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2 Sheets-Sheet 1

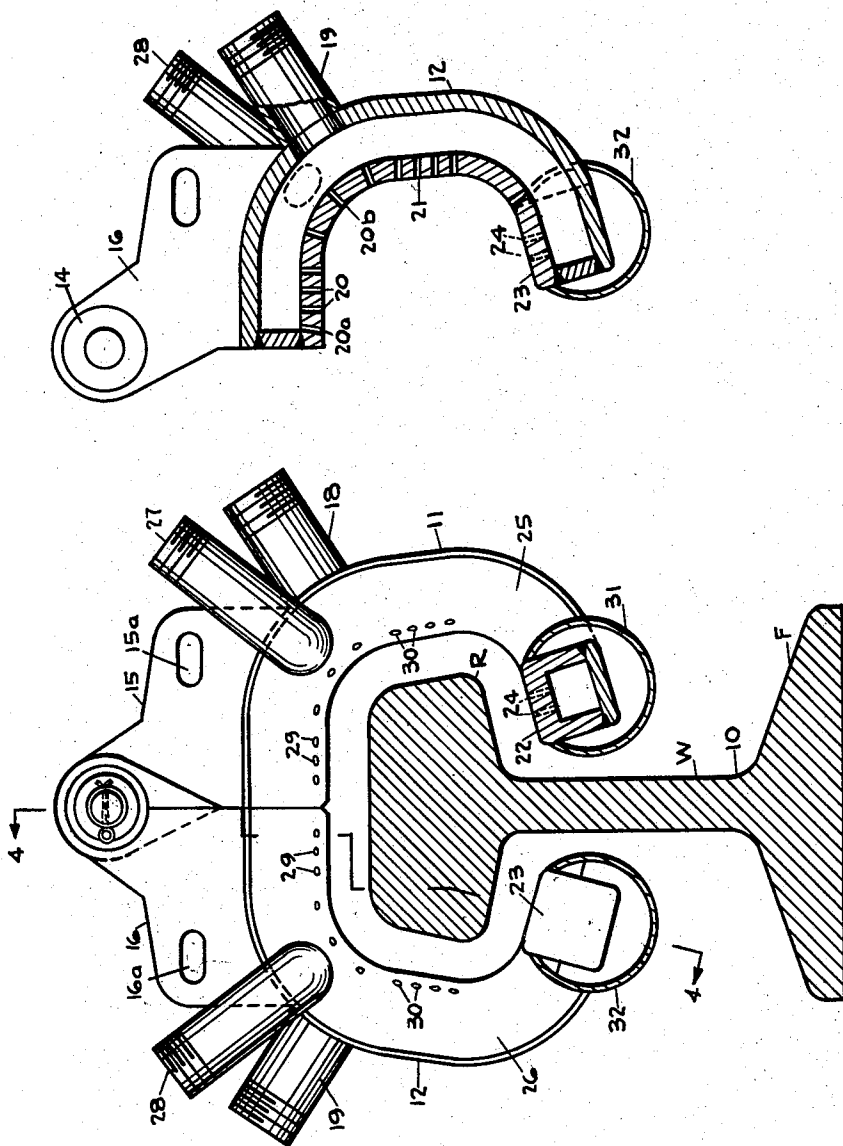


Fig. 2

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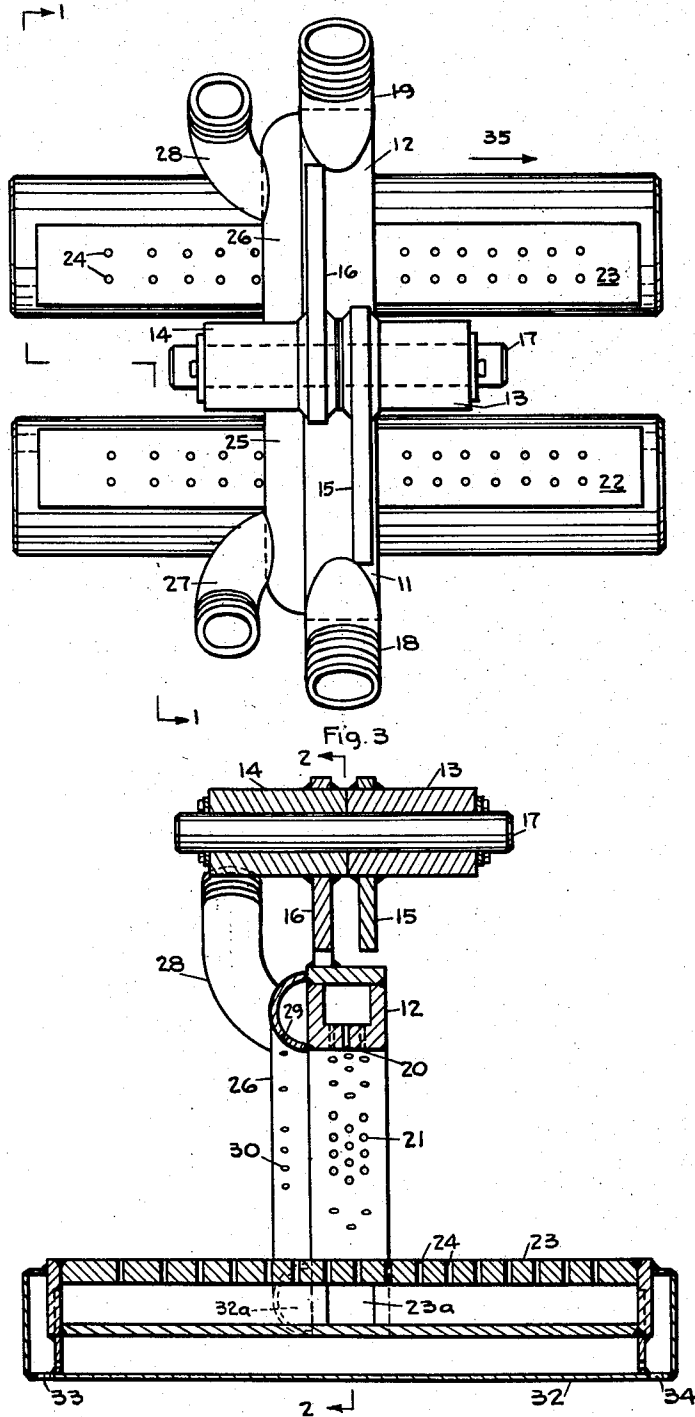


Fig. 4

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METHOD AND APPARATUS FOR FLAME HARDENING OF RAILS AND THE LIKE

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8 Claims. (Cl. 148—21.56)

This invention relates to an improved method and apparatus for surface hardening steel objects, such as the heads of rails, lathe ways, bushings, etc., by applying a flame thereto and to improved metal articles, particularly rails, the heads of which have been hardened by the method of the invention. The invention finds application both in mills where rails and other objects are produced or treated and to objects that have been installed, e.g., rails after they have been laid. For the sake of conciseness the invention will be described as applied to the hardening of rails, it being understood that it may also be applied to other objects.

It is often necessary that the surface zones of metal objects, such as the upper faces of railheads and, in many instances, also the flanks of the railhead, possess a specific hardness, for example, a hardness of 350 to 500 on the Brinell scale, to check too rapid wear on the running surfaces and the butt edges. Such hardening may be effected by application of a flame to harden the rail surface along the full length of the rail but is, more usually, restricted to areas where the impact of rolling stock causes rapid wear, e.g., at joints, curves, turnouts, etc.

It is already known to carry out the flame surface hardening process by heating the surfaces to be hardened by means of a burner to above the critical temperature of the steel, for instance to 1475° F., and then quenching the heated surface by applying a coolant. For this purpose an apparatus may be used consisting of a burner and a device for distributing the coolant, such as air, oil or water, which is moved in a longitudinal direction over the rail or the like in such a way that the upper side and/or the flanges of the railhead are first impinged by the burner flames and then by the coolant.

However, it has been found that by such a process the hardening effected does not conform to all requirements of the rails. These requirements are, besides the surface hardness already referred to, an adequate hardened surface zone, for instance of 4 to 5 mm. in thickness, and a gradual transition from the hardened surface zone to the non-hardened subadjacent zone of the railhead. If the latter requirement is not fulfilled cracks are liable to occur between the two zones, resulting in flaking or shelling of the metal.

As is known, a gradual transition from a hardened to a non-hardened zone can be effected by partial annealing (herein called tempering), after surface hardening, by supplying heat, either from the outside or from within the metal, e.g., through the heat accumulated in the metal object being treated, to produce a temperature close to but below the critical solution temperature. In order to accumulate heat in the object undergoing treatment, the temperature of the latter, as a whole, may be raised before the hardening process is carried out, but this, besides representing an uneconomical expenditure of heat, also involves a less effective hardening and does not result in a distinct surface layer of uniform hardness adjoining a narrow transition zone with a thickness of about

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2 to 12 mm., preferably above 4 mm. and terminating in non-hardened metal.

The main object of this invention is to provide a method and apparatus for hardening thin surface zones of metal objects, particularly rails, wherein the heat required for tempering, i.e., for effecting partial and progressive annealing and produce a gradual transition from the hardened to the non-hardened zone, is supplied at the proper time and place, i.e., in the most economical way and in a way that results in effective hardening. A further object is to provide an improved apparatus for applying the flame and coolant to elongated metal objects such as railheads that can be readily applied to rails; ancillary thereto, it is an object to provide an apparatus that can be readily applied to rails the ends of which are inaccessible, and wherein certain parts of the burner are cooled to avoid overheating of the burner parts. Still another object is to provide a rail having a surface-hardened metal article, especially a railhead, including a thin, hardened surface zone and a transition zone between the surface zone and non-hardened metal, said transition zone having a thickness of about 0.8 to three times the thickness of the surface hardened zone.

In summary, according to the invention the face of a steel object to be hardened is heated in the usual way to heat a thin surface zone to above the critical solution temperature by a hardening flame and quenched by means of a jet of coolant, but tempering is effected in the same operation by applying an auxiliary flame directly to a face of the object other than the said face to be hardened in the vicinity of the hardening flame by one or more burner nozzles and causing heat to flow through the body of the object toward the said surface zone, the auxiliary flame being applied preferably at such a time as to cause the sub-surface zone adjoining said surface zone to be at a tempering temperature at least at about the end of the quenching step. As is understood in the art, the tempering temperature is close to but somewhat below the critical solution temperature. Depending upon the nature of the operation and geometry of the steel object, as explained hereinafter, the auxiliary flame may be applied prior to, during and/or after the application of the hardening flame.

For convenience, the term "hardening flame" is used herein to denote the flame applied to the surface at which hardening is to occur, although actual hardening occurs subsequently upon quenching. As applied to rails, the auxiliary flame is applied to the bottom of the railhead and the hardening flame is applied to the upper face and/or the flanks of the railhead by a burner having one or more burner nozzles, and the surface or surfaces heated by the hardening flame are promptly quenched. As employed herein, the term "burner nozzle" refers to any nozzle or orifice by which combustible fluid is emitted to form a flame. By proceeding in this manner, it was found that thin hardened surface zones, of about 2 to 5 mm. in thickness, can be readily produced, and that the additional heat required for tempering the metal immediately beneath the said hardened zone is supplied at the most suitable place and time, resulting in a transition zone between the hardened zone and a non-hardened sub-surface zone with a thickness between about 2 and 12 mm. usually between 0.8 and three times the thickness of the hardened zone.

The hardening is usually applied to the top face of the railhead, either with or without concurrent surface hardening of the flanks of the railhead; in certain instances, however, only the flanks are surface hardened, e.g., at curves or near switchpoints, etc., where damage to rails is due largely to the action of wheel flanges.

The method can be advantageously carried out by a flame hardening apparatus, as described hereinafter, in-

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cluding a main burner movable longitudinally with respect to a rail or the like (either the apparatus or the rail being movable) for directing the hardening flame downwards onto the railhead and/or the flanks, an auxiliary burner for directing the flame upwards against the underside of the railhead, and a device for directing a jet of coolant, e.g., air, oil or water, against the surfaces that have been heated by the hardening flame but offset longitudinally so that the coolant impinges on the heated surfaces after the passage of the flame.

The invention will be further described with reference to the accompanying drawings forming a part of this specification and showing, by way of example, one specific form of apparatus, wherein:

Figure 1 is a transverse sectional view, taken on the broken section line 1—1 of Figure 3, showing the apparatus applied to a rail;

Figure 2 is a transverse sectional view on one part of the burner, taken on the line 2—2 of Figure 4;

Figure 3 is a plan view of the apparatus; and

Figure 4 is a longitudinal sectional view, taken on the broken line 4—4 of Figure 1, the rail being omitted.

Referring to the drawings in detail, the apparatus is applied to a rail 10 having a flange F, a web W and a railhead R. The apparatus used for treating the railhead and enclosing part of it, includes a companion pair of chambered bodies 11, 12, defining gas chambers and having a hinged connection by means of bushings 13, 14, that are connected to the respective bodies by plates 15, 16, and are rotatable on a pin 17. The bodies, when in operative position, are seen in Figure 1 to have the general shape of an inverted U. They are provided with inlet pipes 18, 19, by which a flexible conduit (not shown) can be connected to admit a combustible gas mixture. The wall of the chamber facing the upper face of the railhead has burner nozzle means, e.g., a plurality of orifices 20, that may be disposed in several longitudinally displaced rows, as shown in Figure 4, to direct a hardening flame against the top of the railhead. It will be noted from Figure 2 that most of the orifices are vertical but that the orifice 20a of each row nearest the upper extremity of each body is inclined from the vertical toward the companion body so that a part of the flame will be directed toward the center of the railhead. Certain other orifices 20b, in the curved part of the wall, are similarly inclined. One or both of the bodies may have additional or alternative orifices 21 in the vertical sides thereof for similarly directing a hardening flame against the flanks of the railhead. The orifices 20, 20a, 20b and 21 are all part of the main burner and are advantageously grouped closely to a plane perpendicular to the longitudinal axis of the rail, so that the hardening flame impinges on a longitudinally restricted area of the railhead. The auxiliary burner includes a pair of tubular bodies 22 and 23 disposed longitudinally with respect to the rail beneath the head and on opposite sides of the rail and fixed to and communicating with the bodies 11 and 12, respectively, through openings such as that shown at 23a in Figure 4, so as to form extensions of the gas chambers; they are provided with nozzles, e.g., orifices 24, directed upwards toward the bottom face of the railhead. The use of such longitudinally elongated tubular bodies, while preferred, is not essential, it being possible to continue the bodies 11 and 12 downwardly and thence inwardly with shapes to extend beneath the railhead to constitute the auxiliary burners. The orifices 24 are advantageously distributed over a longer longitudinal distance, parallel to the longitudinal axis, on the rail, than the orifices 20 and 21, as shown.

In addition to the gas chambers, the apparatus includes coolant chambers bounded in part by walls 25 and 26 and in part by the walls of the bodies 11 and 12, respectively, on which the first-mentioned walls are mounted, and communicating with inlet pipes 27 and 28, respectively, through which a coolant, such as water, oil, air or some other fluid may be admitted by a flexible conduit (not

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shown). The coolant chambers have approximately the same shapes as the gas chambers of the main burner and have jet means, e.g., orifices 29 and 30, for directing jets of cooling or hardening fluid against the surfaces of the railhead that are heated by the main burner; more specifically, when only the top of the rail is to be hardened, only the orifices 29, which are directed toward the top of the railhead, are provided, while when the orifices 21 are used to harden the flanks, the orifices 30, which are directed toward the flanks, are provided. However, no orifices for coolant are directed against the underside of the railhead. The orifices in the walls 25 and 26 diverge from those in the bodies 11 and 12, as shown, so that the streams emerging therefrom impinge upon areas on the railhead displaced longitudinally from the areas reached by the hardening flame. It is preferred to dispose the orifices of the main burner substantially perpendicularly to the longitudinal axis of the rail, whereby more effective heating is achieved, and to incline the orifices 29 and 30 with respect to the perpendicular, away from the bodies 11 and 12, as shown.

It is evident that the bodies 11 and 12 are cooled because they bound the coolant chambers in part; this prolongs the life of the burner. The auxiliary burner tubes 22 and 23 may be likewise cooled by providing jackets 31 and 32 that surround the tubes on three sides and define chambers that communicate with the coolant chamber as shown by the opening 32a in Figure 4. These jackets have orifices 33 and 34 at the ends, directed downwardly and away from the railhead, to permit a small stream of coolant to escape and thereby insure circulation of coolant through the jackets.

The apparatus may be attached to a rail by spreading the companion sections on the pivot pin 17 and thereafter closing them to the position shown. It is moved along the rail in the direction of the arrow 35 (Figure 3); for this it may be mounted on any suitable supporting carriage (not shown) that may run on the rail and engage the apparatus through openings 15a and 16a formed in the plates 15 and 16, respectively. Instead of moving the apparatus along a stationary rail it is, of course, also possible to move the latter through the apparatus, which is kept stationary and need not in this instance comprise relatively movable companion sections.

Although the orifices 24 in the auxiliary burner were shown in Figures 3 and 4 as distributed over a zone extending to each side of the plane that includes the hardening flame and is normal to the surface of the railhead to be hardened, it should be understood that the exact extent and location of the orifices 24 is subject to some variation and may be influenced by such factors as the intensity of the flames, and the dimensions of the railhead and the surface hardness and type of transition zone desired. The heating orifices are so disposed that the subsurface zone adjoining the surface zone heated by the main burner is at a desired tempering temperature at least soon after the quenching of the said surface zone.

In operation, a combustible mixture is supplied to the inlet pipes 18 and 19 and the mixture emerging from the orifices is ignited. The mixture may, for example, consist of propane and oxygen, which is particularly advantageous for hardening high grade steel, as used for rails, in relation to other fuels that cause free hydrogen to form in the combustion gases. The invention is not, however, limited to the use of this particular combustible gas mixture. A coolant fluid is admitted through the inlet pipes 27 and 28. When the apparatus is moved slowly with respect to the rail in the direction indicated by the arrow 35, the successive thin zones beneath limited surface areas of the top and/or flanks, situated at successive cross sections of the railhead, are heated by the hardening flame issuing from the main burner orifices 20, 20a and 20b and, if used, the orifices 21, to temperatures above the critical solution temperature of the steel (e.g., above 1335° F., such as, say 1400° F., to 1500° F. in the case

of steel containing 0.85% carbon); these zones are immediately afterwards quenched by the coolant jet issuing from the orifices 29 and, if used, the orifices 30, whereby the surface zone of the steel is hardened. The bottom of the railhead is heated intensively by the gas flames emerging from the orifices 24, for example, to cherry red. Heating of the bottom of the railhead preferably commences already before the upper side and flanks are heated, so as to allow time for the heat to penetrate through the body of the railhead, and continues preferably during the heating of the top and flank surfaces and even after these surfaces have been already quenched. The heat supplied to the bottom of the railhead passes through the body of the railhead to its hardened surface zones, thus effecting, below these surface zones, partial annealing which decreases toward the top and flank surfaces, resulting in a gradual increase in hardness from the unhardened interior throughout an intermediate, subsurface transition zone.

Thus, it was found that with a railhead treated in this manner the hardness is practically constant in a surface zone from the outside surface to a depth of about 2 to 5 mm., e.g., 4 mm., and then gradually decreases from the hardness of the surface zone to attain the hardness of the unhardened material at a depth of 2 to 12 mm. beneath the surface zone, e.g., 6 mm. from the hardened surface zone or 10 mm. from the outer surface. Such a rail was found to be durable in service, and no scaling has been found on such rails when used for some time with rail traffic at speeds of 75 miles per hour. In contrast, with similar rails that were surface hardened in the same manner but without the application of heat to the bottom of the railhead, the transition zone had a thickness of less than one millimeter; such rails were found to be prone to scaling and on occasion developed cracks.

The surface hardness attained is influenced mainly by the rapidity of quenching; usually a somewhat higher hardness is obtained with water quenching than with air quenching, but this relation does not always hold, e.g., slow quenching and a lower hardness may be obtained by subdividing the quench water into fine drops to form a mist. Typical desired surface hardnesses are about 350 and 500 on the Brinell scale for steel rails, the unhardened subsurface zones below 250, e.g., about 190 to 220 on the Brinell scale. The invention is not, however, restricted to producing a surface hardness within the range indicated, and surface hardnesses as high as 700 have been attained. It may be noted that rails have a tendency to harden at the surface during use, and that the surface hardness in rails after some months of use in heavy traffic exceeds that induced by the process according to the invention.

I claim as my invention:

1. In the method of surface-hardening a steel object by applying a hardening flame successively to adjoining limited areas of a face to be hardened, said flame having a high intensity such as to heat thin surface zones beneath said limited areas to above the critical solution temperature of the steel and immediately afterwards quenching said heated zones by simultaneously applying a jet of coolant that is offset from said hardening flame successively only to said adjoining areas, the improvement which comprises applying an auxiliary flame simultaneously with said hardening flame successively to adjoining limited areas of a face of said object other than the said face to be hardened, said limited areas being situated in the plane that includes said hardening flame and is normal to said last-mentioned face, thereby causing heat to flow from the said other face through the body of the steel object to said surface zones to temper the metal progressively throughout sub-surface zones adjoining said surface zones, said auxiliary flame having an

intensity such as to heat the steel in said sub-surface zones to a temperature close to but not above the critical solution temperature thereof.

2. Apparatus for flame hardening an elongate steel object, said apparatus comprising a main burner adapted to be positioned opposite to and to be moved longitudinally along the object and having orifice means for directing a hardening flame against a first areas of a face of the object, said first area being longitudinally restricted, an adjacent jet device connected to said main burner for directing a jet of coolant only against a second area of the same face of the object displaced longitudinally from said first area, and an auxiliary burner connected to said first burner having orifice means for directing an auxiliary flame against another face of the object in the vicinity of said first and second areas but extending over a greater longitudinal length than said first area.

3. Apparatus according to claim 2 adapted for hardening a rail having a railhead, wherein said main burner comprises a first chambered body having the general outline of an inverted U and having inlet means for admitting combustible gas and orifices directed downwardly toward the top face of the railhead, said jet device includes a second, separate chambered body having the general outline of an inverted U and having inlet means for admitting a coolant and orifices directed toward the top face of the railhead, said orifices in the first chambered body being divergent from the orifices in the second chambered body, and the orifices in said auxiliary burner are positioned to direct an auxiliary flame against the bottom face of the railhead.

4. Apparatus according to claim 3 wherein said first and second chambered bodies have additional orifices directed against the flank of the railhead and similarly divergent from one another.

5. Apparatus according to claim 3 wherein said auxiliary burner is formed in two sections adapted to underlie the railhead respectively at opposite sides of the rail.

6. Apparatus according to claim 5 wherein at least said sections of the auxiliary burner are laterally movable to permit them to be spread apart for application to a railhead.

7. Apparatus according to claim 2 wherein said main burner includes a first chambered body having the general outline of an inverted U and having inlet means for admitting combustible gas and orifices directed toward a face of the object above the bottom face thereof, and said auxiliary burner includes a tubular body extending longitudinally with respect to the object and beneath the said object having orifices distributed along the length thereof directed upwardly toward the bottom face of the object.

8. Apparatus according to claim 7 wherein said tubular body is at least partially jacketed by a wall defining a closed chamber, said closed chamber being in communication with said jet device for receiving coolant therefrom and having an outlet, whereby coolant can circulate through said closed chamber.

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