (not necessary to be shown).

Spaced apart roller electrodes 30, which are preferably adapted to engage with yielding pressure against the surface B of the cylinder A, are suspended from the element 29 in any suitable manner. As disclosed, vertically disposed rods 31, extending downwardly from said element 29, have their lower portions threaded, as at 32, and transverse plates 33 are supported upon the threaded portions of said rods, in spaced relation to each other by nuts 34 upon the rods above and below the plates and spacing sleeves 35 upon the rods and between the plates. Roller electrode carrying shanks 36, of conducting material, have bifurcated lower portions 37 in which the roller electrodes 30 are mounted, and the upper portions of the said shanks 36 are slidable in insulation 38 in openings of the spaced apart plates 33. Coil springs 39 upon the shanks 36, bearing at their upper ends against the insulation in the upper plate 33 and at their lower ends against collars 40 upon the shanks, yieldingly urge the roller electrodes 30 toward the cylinder A, and nuts 41 upon the said shanks 36 and above the upper plate 33 limit the extent of downward movement of the roller electrodes, as will be obvious.

Numeral 42 represents leads from the source of electric current supply, or transformer 29, to the electrodes. As shown, the lower ends of the leads 42 include eyes 43 of conducting material snugly engaging the shanks 36.

As clearly disclosed in Fig. 2, cooling liquid supply pipes 44 may deliver cooling liquid to the vessel at the locations of the roller electrodes, and an overflow pipe 45 may lead from the upper part of the vessel.

With respect to Figs. 3 and 4 of the drawings, I have there shown a metal rail A' having surfaces B' to be structurally modified. The rail may likewise be composed of any one of a variety of different metals.

As disclosed, the rail A' is suitably suspended from a pulley 46 and is adapted to be lowered into cooling liquid C' in a suitable vessel 10', and past roller electrodes 30' which yieldingly engage opposed faces of the said rail. The roller electrodes 30' may be connected with a source of current supply (not shown) and may be mounted upon the vessel 10' in any suitable or convenient manner. As disclosed, roller electrode carrying shanks 36' of conducting material are slidable in insulation 38' in the walls of the vessel 10', and are urged inwardly toward the rail A' by coil springs 39' each between a plate 33' and a collar 40', about as before described. Eyes 43' of conducting material connected with the source of current supply

(not shown), snugly engage the shanks 36'.

Numerals 44' and 45' represent, respectively, cooling liquid supply and overflow pipes, as before described.

Numeral 47 represents guide rolls for the rail suitably mounted in opposed relation upon the walls of the vessel adjacent the walls which support the roller electrodes.

While in each instance I have disclosed the working portions of the roller electrodes submerged in the cooling liquid, it is to be understood that the operation may be carried out in the atmosphere, although it is preferable to have the body being heat treated at least partially submerged in a cooling liquid, or a cooling liquid may be sprayed upon the body at the location of the electrodes.

I have preferred to disclose resistance heating electrodes of the roller type, but in certain instances spot electrodes, or even sliding or wiping electrodes, may desirably be employed.

In the instance of either form of my improved apparatus as disclosed, the roller electrodes and the surface being heat treated are given movement relatively to each other and the electrodes are caused to roll over the surface while current is caused to flow through the body to locally and practically instantaneously heat an engaged portion of the surface, and a localized region of the metal body contiguous with the engaged and heated portion of the surface, above the transformation temperature of the metal. The heat applied to the said surface and localized region will not spread to any material extent, but will be concentrated substantially within the localized heated region, and the resistance heating of the surface will be so accomplished that unheated metal of the said body will surround the localized heated region to materially assist in the quenching operation. That is to say, I accomplish the resistance heating in such manner that the portion of the surface heated above transformation temperature is engaged and protected by a resistance heating electrode, while the localized region heated above transformation temperature and contiguous with the surface heated above transformation temperature is situated within the metal body beneath the heated portion of the surface, and is substantially surrounded by the mass of the unheated metal of the said body. This result is accomplished, as will be apparent, by the utilization of an electrode having a contacting area which is relatively small compared to the mass of the metal body being heat treated, and by controlling the depth into the interior of the metal body to which the localized heated region extends. The conditions can be varied by varying the intensity of the current, the size of the electrode contact, the time of application of the current, or the bulk and thickness of the metal body. The

depth of the localized region heated above transformation temperature will preferably be less than a measurement representing the thickness of the metal at position adjacent the localized heated region so that there will be a bulk of practically unheated quenching metal substantially surrounding the said localized heated region. Considered from a different aspect, practically the whole of the whole of the localized heated region will be situated internally of the metal, beneath the locally heated portion of the surface thereof, to be substantially surrounded by unheated quenching metal of the bulk of metal.

The reason why exceedingly satisfactory results in structurally modifying a surface of a metal body by resistance heating can be obtained will be readily appreciated when it is realized that resistance heating applied by causing a relatively small electrode, usually a copper electrode, to engage a surface of larger area does not cause the heat to be wholly external. On the contrary, the highest temperature attained is beneath the surface, not far distant therefrom, and in a plane substantially parallel with the engaging face of the electrode. As a consequence, the heating of a portion of the metal at and adjacent the surface above critical temperature is accomplished practically instantaneously. Immediately, the heated area is quenched, at least partially by the unheated bulk of metal surrounding the heated area, so that there is no material interval of time in which the heat can spread to portions of a surface adjacent a heat treated portion. Thus, evidently, applications of localized heat to different and contiguous portions of a surface of a metal body, and sufficing to produce upon said body a modified surface of practically uniform and predetermined structure, can be accomplished.

By the employment of electric resistance heating, a minimum amount of heat, considered from the standpoint of the bulk of a metal body being heat treated and its capacity to absorb heat, can be concentrated at and adjacent a surface of a metal body to raise the temperature of a localized region of said body above the transformation temperature of the metal without causing such a spread of the the heat to already modified adjacent areas of the surface as will materially alter the structure of the said adjacent areas.

By reason of the fact that the concentrated heat can be so relatively small in amount compared to the total bulk of metal and its heat absorbing capacity, the arrangement can be such that the temperature of the whole body of metal can be caused to immediately drop below the tempering range practically instantaneously, and during a continuous operation, the bulk of metal can continuously and swiftly absorb the small amount of heat which it is necessary to apply without caus-

ing the temperature of the whole mass of metal to be appreciably elevated as a result. Naturally, the quenching liquid, or other medium, functions continuously to remove heat from the mass of the metal body.

I have produced satisfactory surface modification by resistance heating accomplished by overlapping spots about one-half inch in diameter upon the surface of a steel block. The heating was produced by a heavy current applied through a copper electrode. I have also used a roller electrode the axis of which was held stationary and the metal body moved relatively to it. Such an arrangement greatly increases the speed and ease of carrying out the surface modifying operation. With some types of work, as, for example, the cylinder disclosed in Figs. 1 and 2, the method of heating by use of a roller electrode can be made automatic. The cylinder A can be made to rotate at constant speed while a slow constant movement of the electrodes longitudinally of the cylinder is accomplished, to thus produce a continuous modified surface of practically uniform and predetermined structure upon the surface B of the cylinder. The movement made by the electrodes over the surface B would, in such an event, desirably be along the line of a helical band the edges of which overlapped.

When a resistance heating electrode is utilized to modify a surface of a metal body by overlappingly engaging contiguous portions of the said surface, the overlapped portions are, obviously, heated more than once through the tempering range of the metal. But by reason of the fact that the said overlapped portions can be so quickly passed through the tempering range, the structure thereof is not materially altered by the repeated heating.

While I have, in the instance of each form of the apparatus, disclosed two resistance heating electrodes, it will be obvious that a single resistance heating electrode may in some instances be preferable.

The present method of structurally modifying the surfaces of metal bodies is especially adaptable for use on the many bodies which are liable to become distorted when wholly subjected to high temperatures. Since heating by my method can be intensely localized so that the bulk of the metal body does not become heated to any appreciable extent, the modifying effect produced is usually of greater magnitude than when the same type of metal body is totally heated and liquid quenched by ordinary methods. Obviously, the improved advantageous result inherent in my method is due to a large extent to the fact that the metal body can itself materially assist in the quenching operations to thus hasten the quenching.

It should be noted that my novel method has no relation whatsoever to the heat treat-

ment of the full thickness of a metal body, or of an element, as, for example, a saw tooth, protruding therefrom, by the single application thereto of a resistance heating electrode.

5 On the contrary, the present method contemplates structurally modifying only the surface of a metal body by separately heat treating a plurality of different portions of the said surface, each of which portions is of less
10 area than the whole area of the surface and is substantially surrounded by a considerable bulk of quenching metal of the body.

Having thus fully described my invention, what I claim and desire to secure by Letters
15 Patent of the United States, is:

1. The method of structurally modifying a surface of a metal body by application thereto of an electric current having sufficient intensity to raise substantially instantaneously
20 the temperature of a portion of said metal body above transformation temperature by reason of the natural resistance of the metal of said body to the flow of the current, which consists in subjecting a portion of the surface
25 to the concentrated action of said current, and causing the temperature of a localized region of said metal body contiguous with said portion of the surface and substantially surrounded on all of its sides, except its side constituting the portion of the surface subjected
30 to the current, by unheated metal of said body, to be raised above the transformation temperature of the metal, whereby the said unheated metal of the body about the said
35 localized region heated above transformation temperature can quickly absorb the applied heat at the expiration of the interval of its application.

2. The method of structurally modifying a surface of a metal body by application thereto of an electric current having sufficient intensity to raise substantially instantaneously
40 the temperature of a portion of said metal body above transformation temperature by reason of the natural resistance of the metal of said body to the flow of the current, which consists in subjecting a relatively small portion of the surface to the concentrated action
45 of said current, causing the temperature of a relatively small localized region of said metal body contiguous with said relatively small portion of the surface and substantially surrounded on all of its sides, except its side constituting the relatively small portion of
50 the surface subjected to the current, by a relatively large, practically unheated bulk of metal of said body, to be raised above the transformation temperature of the metal, whereby the said practically unheated, relatively large bulk of metal of said body about
55 the said relatively small localized region heated above transformation temperature can quickly absorb the applied heat at the expiration of the interval of its application to cause
60 the temperature of the whole body of metal

to fall below the tempering range of the metal, and cooling said metal body.

3. The method of structurally modifying a surface of a metal body by application thereto of an electric current having sufficient intensity to raise substantially instantaneously
70 the temperature of a portion of said metal body above transformation temperature by reason of the natural resistance of the metal of said body to the flow of the current, which consists in subjecting a portion of the surface
75 to the concentrated action of said current, causing the temperature of a localized region within the interior of said metal body contiguous with said portion of the surface and substantially surrounded on all of its sides,
80 by a relatively large, practically unheated bulk of metal of said body, to be raised above the transformation temperature of the metal, whereby the said practically unheated bulk of metal of said body about the said relatively
85 small localized region heated above transformation temperature can quickly absorb the applied heat at the expiration of the interval of its application, regulating the temperature of the metal body by surrounding the same
90 with a cooling medium.

4. The method of structurally modifying a surface of a metal body by application thereto of an electric current having sufficient intensity to raise the temperature of a
95 portion of said metal body above transformation temperature by reason of the natural resistance of the metal of said body to the flow of the current, which consists in subjecting contiguous portions of the surface to the concentrated action of said current applied in
100 overlapping relation to the said contiguous portions, and thereby causing a modified surface of practically uniform and predetermined structure to be produced upon said
105 metal body.

5. The method of structurally modifying a surface of a metal body by application thereto of an electric current having sufficient intensity to raise substantially instantaneously
110 the temperature of a portion of said metal body above transformation temperature by reason of the natural resistance of the metal of said body to the flow of the current, which consists in successively subjecting contiguous overlapping portions of the surface to the concentrated action of said
115 current to thereby produce a modified surface of practically uniform and predetermined structure upon said metal body.

6. The method of structurally modifying a surface of a cylindrical metal body by application thereto of an electric current having sufficient intensity to raise substantially
120 instantaneously the temperature of a portion of said cylindrical metal body above transformation temperature by reason of the natural resistance of the metal of said body to the flow of the current, which consists in
125

rotating the cylindrical body and subjecting successive contiguous portions of the surface thereof to the concentrated action of said current to thereby produce a modified surface of practically uniform and predetermined structure upon said cylindrical metal body.

7. The method of heat treating the continuous surface portion of a metal body which comprises bringing a movable electrode of limited contact surface into pressure contact with a portion of the surface to be treated to thereby apply a concentrated electric current to the metal of the body immediately beneath said electrode, and progressively moving said contacting electrode relative to said surface to successively heat contiguous surface portions of said body to the required temperature at a rate sufficient to substantially prevent detrimental conduction of heat to surface portions already subjected to heat treatment.

8. The method of heat treating the continuous surface portion of a metal body, which comprises bringing a roller electrode into contact with a portion of the surface to be treated, applying an electric current to said body through said electrode to heat a portion of said body immediately beneath the limited contact of said electrode for a substantial depth to the required temperature for heat treating the same, and relatively rotating said contacting electrode along the surface to be treated to progressively and successively heat treat contiguous surface portions of said body to the required depth at a rate sufficient to prevent detrimental conduction of heat to surface portions previously subjected to heat treatment.

In testimony whereof, I have signed my name at Milwaukee, this 11th day of July, 1928.

ORRIN E. ANDRUS.