

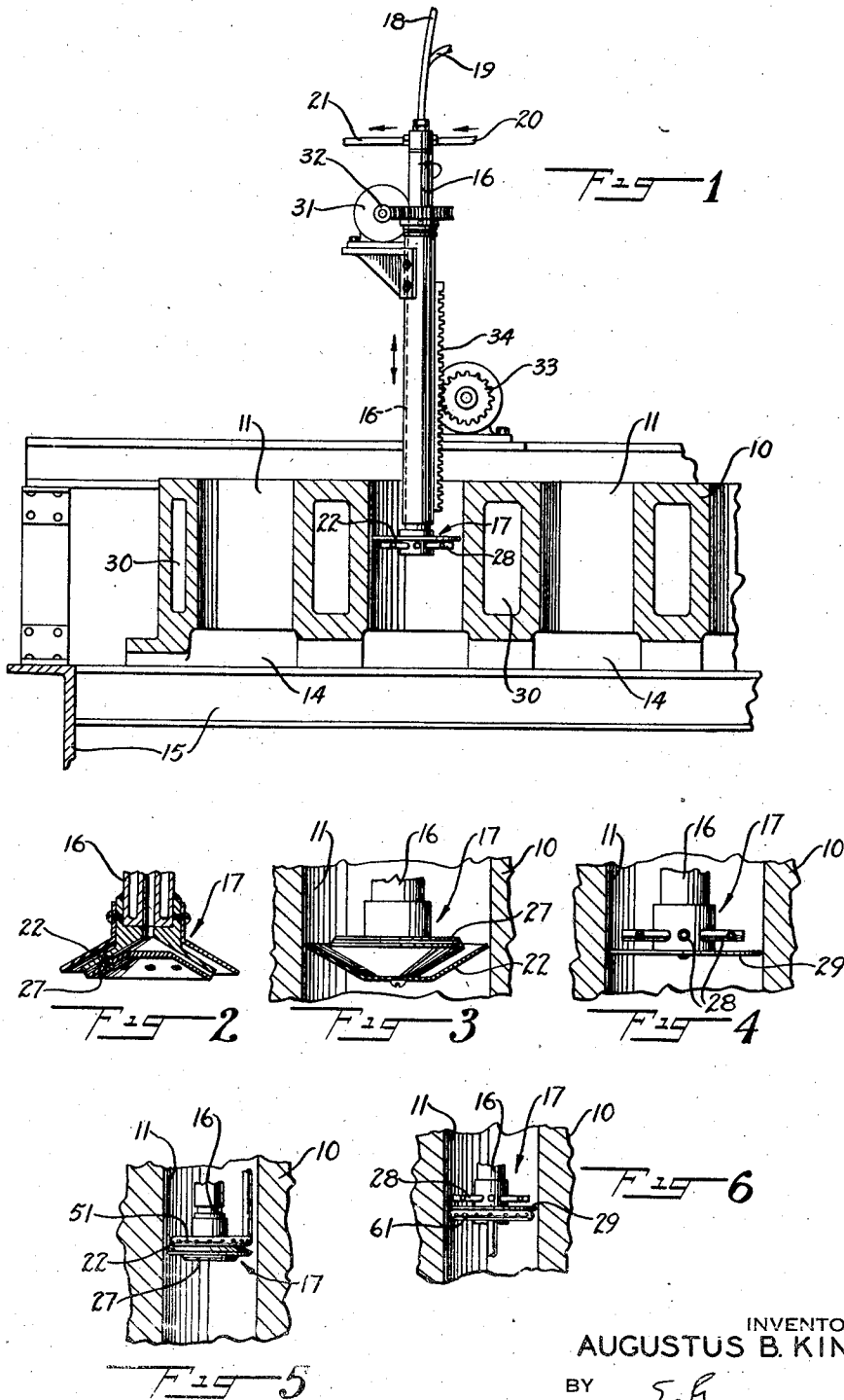
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METHOD OF AND APPARATUS FOR HARDENING SURFACES OF METAL BODIES

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METHOD OF AND APPARATUS FOR HARDEN-
ING SURFACES OF METAL BODIES

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uary 19, 1935. This application July 13, 1938,
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This invention relates to the hardening of surfaces of metal bodies, and more particularly to the hardening of cylindrical surfaces of metal bodies, such as the inner walls of cylinders of internal combustion engines. This application is a continuation of my application Serial No. 2,501, filed January 19, 1935.

Wear on the inside surface of the usual cast iron cylinders has long been one of the limiting factors in the life of internal combustion engines. Attempts have been made to increase the wear resistance by the use of liners, or by nitriding or carburizing the inside surfaces of such cylinders. It has also been proposed to harden the surface of the inner walls of hollow bodies such as cast iron automotive cylinders by first heating these surfaces with ordinary oxy-acetylene or similar burners, and then rapidly cooling the cylinders by submerging them in a tank of hardening liquid. This hardening method suffers from the drawback that while the lower portion of the cylinder is quenched in water, there is formed above the water a so-called "closed space" and the burners such as oxy-acetylene do not function satisfactorily in such spaces. Generally speaking, no attempt in either of these directions has been found satisfactory, both because of difficulties inherent in the elaborate apparatus required, the physical properties of the metals used, and because of the relatively high expense involved.

Among the objects of the present invention are: to provide an improved method of hardening surfaces of metal bodies; to provide an improved method of hardening cylindrical surfaces of metal bodies; to provide an improved method of hardening inner surfaces of cylinders of internal combustion engines and other hollow metal bodies; to provide an improved apparatus for hardening surfaces of metal bodies; and to provide an improved apparatus for hardening inner surfaces of cylinders of internal combustion engines in order to produce cylinders having substantially the same chemical composition in all parts, but an appreciable difference in hardness between the inner wall surface and the main body thereof.

In hardening inner surfaces of hollow metal bodies, for example, the objects of this invention may be accomplished by using a grade of relatively soft cast iron, or a steel containing in addition to carbon relatively small amounts of chromium, or nickel, or molybdenum, for the manufacture of hollow metallic bodies such as cylinders of internal combustion engines, and in

accordance with this invention there is provided an apparatus for and method of hardening the inner wall surface of such hollow metallic bodies which comprises progressively heating successive portions of said wall surface to a temperature above its critical range in a manner which tends to concentrate the zone of heat application to a relatively narrow circumferential portion, and establishing a steep temperature gradient in said wall surface by producing a rapid dissipation of heat into the mass of said metallic body.

In accordance with the principles of this invention, a surface of a metal body may be hardened by maintaining said surface in a vertical position, heating successive horizontal zones of the surface beginning at the lower end thereof, and cooling successive heated horizontal zones by directing a cooling medium against the same, such as in the form of cooling jets, the heating and cooling progressing concurrently upwardly along said surface. It is advantageous to use a liquid cooling medium because then the liquid of the cooling jets runs downwardly by gravity along the treated lower portions of the surface after the liquid impinges against the highly heated surface, and thus further cools the treated surfaces and also is quickly and simply removed from the vicinity of the heating medium. The successive horizontal zones may be heated by a row of heating jets directed substantially perpendicularly against the surface, and, since the surface is preferably maintained in a substantially vertical position, the rising heat from the jets will tend to preheat untreated higher portions of the surface, while the liquid of the cooling jets will flow downwardly by gravity along the surface and thereby avoid interference with the heating jets. In addition, a substantially horizontal movement of the heating and cooling jets with respect to the surface may also be employed during the relative vertical movement of the heating and cooling jets and the metal surface.

Also in accordance with the principles of this invention, the inner surface of a hollow metal body may be hardened by maintaining the body substantially open at both ends to permit a natural upward flow or circulation of air there-through, heating successive portions of the inner surface, and screening a portion of the interior of the body to form a passage adjacent the inner surface so as to direct an annular stream of cooling air against the heated surface. When heating is accomplished by means

of heating flames, the hollow metal body is maintained open at both ends so that the current of air flowing through the body will provide air for secondary combustion of the heating flames. In hardening a cylindrical surface, a relative rotational movement between the heating and cooling jets and surface may be effected concurrently with the relative vertical movement between the heating and cooling jets and surface, the relative vertical movement being substantially parallel to the surface.

The novel and characteristic features of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its mode of operation, together with additional objects and advantages thereof, may be better understood from the following description of a specific embodiment thereof, and of the method of its operation, when read with reference to the accompanying drawing, in which:

Fig. 1 shows a side elevation, partly in section, of one embodiment of a suitable surface hardening apparatus, operatively mounted in relation to a cylinder block of an internal combustion engine;

Fig. 2 represents a vertical sectional view through one type of burner; and

Figs. 3 to 6 show views of different types of burners.

Referring now more particularly to Fig. 1, a cylinder block 10, comprising a plurality of cylinders 11 is mounted on a suitable hollow support 15, in such a manner that air may freely enter and escape through the openings 14 of the cylinder block coating. The water jackets 30 in the cylinder block 10 may be filled with a cooling medium, in order to facilitate the production of a steep temperature gradient and consequently a rapid cooling and quenching of the metal portions undergoing the surface hardening treatment.

Situated partly above the cylinder block 10 is a hollow shaft 16, provided at its lower end with a star-shaped burner head 17 having a plurality of radially extending nozzles 28 at its periphery. The shaft 16 comprises a longitudinal mixing passage for two gases entering through the hose lines 18 and 19, respectively, and a passage for conducting a cooling medium from the supply line 20 towards the burner head 17 and thence to the discharge line 21. Means are also provided toward the lower end of the burner and above the nozzles 28 for preventing the rapid upward escape of the heat generated by the nozzles 28, i. e. a baffle plate or screen 22. The general nature and function of this plate is described in more detail in connection with Fig. 2.

The longitudinal axis of the shaft 16 is in substantial alignment with the longitudinal axis of the cylinder to be treated. A suitable mechanism consisting of motor 31 and worm gear 32 may be provided to impart an oscillatory or rotary motion to the shaft 16 and to the burner head 17. Means may also be provided, as shown at 33 and 34, for producing a vertical motion of the burner within the cylinder, substantially along the vertical axis of the latter, or for disengaging the burner head entirely from the interior of the cylinder. Alternatively, relative motion between the cylinder block 10 and the whole burner assembly may be effected by the vertical displacement of the cylinders with reference to the burner head.

Fig. 2 shows a longitudinal enlarged scale sec-

tion through a modified type of burner. Above the conical nozzle head 27 of the burner there is secured an exchangeable conical baffle plate or screen 22. The diameter of the base of this baffle is larger than that of the base of the conical nozzle and slightly smaller than the inner diameter of the cylinder under treatment. The purpose of this baffle plate is two-fold: first, it confines and localizes the point of application of the heating flames, and second, when mounted above the nozzle head, it causes a down-draft of the surrounding cold air toward the heated portions and thus produces sudden cooling or air-quenching.

When using burners of the type illustrated in Figs. 1 and 2, the heat treating operation may be effected by moving the burner and cylinder block relatively to each other so that the burner gradually descends from above into the cylinder. Consequently, the burning gas, escaping under substantial pressure from the discharge openings of the nozzles, will progressively heat annular zones on the inner surface of the cylinder. Due to the intense heat generated by the flame striking directly a comparatively small portion of the entire inner surface area of the cylinder, this portion will be heated very rapidly, and to a sufficient depth, to a temperature above the critical point, and thereby cause some of the carbon to go into solid solution which, upon rapid cooling, will form a hard metal layer upon the inner surface of the cylinder.

This rapid cooling is achieved, at least partly, by maintaining the temperature of the main body of the cylinder block well below about 700° C. Due to heat conduction from the directly heated surface portion into the relatively cold mass of the surrounding metal, a rapid decrease of temperature of the annular zone covered by the flame will result immediately after the flame is removed from such zone. Inasmuch as the flame moves progressively with reference to the inner wall of the cylinder, the directly and consecutively heated annular zones will, in turn, be progressively removed from the flame, and a progressive, uniform, rapid cooling of the heated zones will result. Accordingly, a steep temperature gradient prevails at each zone, with the effect that the resultant quick removal of heat from the high temperature zone will cause the formation at such zone of a surface layer of metal which is substantially harder than that of the untreated metal. Furthermore, the method of keeping the surrounding metal at a relatively low temperature and using merely the temperature difference within an otherwise homogeneous mass of metal for creating the desired steep temperature gradient at the treated surface will tend to produce a cylinder block which is more free from internal stresses than blocks, for example, which after heat treatment are quenched by submersion in a quenching fluid, while at the same time the main object of such treatment, i. e. creating a uniform surface on the inner wall of the cylinders of great comparative hardness, is attained to a desired degree.

Instead of employing a conical burner such as in the arrangement shown in Fig. 2, it may be of advantage to use an inverted conical burner, as shown in Fig. 3, and to begin the heat treating operation at the lower end of the cylinder, the burner in that case moving upwardly with reference to the cylinder during the treatment. The effect of using an inverted burner will be

that an upwardly directed draft is created in the cylinder and that the cool air enters from the bottom following the direction of the natural draft. The combination of the forces from the draft caused by the burner, and from the natural draft, tends to increase the velocity of the flow of air through the cylinder. A heat resisting baffle is provided at the burner in the same manner as described above, in this modification, however, preventing the flames in the upper section of the cylinder from heating too rapidly the cool air entering the lower section from below.

One of the important features in this method is to insure not only a very rapid heating of consecutive annular zones of the inner surface of the cylinder, but at the same time a heating which is uniform along the entire periphery of such zone. To accomplish this uniform heating, a rotary or oscillatory motion around the longitudinal axis of the shaft 16 may be imparted to the burner 17 as described above. In the event that for any reason the heat intensity of the conical flame should not be the same at each point of the periphery, the rotary or oscillatory motion of the burner, and consequently of the flames, will tend to equalize any difference in the amount of heat received from the flame by any definite point of the heated annular zone, inasmuch as each point of the heated zone will receive its heat not from one single corresponding point of the flame, but successively from a plurality of such points so that any intensity differences will be averaged and thus equalized. When practicing this embodiment of the invention, in lieu of the conical burner described above, a burner with a plurality of radially arranged nozzles may preferably be used. An example of such burner having 8 nozzles is represented in Figure 4. The nozzles 28 are preferably so constructed as to generate flames of a high intensity, which, when the burner oscillates or rotates, will heat an annular zone on the inner wall of the cylinder and will thus impart heat of high intensity uniformly to all points of the annular zone. A heat baffle 29 is secured below the nozzles, in case of an upwardly progressive motion. Should it be found preferable to carry out the heating operation in a progressive downward motion, the heat resisting baffle may be secured above the radial nozzles, in order to prevent a too rapid heating of the cool air entering from above.

In cases where it is desired to secure a more rapid quenching than air quenching and/or heat conductivity quenching, an apparatus such as disclosed schematically in Figs. 5 and 6 may be used. In accordance with this modification of the invention, a very drastic cooling is obtained by providing means, preferably at the rear side of the baffle plate, for directing a spray of cold water or cold compressed air against the metal wall, as shown at 54 and 51. This spray mechanism is preferably adapted to follow the relative movement of the burner in its axial direction, and may also be arranged to follow the rotary motion of the rotary or oscillatory type of burner where such is used.

As illustrative of the results which may be accomplished by the use of the process described above, the hardness of the surface in an ordinary cast iron cylinder has been increased from 160 to approximately 350 Brinell.

A further advantage of this method of hardening cylinders of internal combustion engines is

that it is possible to use a grade of cast iron which is sufficiently soft to be easily machinable, since the desired wear characteristics may be imparted to such a material by the subsequent hardening operation. In contra-distinction to this it has been necessary heretofore to use a relatively hard cast iron in order to obtain the wearing properties which are desired in practical use.

It will be evident that the method of this invention may be applied generally to the hardening of vertically disposed metal surfaces, and particularly to the hardening of vertically disposed curved surfaces such as the inner cylindrical surfaces of metal bodies as well as the outer cylindrical surfaces of metal bodies, and also to inner surfaces of hollow bodies other than cylinders of internal combustion engines. It will be further understood that various changes in the apparatus described may be made without departing from the spirit and scope of this invention.

What is claimed is:

1. The method of hardening the inner periphery of a tubular ferrous chamber, comprising mounting the tubular chamber in a vertical position, directing heating jets substantially radially against a horizontal circumferential zone of the inner periphery at the lower end thereof, directing cooling jets generally radially against the inner periphery beneath the heating jets, providing an upward helical motion of the heating and cooling jets with respect to the tubular chamber, and passing air upwardly through the tubular chamber past the heating and cooling jets.

2. A process of substantially uniformly hardening an interior metal surface of a tubular chamber open at both ends, which comprises progressively applying high temperature heating flames to successive annular zones of said surface; progressively applying a quenching medium to such heated zones; and maintaining said chamber open at both ends during such heating and quenching so as to permit flow into and through said chamber of air for secondary combustion of said heating flames.

3. A process of substantially uniformly hardening an interior metal surface of a tubular chamber open at both ends and disposed substantially vertically, which comprises progressively applying a high temperature heating medium to successive annular zones of said surface; progressively applying a quenching medium to such heated zones; and maintaining said vertically disposed chamber open at both ends during such heating and quenching so as to induce a draft of air therethrough along said surface.

4. A process as set forth in claim 3, in which the application of said heating medium is started adjacent the lower end of said surface and progresses upwardly.

5. A process as set forth in claim 3, in which the quenching medium is a liquid and is applied closely following the application of said heating medium and discharges through the open lower end of said chamber.

6. In the method of securing beneficial changes in the constitution of the inner surface of a tubular ferrous body, the steps comprising maintaining said body sufficiently open at both ends to permit a flow of air therethrough, directing heating jets against the inner surface, and screening a portion of the interior of the tubular body to form an annular passage adjacent the inner sur-

face so as to direct a stream of air against the heated surface.

7. The method of securing beneficial changes in the constitution of the inner periphery of a tubular ferrous body which comprises maintaining said body sufficiently open at both ends to permit a flow of air therethrough, directing heating jets generally radially against the inner periphery of the tubular body, screening a portion of the interior of the tubular body at a zone adjacent to the heating jets to form an annular passage adjacent to the periphery so as to direct a stream of air against the heated surface, providing relative rotary movement of the jets with respect to the periphery, and providing relative movement between the jets and the periphery along the axis of the tubular body.

8. In the method of securing beneficial changes in the constitution of the inner surface of a tubular ferrous chamber open at both ends, the step comprising projecting heating jets against the inner periphery of the tubular chamber at an angle thereto to promote the flow of air through the tubular chamber.

9. In the method of securing beneficial changes in the constitution of the inner surface of a tubular ferrous body, the steps comprising mounting the tubular body in a generally vertical position, and projecting heating jets upwardly against the inner periphery of the tubular body to promote the natural flow of cooling fluid through the tubular body.

10. In the method of securing beneficial changes in the constitution of the inner surface of a tubular ferrous body open at both ends, the steps comprising projecting a hollow conical jet of heating gas against a peripheral zone of the tubular body to promote the flow of air therethrough, and rotating the jet to equalize the distribution of heat about the peripheral zone.

11. Apparatus for heat treating the inner surface of a hollow metal body comprising heating means adapted to travel along and in spaced relationship with the interior surface of said hollow body to raise the temperature thereof; a baffle associated with said heating means for concentrating heat upon peripheral annular sections of said inner surface, said baffle corresponding in shape to and being spaced from said inner surface to provide an annular air passage therearound so as to permit a current of air to flow therethrough so as to cool the heated portions; and means for effecting a relative movement of said heating means and said baffle longitudinally with respect to the interior surface of said body.

12. Apparatus for heat treating the inner surface of a hollow metal body as defined in claim 11, including a spray device operatively associated with said heating means and baffle and said movement effecting means in such a manner as to direct a stream of fluid quenching medium upon the heated portions to augment the effect of such air and thereby cool the heated portions rapidly.

13. Apparatus for obtaining beneficial changes in the constitution of the inner periphery of a tubular ferrous body comprising a heating head, means for mounting said body in substantially a vertical position, means associated with said heating head for projecting a heating jet upwardly against said periphery, and means for providing relative axial and rotational movement between said jet and said body whereby successive peripheral portions of said body are raised to a high temperature, the upward projection of

said jet promoting the flow of air through said tubular body.

14. Apparatus as defined in claim 13 including a baffle adjacent to said heating jet and restricting the passage through the tubular body to a narrow annular space adjacent to the heated peripheral portion, whereby the air flowing upwardly through the tubular body is constrained to pass in close proximity to the heated peripheral portion.

15. A method of hardening a surface of a metal body comprising progressively applying a high temperature heating medium locally to successive substantially horizontal zones of said surface while maintaining all portions of said surface in a substantially vertical position and while maintaining unobstructed the entire space adjacent and along said surface and above the points of application of said heating medium to permit a free and unobstructed rise of heated gases upwardly along said surface from said points of heat application; screening a portion of the space beneath said heating medium to form an air passage adjacent said surface through which a stream of relatively cool air is directed against said surface; and directing a cooling liquid against successive zones so heated, said heating medium and cooling liquid being initially applied adjacent the lower end of said surface and the heating and cooling progressing upwardly concurrently so that the heated gases rising from the points of application of said heating medium preheat untreated higher portions of said surface and the cooling liquid runs downwardly by gravity along the treated lower portions of said surface after such liquid impinges against said surface.

16. A method of hardening a surface of a metal body comprising directing a row of high temperature heating flames against a substantially horizontal zone of said surface while maintaining all portions of said surface in a substantially vertical position and while maintaining unobstructed the entire space adjacent and along said surface and beneath the points of application of said heating flames to permit a free and unobstructed rise of heated gases upwardly along said surface from all points of application of said heating flames and to permit a flow of air to said flames from beneath for secondary combustion thereof; directing a row of liquid cooling jets against a substantially horizontal zone of said surface beneath said heating flames; and effecting a relative movement upwardly substantially parallel to said surface and also horizontally between said body and both said heating flames and said liquid cooling jets, said heating flames and said liquid cooling jets being initially applied adjacent the lower end of said surface so that heating and cooling progresses upwardly concurrently with heated gases rising vertically along said surface, from the points of application of said heating flames, to preheat untreated higher portions of said surface, and cooling liquid running downwardly by gravity along the treated lower portions of said surface after impinging against said surface.

17. A method of hardening a cylindrical surface of a metal body comprising directing an annular row of heating flames substantially radially against a substantially horizontal circumferential portion of said surface adjacent the lower end thereof while maintaining the axis of said surface in a substantially vertical position; direct-

ing an annular row of liquid cooling jets beneath said heating flames and substantially radially against each portion of said surface immediately after it has been heated by said heating jets; maintaining unobstructed the entire space adjacent and along said surface and above the points of application of said cooling jets to permit a free and unobstructed rise of heated gases upwardly along said surface from said points of heat application and to permit a flow of air to said heating flames for secondary combustion thereof; effecting motion of said heating jets and cooling jets relatively to said body upwardly and substantially parallel to the axis of said surface, to progressively heat and quench successive portions of said surface; and maintaining the axis of said surface in a substantially vertical position during such relative motion so as to cause said liquid to flow downwardly by gravity along said surface after impinging against the latter and thereby avoid interference of said liquid with said heating jets, and also to cause the heated gases rising from the points of application of said heating flames to preheat higher untreated portions of said surface.

18. Apparatus for hardening a surface of a metal body comprising, in combination, means for maintaining said surface in a substantially vertical position; means for applying a high temperature heating medium to a horizontal zone of said surface; means for directing a cooling liquid against a horizontal zone of said surface adjacent to but beneath the horizontal zone to which said heating medium is applied; means for effecting relative movement, upwardly substantially parallel to said surface and also transversely of the vertical dimension of said surface, between said body and both such means for applying the heating medium and cooling liquid so that said heating medium and cooling liquid will be initially applied adjacent the lower end of said surface and the heating and cooling will progress upwardly concurrently so that the rising heat

from said heating medium will tend to preheat untreated higher portions of said surface and the cooling liquid will run downwardly by gravity along the treated lower portions of said surface after such liquid impinges against said surface; and baffle means disposed beneath said heating means but above said cooling means and corresponding in shape to said surface but spaced therefrom so as to form an air passage adjacent said surface, said baffle means serving to direct toward said surface, at and immediately below said heating means, a current of relatively cool air induced to flow upwardly by the heated gases rising upwardly along said surface from said heating means.

19. Apparatus for hardening a cylindrical surface of a metal body comprising, in combination, means for maintaining said surface with its axis in a substantially vertical position; means for directing an annular row of heating jets substantially radially against said surface; means for directing an annular row of liquid cooling jets substantially radially against said surface and adjacent to but beneath said heating jets; means for advancing both of such jet directing means upwardly relatively to, and substantially parallel to, said surface, to heat and quench successive portions of said surface while the rising heat from the heating jets preheats higher portions of said surface and the cooling liquid runs downwardly by gravity along treated lower portions of said surface after such liquid impinges against said surface; and baffle means disposed below said heating jets but above said cooling jets and spaced from said surface to provide an annular air passage adjacent said surface, said baffle means serving to direct toward said surface, at and immediately below said heating jets, a current of relatively cool air induced to flow upwardly by the heated gases rising upwardly along said surface from said heating jets.

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