

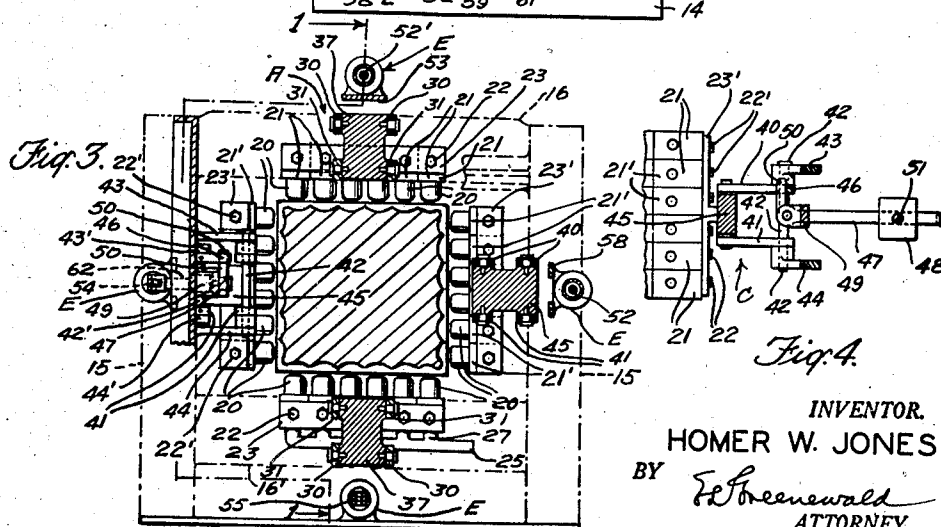
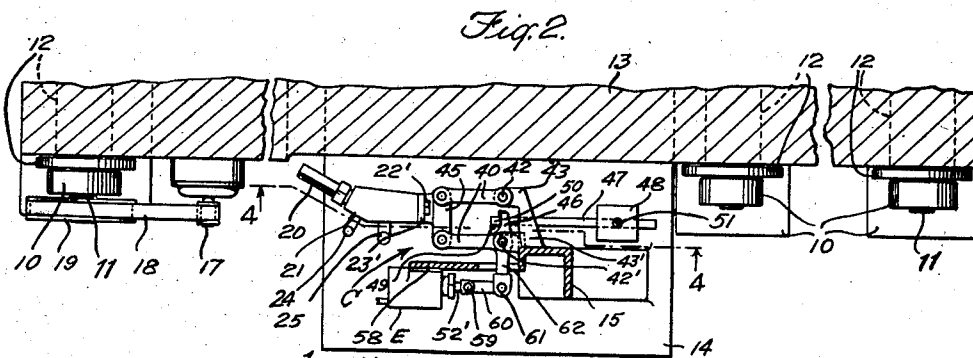
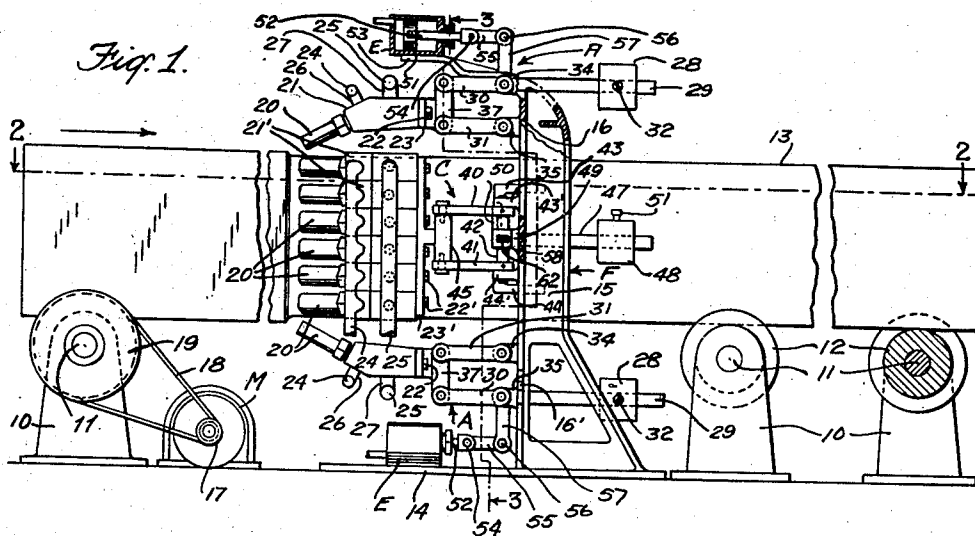
July 26, 1938.

H. W. JONES

2,125,175

METHOD OF REMOVING METAL FROM THE SURFACES OF BILLETS  
OR SIMILAR METAL BODIES, AND THE PRODUCT

Original Filed Oct. 28, 1933 2 Sheets-Sheet 1



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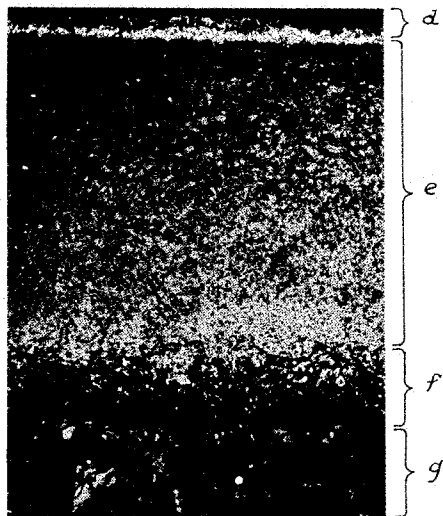
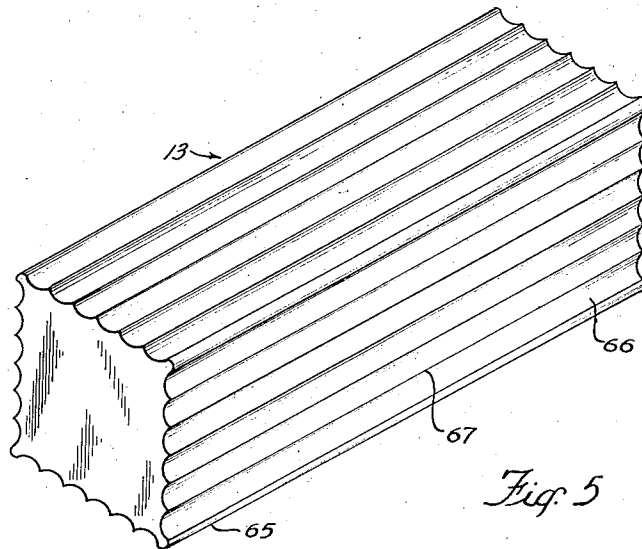
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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

2,125,175

## METHOD OF REMOVING METAL FROM THE SURFACES OF BILLETS OR SIMILAR METAL BODIES, AND THE PRODUCT

Homer W. Jones, Westfield, N. J., assignor, by mesne assignments, to Union Carbide and Carbon Corporation, a corporation of New York

Original application October 28, 1933, Serial No. 695,570. Divided and this application March 26, 1938, Serial No. 198,196

16 Claims. (Cl. 148—9)

My invention relates to a method of thermo-chemically removing metal from the surfaces of metallic bodies, such as steel billets and the like of rectangular cross-sections, and to the resultant article or semi-finished body.

This application is a division of my copending application Serial No. 695,570, filed October 28, 1933, entitled "Apparatus for removing metal from the surfaces of metallic bodies."

It has generally been the practice heretofore to employ heavy machine tools, such as planing, shaping, milling, and chipping machines, for removing or cutting metal from the surfaces of metallic bodies. Such machines are not entirely satisfactory, because they remove metal at a very slow rate. Further, they are expensive, and their operating costs are high because power is required both for relatively moving the cutting tool and the metallic body and for carrying out a cutting operation. In such machines, also, the greater the hardness of metal the greater is the amount of power required to make a cut.

Within the last few years the objections of heavy machine tools have been avoided by employing blowpipes having nozzles particularly adaptable for removing surface metal from metallic bodies. These nozzles are constructed so as to permit the passage of a comparatively large volume of oxidizing gas at a relatively low velocity in such a manner that surface metal is removed and grooves or channels are produced having gradually sloping sides. By making cuts in this manner, the sloping sides of the channels will tend to flatten out and will not fold over and be rolled into the metallic body upon further rolling thereof.

In removing surface metal in steel mill operations it has been the practice for an inspector to draw chalk marks around the defects and seams on the surfaces of a semi-finished shape. An operator employing a blowpipe of the character just described then removes the defects marked on the top surface of the metallic body and, after such defects are removed, the metallic body is turned or rotated to present other surfaces to the operator in order to enable him to remove easily the defects in the metallic body.

It has not been entirely satisfactory to remove defective metal from the surfaces of metallic bodies when different surfaces of a bar or slab or successive portions of the peripheral surface of a round billet are presented to form a top surface, because in this position there is a tendency generally for fin material to remain

on each side of a groove or channel so cut in the surface. The formation of fins is due to the washing effect of the slag as it is forced out of such cut and over the surface of the work by the force of the oxidizing gas stream. The slag may comprise both oxidized and fused or molten metal, and the latter has a tendency to freeze on the sides of the channel and is exceedingly difficult to remove.

I have found that the amount of fin material formed can be reduced considerably by applying the oxidizing gas streams so as to simultaneously impinge obliquely against regions extending across each of the surfaces to be conditioned, such as the top, sides, and bottom of a metallic body. By this method, the oxidized and fused or molten metal is forced out of the channel by the force of the oxidizing gas stream and falls away therefrom by the force of gravity. When surface metal is removed in this manner, a substantially smaller amount of fin material is produced on the sides of the channel and a desirable corner formation of the body results. Since it is desirable to utilize the force of gravity for reducing the amount of fin material produced on the sides of the channels, my method is particularly adaptable for simultaneously removing surface metal from all sides of a multi-sided steel billet or for removing surface metal from the entire peripheral surface of a round billet. In such cases the fin material will be greatest where the force of gravity is least effective in carrying away the metal removed by the oxidizing gas stream. The body produced by desurfacing in this manner is provided with a clean smooth new surface free of slag having an improved metallurgical structure as hereinafter described, and having a plurality of contiguous longitudinal shallow channels formed by the oxidizing gas streams.

An object of my invention, therefore, is to remove metal simultaneously from opposite surfaces of metallic bodies with oxidizing gas streams in such a manner that the force of gravity is utilized for carrying away the metal removed.

Another object of my invention is to remove surface metal simultaneously from all sides or the entire peripheral surface of a metallic body by applying oxidizing gas streams against the metallic body along a zone extending about the entire perimeter thereof, and by moving the oxidizing gas streams and metallic body relatively to each other.

A further object of the present invention

therefore is to provide a new article of manufacture produced by thermochemically shallow layers of surface metal from the longitudinal surfaces of a semi-finished steel shape such as a steel billet. A further object of the invention is to provide a semi-finished steel billet or the like which has a new surface substantially free of defects, an improved metallurgical surface structure, and longitudinal contiguous shallow surface channels.

Further objects and advantages of my invention will become apparent as the following description proceeds, and the various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. In the drawings:

Fig. 1 is a side elevation, partly in section, of an apparatus for producing the semi-finished article according to the present invention by removing metal from the surfaces of the side walls and top and bottom of a metallic body, the grooves formed by the removal of the metal being omitted for clearness;

Fig. 2 is a fragmentary sectional view taken on line 2—2 of Fig. 1 to illustrate more clearly the portion of the apparatus for removing surface metal from a side wall of the metallic body;

Fig. 3 is a sectional view taken on line 3—3 of Fig. 1 illustrating the contiguous shallow channels and rounded corners produced by the surfacing operation;

Fig. 4 is a sectional view taken on line 4—4 of Fig. 2;

Fig. 5 is an isometric view showing an article produced in accordance with the present invention; and

Fig. 6 is a view showing a photomicrograph of a portion of the article shown in Fig. 5.

Referring to the drawings, the apparatus for removing surface metal from a rectangular steel billet in accordance with the principles of my invention may comprise a plurality of pedestals 10 having shafts 11 journaled thereon to which are secured rollers 12 to provide a conveyor for supporting and moving a number of metallic bodies, such as rectangular shaped billets 13 in the direction of their length, through an opening formed in a frame F for supporting the cutting gas apparatus. The frame structure F may comprise a base 14 and vertical side members 15 to which are secured upper and lower transverse members 16 and 16', respectively.

The billets 13 may be moved in any suitable manner, and as shown a variable speed driving motor M having a pulley 17 secured to the shaft thereof drives a belt 18 which is connected to a pulley 19 secured to one end of a shaft 11 for driving a roller 12. Although only one roller 12 is shown as driven, it is to be understood that other rollers 12 may be driven in a similar manner to insure a continuous movement of a number of billets 13 toward and away from the frame structure F.

In the apparatus shown, the oxidizing gas stream applying devices are arranged to apply the oxidizing gas so as to impinge against a zone of surface extending entirely across all four faces of the billet 13 and comprise gangs of blowpipe nozzles 20 disposed at an acute angle to the direction in which the applied streams advance over the surfaces of the top, bottom, and side walls. Each nozzle is adapted for applying heating jets and/or oxidizing gas streams on the surfaces of the billet 13 to remove metal therefrom

as it is moved with respect to the blowpipe. In this arrangement, it is seen that effects resulting from the application of high temperature heat on one face are compensated for by the effects produced on the opposite surface by such application.

In removing surface metal with oxidizing gas streams, a portion of the metal is preferably removed in an oxidized form and another portion is removed in the form of molten metal which is blown away with the oxidized metal by the oxidizing gas streams. To remove metal a portion at least of the surface must be raised to an ignition or kindling temperature before the oxidizing gas stream is applied thereto. The entire metallic body can be raised to an ignition temperature, as in a furnace, or successive portions of the surface metal can be progressively raised to an ignition temperature prior to the application of the oxidizing gas stream, as by the blowpipe nozzles 20.

The blowpipe nozzles 20 are so constructed that they will permit the passage of a comparatively large volume of oxidizing gas at a relatively low velocity, and may comprise a central passage for an oxidizing gas to provide an oxidizing gas stream. A plurality of passages surrounding the central passage may be provided for a combustible gas to produce a heating flame to raise the metal to be removed to an ignition temperature. Suitable nozzles of the character indicated are disclosed and claimed in applicant's copending application Serial No. 695,571, filed October 28, 1933.

As shown in the drawings, a plurality or gang of nozzles 20 are arranged adjacent to each other and inclined relatively to the top, bottom, and side surfaces of the billet 13 to apply oxidizing streams obliquely against and lengthwise of said surfaces for removing metal in a single pass from the entire peripheral surface of the billet. The nozzles 20 are threadedly secured to nozzle heads 21 having an oxidizing gas passage and a combustible gas passage communicating with similar passages in the nozzles 20. The nozzles disposed at the top and bottom of the billet 13 are arranged adjacent to each other by securing their respective nozzle heads 21 by cap screws 22 to bars 23, and the nozzles at the sides of the billet are similarly arranged by securing their respective nozzle heads by cap screws 22' to bars 23'. The outside nozzles 20 may be arranged sufficiently near the corners of the bar or billet so that the oxidizing gas streams will flow over such corners. In this manner, the surfaces of the corners are removed and the corners may be more or less convexly rounded, as shown at 25 in Fig. 5.

The oxidizing gas, such as oxygen or a mixture of oxygen and air, and a combustible gas, such as a mixture of oxygen and acetylene, may be delivered from a suitable source of supply through flexible conduits (not shown) to manifolds 24 and 25 having connections 26 and 27, respectively, communicating with the oxidizing and combustible gas passages in the heads 21 and 21'.

In removing metal by moving the billet 13 with respect to the nozzles 20, it may be desirable under certain conditions to permit the tips of the nozzles to rest or ride on the bottom of the channel, that is, on the newly-exposed surface; and under other conditions it may be desirable to maintain the tips of the nozzles spaced from the surface, as will be hereinafter explained.

When surface metal is removed with the tips of the nozzles riding on the newly-exposed sur-

face, it is desirable that the tips of the nozzles only bear lightly on the surface of the work, so as to minimize the friction and chattering between the nozzles and the work. For this reason, the groups of nozzles 20 and heads 21 disposed at the top and bottom surfaces of the billet 13 are counterbalanced in a suitable manner, so that the top and bottom groups of nozzles 20 will bear lightly and yieldingly follow the channel formed.

The groups of nozzles disposed at the sides of the billet 13 are arranged to be urged likewise toward the side surfaces in such a manner that the nozzles will bear lightly and yieldingly follow the channels formed.

Referring to the group of nozzles 20 and heads 21 disposed adjacent the top and bottom surfaces of the billet 13, in order to prevent the entire weight of these nozzles and heads from riding on the newly-exposed surface, they are counterbalanced by mechanism comprising a weight 28 which is slidably mounted at one end of a lever arm 29. The weight 28 counterbalances the weight of these nozzles 20 and heads 21 through a parallel linkage A comprising a pair of horizontal links 30 arranged in the same horizontal plane in spaced and parallel relation, and a second similarly arranged pair of horizontal links 31 below and in the same vertical planes as the links 30, as shown in Figs. 1 and 3. The links 30 and 31 are pivotally connected at one end thereof to projections 34 and 35, respectively, which may be attached to or formed integral with the upper and lower transverse members 16 and 16', respectively, of the frame structure F. The opposite ends of the links 30 and 31 are pivotally connected to the upper and lower ends and to the opposite sides of a block 37 which serves as a vertical link in the parallel linkage A, and which may be formed integral with the bar 23 to which the nozzle heads 21 are secured. The lever arm 29 forms an extension of one of the horizontal links 30, and by properly positioning the weight 28 thereon by a set screw 32, the weight of the nozzles 20 and heads 21 can be readily counterbalanced, so that the tips of the nozzles 20 will bear lightly on the newly-exposed surface of the billet as the nozzles 20 and billet are moved relatively to each other.

Each group of nozzles 20 disposed at a side of the billet 13 may be maintained in contact with a side surface thereof by a parallel linkage C biased to move the nozzles 20 toward the billet 13. Each linkage C comprises a pair of upper horizontal links 40 arranged in the same horizontal plane and in spaced and parallel relation, and a second similarly arranged pair of lower horizontal links 41 below and in the same vertical planes as the links 40. The links 40 and 41 nearest the billet 13 are secured at one end thereof to a vertical pin 42 which is pivotally mounted on brackets 43 and 44 attached to the vertical side members 15 of the frame structure F, and the outer links 40 and 41 are secured at one end thereof to a vertical pin 42' which is pivotally mounted on projections 43' and 44' attached to the vertical side members 15 of the frame structure F. The opposite ends of the links 40 and 41 are pivotally connected to the top and bottom corner portions of a block 45 which serves as the vertical link of the linkage C and which may be formed integral with the bar 23' to which the nozzle heads 21 at the side of the billet 13 are secured.

To cause the linkage C to swing toward the side of the billet 13 so that the tips of the nozzles 20 will contact the side surface thereof, the end of

the upper and outermost link 40, which is secured to the pin 42', is provided with a right angle extension 46 extending toward the billet 13; the link 40 and its projection 46 forming a bellcrank, as shown in Fig. 2. In the space between the upper links 40 and lower links 41, a lever arm 47 having a weight 48 slidably mounted thereon, is pivotally connected at one end thereof to a projection 49 attached to a vertical side member 15 of the frame structure F, as most clearly shown in Fig. 4. The pivotally connected end of the lever arm 47 is provided with an upward extending extension 50, the upper end of which is adapted to contact the extension 46 of the upper and outermost link 40 and cause the linkage C to swing on the pivotally mounted pins 42 and 42' toward the billet 13. By properly positioning the weight on the lever arm 47 by a set screw 51, the moment of force of the weight and lever arm can be so adjusted that the nozzles 20 will be moved by the linkage C to contact the surface of the billet 13 with the tips of the nozzles bearing lightly on the newly-exposed surface as the billet is moved with respect to the nozzles. In a similar manner the group of nozzles 20 disposed at the opposite side of the billet 13 are biased toward the other side surface of the billet to remove surface metal with the tips of the nozzles riding on the new surface produced.

To increase the flexibility of the apparatus, suitable means is provided for maintaining the tips of the nozzles 20 spaced from the top, bottom, and side surfaces of the billet 13. This may be accomplished automatically, as for example, pneumatically, by providing cylinders E adapted to be connected to a suitable source of compressed air (not shown), and having therein movable pistons 51 connected to piston rods 52 extending through an opening in the end wall of the cylinders.

As shown in Fig. 1, the air cylinder E at the top of the frame structure F is mounted on a plate 53 attached to the upper transverse frame member 16. The end of the piston rod 52 is pivotally connected at 54 to one end of a link 55, the opposite end of which is pivotally connected at 56 to the upper end of a link 57 forming a right angle extension of one of the horizontal links 30 of the linkage A. The horizontal link 30 and its extension 57 form a bellcrank for converting the straight line motion of the piston rod 52 to an angular motion of the linkage A. When the piston 51 is caused to move to the right by admitting air under pressure into the cylinder E, the bellcrank, which is pivotally mounted on the projection 34, will turn to the right and swing the linkage A and nozzles 20 carried thereby upward against the movement of force of the lever arm 29 and weight 28. The distance of the tips of the nozzles 20 from the top surface of the billet can be readily controlled by regulating the pressure of the air in the cylinder E.

A cylinder E is mounted on the base 14 of the frame structure F, and the piston therein is connected to the lower linkage A in the same manner as described above for moving the lower group of nozzles 20 away from the lower surface of the billet and for adjusting the lower nozzles in reference thereto.

The linkages C at the sides of the billet 13 are likewise pivotally connected to the pistons in cylinders E for maintaining the tips of the nozzles 20 spaced from the side surfaces of the billet. As shown in Fig. 2, the cylinder E is mounted on a plate 58 attached to the side member 15 of

the frame structure F. The piston rod 52' is pivotally connected at 59 to one end of a link 60, the opposite end of which is pivotally connected at 61 to the outer end of a link 62 forming a right angle extension of one of the upper horizontal links 40 of the linkage C. The outer link 40 and its extension 62 form a bellcrank for converting the straight line motion of the piston rod 52 into an angular motion of the linkage C; and, as explained above in connection with the linkage A, the pressure of air in the cylinders E at the sides of the billet can be controlled so as to regulate the distance of the tips of the nozzles 20 from the side surfaces of the billet.

In the event it is desired to remove surface metal from round billets the nozzles 20 may be arranged on a circular head adapted to encompass the billet so that the nozzles converge on the axis of the billet and form an acute angle therewith of between 10° and 35°. The head may be made in a plurality of sections and operated by linkage mechanism similar to that shown in the drawings.

The operation of the apparatus illustrated in the drawings is substantially as follows: It will be assumed that the billet 13 or other work to be treated is mounted on the rollers 12 and in proper alignment, with the right hand end of the billet 13 adjacent the tips of the nozzles 20; that the positions of the counterweights 28 and 48 on the lever arms 29 and 27, respectively, have been adjusted so that the nozzles 20 will bear lightly on the bottom of the cut; that the source of compressed air is not connected to the cylinders E and that the pistons therein will move freely; and that the manifolds 25 are supplied with a mixture of oxygen and acetylene, respectively.

With the above assumed conditions, the combustible gas issuing from the tips of the nozzles 20 is ignited so that the heating flames will be applied to the entire peripheral surface of the billet at the right hand end thereof. As soon as the portions of the peripheral surface at the end of the billet have reached an ignition temperature, oxygen is supplied to the manifolds 24 and the motor M is connected to a suitable supply of electrical energy (not shown) to drive the billet 13 from left to right, as indicated by the arrow shown in Fig. 1. The oxidizing gas streams issuing from the orifices of the nozzles 20 are applied at an acute angle to the surfaces of the billet 13 and will oxidize the surface metal at the right hand end thereof which has been raised to an ignition temperature by the heating flames; and this oxidized metal, along with molten metal, will be blown ahead of the nozzles 20 in the form of a slag by the force of the oxidizing streams. The several oxygen streams issuing from the four groups of nozzles 20 thus effect superficial metal combustion along a relatively wide transverse zone of each surface of the billet 13 and, during the movement of the billet relatively to the nozzles 20, the volume, velocity, and angle of impingement of the oxygen streams as well as the rate of such movement are so correlated as to maintain such superficial metal combustion on successive surface zones from one end of the billet to its opposite end, to produce continuous and uniform thermo-chemical removal of a wide shallow layer of metal from each of the surfaces of the billet throughout the entire lengths of the latter.

The tips of the nozzles 20 may rest on the bottom of the cut started at the right hand end of the billet 13, whereupon the latter is moved rela-

tively fast on the rollers 12, the heating flames of the nozzles 20, together with the molten metal and oxides blown ahead of the nozzles, raising successive surface portions to an ignition temperature; and the oxidizing gas streams oxidizing the successive surface portions which have been raised to an ignition temperature. During the entire operation, oxidized and molten metal are blown ahead of the zone of reaction by the force of the oxidizing gas streams; while at the sides and bottom of the billet such oxidized and molten metal are effectively carried away by the force of gravity to fall clear of the nozzle supporting mechanism which holds the nozzle offset a substantial distance from the supporting frame.

In the description of the operation of the apparatus, it has been stated that the oxidizing gas streams blow away oxidized and molten surface metal, and this mixture of oxidized and molten surface metal has been termed a "slag". Although the surface metal removed can be reduced completely to an oxidized form, it has neither been desirable nor necessary to do so in practice. For example, it has been calculated that approximately 4½ cubic feet of oxygen are required to oxidize completely one pound of an ordinary grade of low carbon steel containing about .2% carbon. In actual practice it has been possible to remove a pound of this steel with approximately 2 cubic feet of oxygen. It is therefore apparent that a portion of the surface metal removed is in an oxidized state, and that the remaining portion is in a partially oxidized state and in an unoxidized state or molten form. By removing a substantial portion of surface metal without completely oxidizing the same, considerable economy can be effected in the amount of oxidizing gas required to remove metal from the surfaces of metallic bodies.

Although the removed metal or slag blown ahead is reduced substantially to a non-adherent state, there is a tendency for the molten metal forming part of the slag to freeze on the sides of the channel and form fins. By properly controlling and correlating the variable factors, such as the acute angle of the nozzles with respect to the work, the velocity of the oxidizing gas, and the rate of relative movement of the nozzles and the work, the amount of fin material formed can be controlled and the efficiency of the process regulated by the mutual spacing of the oxidizing gas streams and the adjustment of the distance of the nozzles from the work. As stated above, however, it is generally not desirable to completely oxidize the metal removed in order to remove surface metal as economically as possible. It has been found that fin material formed on the sides of a cut when the slag is not completely oxidized is extremely small when the force of gravity can be utilized to carry away the slag from the surface of the work. For this reason, it is a distinct advantage to remove surface metal from the sides and bottom of a metallic body, and at the same time remove such metal with a minimum consumption of oxidizing gas. Where metal is to be removed from a single side or portion of a peripheral surface of a body it can be so arranged that the force of gravity can be effectively utilized to carry away the metal removed. In cases where metal is to be removed from all sides or the entire peripheral surface of a metallic body, it is preferable to remove the surface metal in a single pass of the nozzles relative to the metallic body. In such cases the force of gravity will carry away

removed metal from a considerable portion of the peripheral surface of the metallic body.

In the normal production work the new surfaces produced are sufficiently smooth for all practical purposes. In certain instances, however, it is desirable to produce particularly smooth surfaces. In order to make channels which are particularly smooth, the nozzles 20 are adjusted so that their tips will be spaced from the bottom surface of the channels produced. This is accomplished by connecting the cylinders E to a source of compressed air so that the linkages A, B, and C will swing the nozzles 20 away from the top, bottom and side surfaces of the billet 13 against the moments of force of the lever arms and weights associated with the linkages. By varying the pressure of the air supplied to the cylinders E through a suitable pressure regulating valve or similar device, the distance of the tips of the nozzles 20 from the surfaces of the billet can be readily controlled. Although smoother cuts are obtained when the tips of the nozzles are spaced from the bottom of a cut, it is considerably more economical to remove metal with the nozzles riding upon the newly-exposed surface because in the latter case less oxidizing gas is required to remove a pound of metal, other factors remaining substantially the same.

The air cylinders E may also be employed to swing the nozzles 20 away from the surfaces of the work to start a cut at an end or at a point intermediate the ends of the work, or to align the nozzles with respect to the work before starting a cut.

It has been stated that the nozzles 20 are of such a type that they will permit the passage of a comparatively large volume of oxidizing gas at a relatively low velocity. In practice it has been determined that the best results under average conditions are obtained in most cases when the pressure of the oxidizing gas is adjusted to produce an oxidizing gas stream having a velocity between 550 and 750 feet per second. However, higher or lower oxidizing gas stream velocities may be used to suit different conditions and results desired. The velocities of the oxidizing gas streams stated herein are the calculated velocities of the gas discharged from the nozzles based on the assumption that a measured quantity of gas discharged in a given time has a temperature of 70 degrees F. and is at atmospheric pressure.

The newly-formed grooved surface produced on a billet is illustrated in Fig. 5 where the contiguous parallel shallow channels are indicated at 66. The channels have sides which slope gradually to ridges 67 that define the contiguous boundaries between the channels. The desurfacing process described herein provides a desired convexly rounded contour of the corners 65.

The depth of the grooves or channels 66 and the height of the ridges 67 between them may be made more or less pronounced than illustrated herein to suit the working conditions. The depth and width of the channel are affected by the velocity of the oxidizing gas stream, both the depth and width increasing with an increase in the velocity of the oxidizing gas stream. The nozzles employed in the present apparatus are capable of producing individual cuts or grooves about  $1\frac{1}{2}$  inches in width and  $\frac{1}{2}$  inch in depth when the discharge velocity of the oxygen is about 585 feet per second and the rate of movement of the nozzle with respect to the surface is about 6 feet per minute. Cuts of such rela-

tively wide width are clearly shown in Figs. 3 and 5. The depth and width of the channels, therefore, can be partially controlled by varying the velocity of the oxidizing gas streams.

In the drawings the nozzles 20 are shown at an acute angle of approximately 25 degrees with respect to the work. Satisfactory cuts have been made with nozzles at acute angles varying from 10 to 35 degrees with respect to the surface of the work. Although the nozzle heads 21 are shown fixedly secured to the bars 21 and 21', it may be desirable to provide means for varying the acute angle of the nozzles with respect to the work, and to provide suitable indicating means for setting the nozzles at a particular acute angle. Although the depth of a cut does not change appreciably with a change in the angle of the nozzle with respect to the work, a marked increase in the width of a cut is obtained with an increase in the angle at which the nozzle is set.

At very low speeds satisfactory cuts are not obtained. This in part is caused by the metal slag piling up ahead of the nozzle. In order to avoid the undue reaction of the oxidizing gas stream on the surface of the work, it is moved relatively to the work at a speed sufficient to prevent the oxidizing gas stream being applied for too long a time at any particular portion of the surface of the work. By way of example, satisfactory cuts have been made on cold metal by moving nozzles relatively to the work at speeds varying from 4 to 90 feet per minute, i. e., at a substantially uniform rate of speed higher than the maximum speed heretofore conventionally employed for severing metal by means of an oxygen jet.

For example, when using well known high velocity oxygen jets for cutting or severing mild and structural steels at room temperatures, conventional machine cutting speeds for propelling the cutting nozzle or blowpipe relatively to the steel body vary from about 2.4 inches per minute for steel of 12 inches thickness to 32 inches per minute for steel of one-eighth inch thickness.

Removing surface metal in the manner described above is particularly advantageous in steel mill operations where semi-finished steel shapes are at an elevated temperature, such as 1600° F. or higher, for example, after a rolling operation which reduces the cross section of the semi-finished shapes and elongates them. When machine tools and chipping tools are employed to remove surface metal, it is necessary to allow the bars and billets to cool before surface metal can be removed with appreciable accuracy. With my improved apparatus, surface metal can immediately be removed from bars and billets that are at an elevated red heat temperature during rolling operations. Although the work may be sufficiently heated after a rolling operation for an oxidizing gas stream to remove surface metal when applied thereto, it is desirable in some instances to apply heating flames even on the heated work so as to increase the speed of metal removal and to remove a greater amount of surface metal per cubic foot of oxidizing gas.

It has also been observed that relatively hard metals, such as steels having high amounts of combined carbon, respond more readily to the action of oxidizing gas streams than metals of lower hardness, such as the low carbon steels. Since the harder metals respond more readily to the action of an oxidizing gas stream than metals of lower hardness, the cost of removing surface metal does not increase with the hardness of the

metal cut, as is the case with the heavy machine-tools heretofore used where the amount of power required to make a cut increases with the hardness of the metal.

5 The resulting article produced, when a body of ferrous metal is desurfaced in accordance with the invention, has a new envelope with properties whereby the article may be identified and differentiated from the metal of the body before  
10 being processed and also distinguished from that of similar articles produced by other processes. The new envelope has a surface which is clean, smooth and glass-like and relatively free from discoloration and is characterized by a series of  
15 contiguously formed uniform parallel channels or paths traversing the surface. The photomicrograph depicted in Fig. 6 shows a portion of the envelope, extending to the surface, of a typical etched and polished section of such desurfaced  
20 body; the portion being composed of four zones or strata of different crystal structures, denoted respectively *d*, *e*, *f*, and *g*. Here the lowermost stratum *g* shows the unchanged interior structure of the body, while the strata *d*, *e*, and *f* are  
25 seen to consist of a changed or new fine grain structure that is substantially free from mechanical deformation and is of increased hardness. The zone *f* comprises largely troostite which is formed by rapidly cooling from a temperature  
30 just above the transformation temperature; while zone *e* comprises mainly martensite formed by cooling from a higher temperature. The topmost stratum *d* is seen to consist of a layer that contains needles of martensite embedded in a matrix  
35 of austenite whose presence shows that this zone has an excess of carbon over that of the average composition of the body, which carbon is relatively uniformly distributed and imparts to the body a surface having increased hardness and  
40 resistance to oxidation. The appearance of zone *d* at the desurfaced face indicates that this portion was cooled from the fused state.

The average depth or extent of this new structure below the surface is  $\frac{1}{16}$  inch. A billet desurfaced according to the present invention thus  
45 has the further advantage, as an intermediate product to be processed in the steel mill, over a billet otherwise desurfaced, that the excess of carbon engendered in its surface counteracts the surface decarburization usually encountered in  
50 connection with the reheating of such intermediate products, since there exists in the surface of a billet, when thus desurfaced, a desired excess of carbon.

55 While I have shown and described a particular embodiment of my invention including a rectangular metallic body in which surface metal is removed from all sides, it will be apparent that modifications can be made for removing surface  
60 metal from any multi-sided or round metallic body, and that certain features can be used independently of others without departing from the spirit and scope of my invention.

I claim:

65 1. A conditioned semi-finished billet of rectangular cross section having all four of its lateral sides consisting of surfaces formed by thermo-chemically removing a shallow layer of surface  
70 metal from each of said sides by applying oxidizing gas streams obliquely against successive portions of said sides while such portions are at ignition temperature.

75 2. A thermo-chemically surfaced elongated steel body having substantially its entire lateral surface consisting of contiguous parallel shal-

low channels thermo-chemically produced by the application of voluminous relatively low velocity oxidizing gas streams against and longitudinally of said surface when at ignition temperature so as to remove metal from the entire lateral surface of said billet, said channels extending continuously lengthwise of said body from adjacent one end thereof to adjacent the other end thereof and having substantially uniform depth and width throughout the entire length thereof.

3. A thermo-chemically surfaced steel billet of rectangular cross section having at least two of its lateral surfaces substantially free from surface defects such as cracks and seams, and consisting of contiguous parallel shallow channels thermo-chemically produced by the application of voluminous relatively low velocity oxidizing gas streams against said surfaces when at ignition temperature so as to remove metal from such surfaces, said channels extending continuously from adjacent one end of said billet to adjacent the other end of the same, said channels having sides sloping gradually to ridges severally defining the contiguous boundaries of said channels.

4. A thermo-chemically surfaced steel billet of rectangular cross section having all four of its lateral surfaces substantially free from surface defects such as cracks and seams, each of said surfaces consisting of contiguous parallel shallow channels thermo-chemically produced by the application of voluminous relatively low velocity oxidizing gas streams to said surfaces when at ignition temperature so as to remove metal from such surfaces, said channels extending continuously from adjacent one end of said billet to adjacent the other end of said billet and having sides sloping gradually to ridges severally defining the continuous boundaries of said channels, the four longitudinal corners of said billet being convexly rounded.

5. As an article of manufacture, a body of ferrous metal which has been desurfaced with oxidizing gas impinged with a relatively low velocity, said body being characterized by the formation of a new surface envelope consisting of a layer having a hard, smooth, glass-like, rust-resisting surface produced by the impingement of oxidizing gas at a relatively low velocity and in voluminous amounts when said surface is at ignition temperature, and is composed of a substantially uniform fine-grained structure that contains carbon relatively uniformly distributed therein and in excess of that of the average composition of the body, said surface having a plurality of contiguous channels formed by the oxidizing gas traversing the same.

6. As an article of manufacture, a body of ferrous metal which has been desurfaced by a thermo-chemical reaction with a stream of oxygen impinged with a low velocity, said body being characterized by the formation of a new envelope having a hard, smooth, glass-like highly rust-resistant surface produced by the impingement of oxidizing gas at a relatively low velocity and in voluminous amounts when said surface is at ignition temperature, said surface being composed of a uniformly fine grain structure that contains carbon substantially uniformly distributed in excess of that of the average composition of the body, said surface consisting of contiguous channels which are substantially free from steep sides, fins and discoloration.

7. As an article of manufacture, a semi-finished hot rolled steel billet which has been desurfaced by a thermo-chemical reaction of the

surface metal thereof with relatively low velocity oxidizing gas streams progressively and longitudinally applied obliquely against and along the surfaces while the latter are at an ignition temperature, said billet having a longitudinal surface consisting of contiguous longitudinal shallow channels which are uniform, smooth and rust-resistant, said channels comprising a new relatively thin surface envelope composed of a uniformly fine grain structure containing carbon substantially uniformly distributed and in excess of that of the average composition of the billet.

8. As an article of manufacture, a semi-finished hot rolled steel billet which has been desurfaced by a thermo-chemical reaction of the surface metal thereof with relatively low velocity oxidizing gas streams progressively and longitudinally applied obliquely against and along the surfaces while the latter are at an ignition temperature, said billet having a longitudinal surface comprising a new relatively thin surface envelope composed of a uniformly fine grain structure containing carbon substantially uniformly distributed and in excess of that of the average composition of the billet.

9. The method of thermo-chemically removing a layer of metal from a surface of a body of ferrous metal such as a steel billet, which comprises relatively moving said body in the direction of its length with respect to a blowpipe device; delivering a high temperature heating flame and a voluminous low-velocity oxygen stream obliquely against a zone of metal extending completely across said surface to effect superficial metal combustion along such zone; so correlating the volume, velocity and angle of impingement of said stream and the rate of such relative movement that a substantially uniform layer of surface metal is removed from said surface; and during such relative movement, maintaining said surface of the body at a substantial angle to a horizontal plane to cause the slag which forms at the zone of combustion to flow transversely off the surface under the influence of gravity whereby substantially little fin material adheres thereon.

10. The method of desurfacing bodies of ferrous metal having a rectangular cross section which comprises raising the temperature of the surface to be removed to its ignition temperature, applying a relatively voluminous amount of oxidizing gas at acute angles to two adjacent sides of said body in the form of relatively wide streams of oxidizing gas impinging at a series of points extending entirely across each of said adjacent sides, compensating for the effects of such application on adjacent sides by the simultaneous impingement of similar relatively wide streams of oxidizing gas similarly applied to sides opposite said first named adjacent sides, and effecting relative motion between said body and said oxidizing gas streams whereby a body entirely desurfaced on four sides is produced in one pass.

11. In the process of hot rolling bodies of ferrous metal that have rectangular cross sections, the steps for effecting desurfacing of such body at a desired point in the mill processing the body being rolled, which consist in relatively moving said body at said point in the mill horizontally with respect to a device provided to deliver oxidizing gas while the average temperature of said body may be as great as 1600° F., and delivering a relatively voluminous amount of oxidizing gas so as to impinge simultaneously on opposite sides with low velocities in a substantially continuous

series of points which extend entirely across the width of said impinged sides and inclined to said impinged sides at constant acute angles to the direction of advance, said angles having values between 10 and 35 degrees, whereby surface metal is removed from said body from a plurality of sides in a single pass, the removed material falling away leaving clean sides and a corner formation relatively free from fins.

12. In a process of hot rolling bodies of ferrous metal that have rectangular cross sections, the steps for effecting desurfacing of such body at a desired point in the mill processing the body being rolled, which consist in relatively moving said body at said point in the mill horizontally with respect to a device provided to deliver oxidizing gas while the temperature of the surface of said body may be as great as 1600° F., and delivering a relatively voluminous amount of oxidizing gas from said device so as to impinge simultaneously on all four sides with low velocity in a substantially continuous series of points which extend about the entire periphery of the body, the delivery of said oxidizing gas being inclined to said surfaces at constant acute angles to the direction of advance over said surface, said angles having values between 10 and 35 degrees, whereby surface metal is removed from said body from all four sides in a single pass leaving a body having rounded corners substantially free from fins.

13. A process for simultaneously thermo-chemically removing a layer of metal from each surface of two opposite longitudinal sides of a ferrous metal body of rectangular cross-section, such as a steel billet, which comprises applying a high temperature heating flame and a voluminous low-velocity oxygen stream obliquely against a zone of metal extending across each of said surfaces to effect superficial metal combustion along such zones; effecting continuous relative motion between said body and such flames and streams lengthwise of said surfaces; and so correlating the volume, velocity, and angle of impingement of each of said streams and the rate of such relative motion that combustion of superficial metal is maintained on each of said surfaces during such relative motion to produce substantially uniform thermo-chemical removal of layers of metal from both of said longitudinal sides in a single pass of said body relatively to said flames and streams.

14. A process for simultaneously thermo-chemically removing a wide shallow layer of metal from each surface of two opposite longitudinal sides of a ferrous metal body of rectangular cross-section, such as a steel billet, which comprises continuously moving said body at a uniform rate and horizontally in the direction of its length while said body is at an elevated hot rolling temperature and while said sides are maintained substantially vertical; during such movement of said body applying a low-velocity voluminous stream of oxidizing gas obliquely against a zone of metal extending entirely across each of the surfaces of said vertical sides to effect superficial metal combustion along such zones; and so correlating the volume, velocity, and angle of impingement of each of said streams and the rate of movement of said body that combustion of superficial metal is maintained on each of such vertical surfaces throughout such movement to produce thermo-chemical removal of substantially uniform layers of metal from both of such

vertical sides in a single pass of said body relatively to such streams of oxidizing gas.

15. A process for simultaneously thermo-chemically removing a layer of surface metal from each of the four longitudinal sides of a ferrous metal body of rectangular cross-section, such as a steel billet, which comprises concurrently applying to each of said sides a high temperature heating flame and a relatively low-velocity voluminous oxygen stream directed obliquely against a zone of metal extending across the entire width of each of said sides to effect superficial metal combustion along each of such zones; effecting continuous relative motion between said body and such flames and streams in the direction of the length of said body and from one end thereof to the other end thereof; and so correlating the volume, velocity, and angle of impingement of said streams and the rate of such relative motion that superficial metal combustion is maintained on each of said sides during such relative motion to produce thermo-chemical removal of layers of metal from all of said sides in a single pass of said body relatively to said flames and streams.

16. A process for thermo-chemically removing a shallow layer of metal from the entire lateral surface of an elongated ferrous metal body, such as a steel billet, which comprises concurrently applying high temperature heating flames and relatively low-velocity voluminous oxygen streams obliquely against a zone of metal extending around the entire periphery of said body to effect superficial metal combustion along such peripheral zone; effecting continuous relative motion between said body and such flames and streams in the direction of the length of said body and at a uniform rate from one end of said body to the other end thereof; and so correlating the volume, velocity, and angle of impingement of said streams and the rate of such relative motion that superficial metal combustion is maintained at successive peripheral zones of impingement of said flames and streams during such relative motion to produce thermo-chemical removal of a shallow layer of metal from the entire lateral surface of said body in a single pass of said body relatively to said flames and streams.

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