

D. B. COFER ET AL

METHOD OF HOT FORMING METAL

Filed Nov. 12, 1964

4 Sheets-Sheet 1

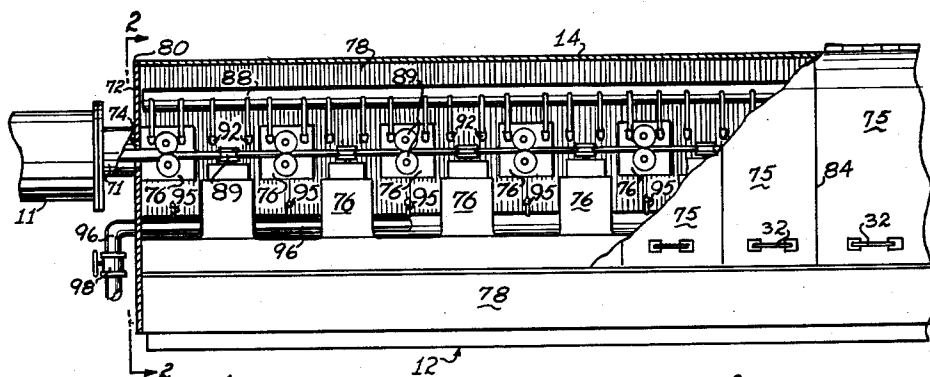


Fig 1A

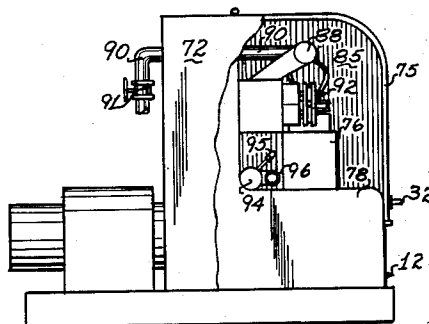


Fig 2

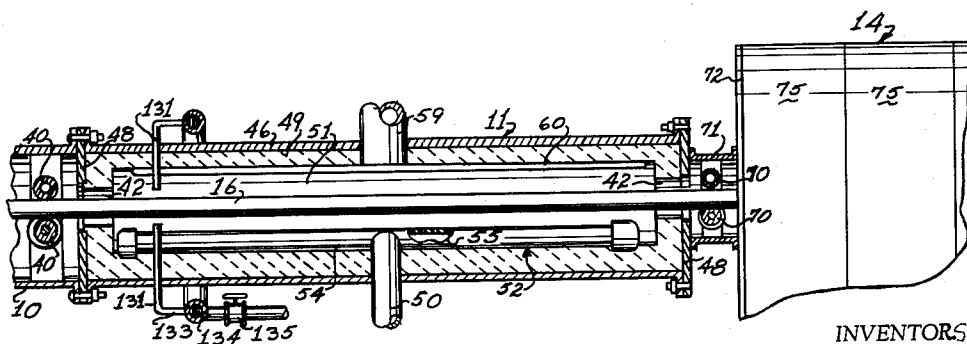


Fig 1 B

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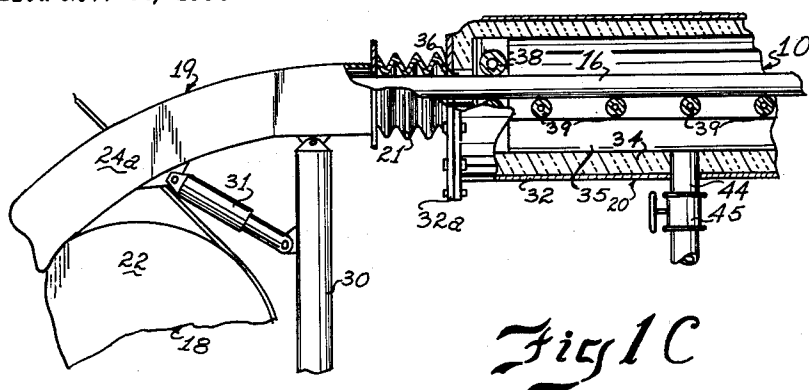


Fig 1C

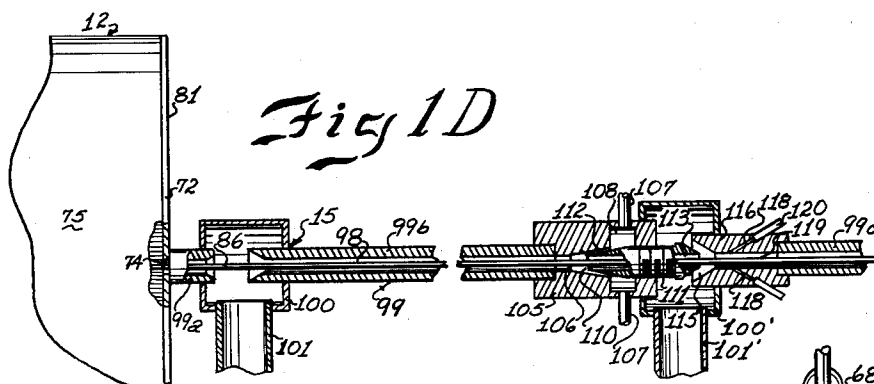


Fig 1D

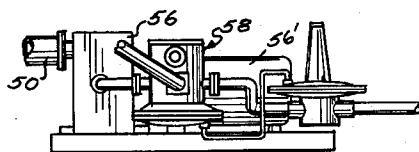


Fig 3

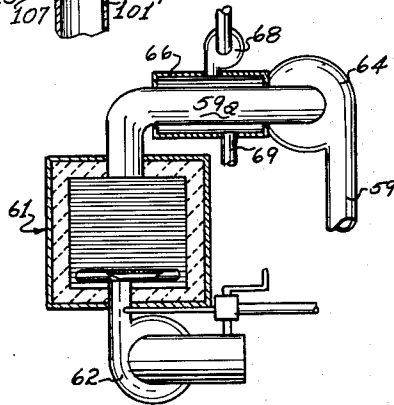


Fig 4

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Fig 5

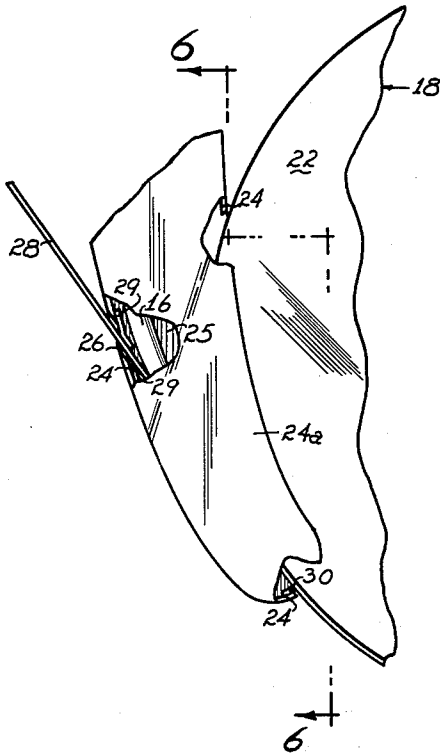


Fig 6

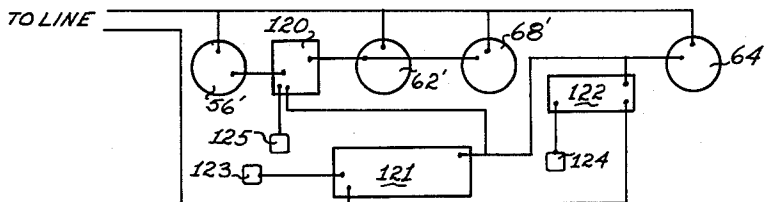
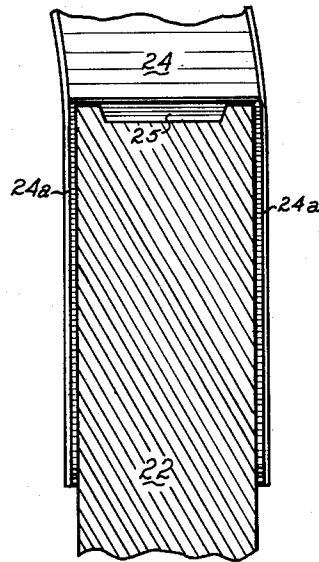


Fig 7

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Fig 8

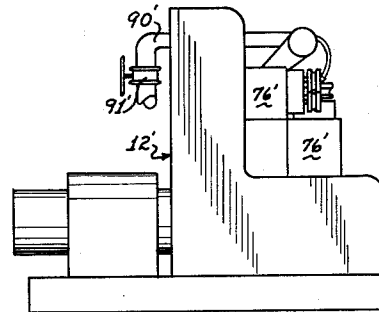
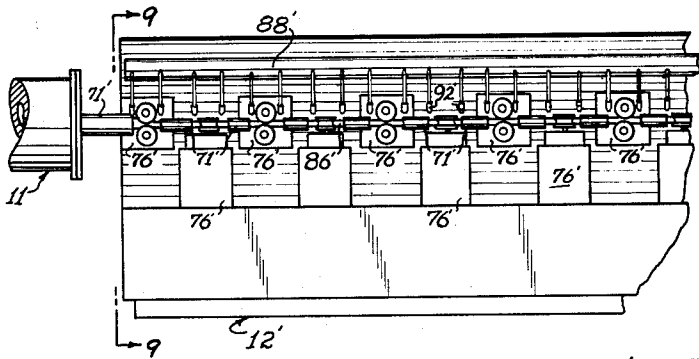


Fig 9

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METHOD OF HOT FORMING METAL

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Filed Nov. 12, 1964, Ser. No. 410,805
10 Claims. (Cl. 72-364)

This invention relates generally to the hot forming of metal and more particularly to a method of hot forming of metal by which oxide coatings on the metal are eliminated and their formation precluded continuously and by which the temperature of the metal may be selectively controlled.

Various hot forming processes wherein metal at hot forming temperatures is rolled, forged or otherwise worked, and subsequently cooled, are well known in the art. In these processes, it is highly desirable that oxide coatings formed on the metal prior to hot working be removed and the formation of oxide coatings on the metal during the hot working process be prevented. It is also desirable that the temperature of the metal during heating and cooling be constantly and accurately controlled.

Should oxide coatings be present as the metal is rolled, forged or otherwise hot formed, the oxides tend to become imbedded in the metal during forming. Such included oxides serve to reduce the strength, ductility, and conductivity of the formed metal. Moreover, oxide coatings on the hot formed metal produce a drab unsightly surface on the metal which interferes with subsequent working of the metal, such as wire drawing, by wearing and mutilating the drawing dies and preventing the product from exhibiting those characteristics of strength, ductility and conductivity generally required for commercial use of the finished product.

While progress has been made in the development of methods of hot forming metal wherein the formation of oxide coatings on the metal is prevented as the metal is being hot formed, such methods and apparatus have not removed oxide coatings formed on the metal before the hot forming and some of which might be formed during hot forming despite precautions against such formations. Thus, with previous methods, oxide coatings were generally present on the metal after the hot forming.

Previous methods have generally heated the metal to hot forming temperature at a substantial distance from the hot forming apparatus, and in transportation to the hot forming apparatus, uncontrolled temperature changes occurred on the metal, resulting in the metal being hot formed at non-uniform temperatures along its length, causing both stresses in the metal as it was formed and excessive loading conditions within the hot forming apparatus. This has also prevented the metal from exhibiting those characteristics of strength, ductility and conductivity generally required for commercial use of the finished product.

The invention disclosed herein provides a method of hot forming a metal in which oxide coatings are removed and their formation is prevented prior to and during the hot forming and the subsequent cooling of the metal and in which the metal is at a selected uniform hot forming temperature when the hot forming of the metal is to be initiated. More particularly, the invention provides a continuous controlled environment both as to temperature and removal of oxide coatings as well as the prevention of the formation of other oxide coatings for application in the hot forming of metal bars, ingots, or the like into metal rods. Therefore, the invention substantially eliminates those problems resulting from the presence of oxide coatings and the lack of temperature control which are associated with previous methods of hot form-

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ing metal. Moreover, the need for an acid pickle is eliminated, thus reducing operating cost.

The invention is particularly well adapted to the hot forming of a continuously cast bar. The apparatus disclosed herein for accomplishing the method of the invention provides a tubular member into which a cast bar passes as it is continuously discharged from a casting machine and in which an oxide reducing environment is maintained, a furnace into which the cast bar passes directly from the tubular member and in which is provided a temperature controlled oxide-reducing environment, a rolling mill for hot working the cast bar to produce rod therefrom in an oxide reducing environment into which the rolled rod passes directly from the furnace, and a cooling member for cooling the rolled rod below its oxidation temperature in an oxide reducing environment into which the rolled rod passes directly from the rolling mill. Therefore, the cast metal bar first has any oxides thereon removed after entry into the reducing environment and further formation of oxides is precluded by such environment.

While the various inventive concepts of the present method are broadly applicable in the hot forming of a wide variety of metals and their alloys; in particular, iron, steel, aluminum and copper are contemplated for working by the present method. However, in the production of oxide free, pure copper rods for subsequent wire drawing, the present invention is of significant value. Further, the present method lends itself to application to continuous copper bar casting equipment wherein a fully controlled environment both as to temperature and as to a reducing medium can be provided. Thus, there is insured a clean, bright, uniformly ductile, copper rod free from included oxides or internal stress variation and hence a product admirably suited to be drawn as wire as the terminal operation of a single continuous process from continuous casting to finished wire. It is, of course, to be noted that stress free, oxide free, bright copper rod provides ideal material for the drawing of wire of uniform and high quality strength, ductility and conductivity. Further, such rods may be easily drawn with minimum power requirements and die wear abrasion or mutilation.

A very important feature of the present method steps is the combination, cooperation and simultaneous action of the oxide removal from and formation prevention on the metal bar with the temperature control of the metal bar, each as an incident to the other. Thus, in a single series of successive steps, a clean, bright internally and externally oxide free rod is produced with a substantially stress free structure. As more fully hereinafter discussed, the heat control gases are produced by combustion with limited oxygen, thus producing a reducing environment while effecting the desired temperature control. This is not to suggest that the method and means for the production of an oxide free product may not be resorted to without the beneficial effect of heat control, nor that the heat control of the invention may not be effective and efficient in the production of rods of uniform physical characteristics regardless of oxides. However, in the most advantageous use of the principles of the invention, both desiderata are achieved by the same method steps.

The above and other features and advantages of the invention will become apparent from the following description when taken in conjunction with the accompanying drawings in which like characters of reference designate corresponding parts throughout the several views, and wherein:

FIG. 1A is a side elevation with the cover partly broken away of a rolling mill effective to practice the method of the invention;

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FIG. 1B is a vertical longitudinal sectional view of a furnace for use with the rolling mill shown in FIG. 1A to further practice the method of the invention;

FIG. 1C is a side elevation partially broken away of the receiving member for use with the rolling mill and furnace of FIGS. 1A and 1B to further practice the method of the invention;

FIG. 1D is a longitudinal sectional view of the cooling member for use with apparatus of FIGS. 1A, 1B, and 1C to further practice the method of the invention;

FIG. 2 is an elevational view partly broken away of the rolling mill taken on the line 2—2 in FIG. 1A;

FIG. 3 is an elevational view of the supply mechanism for supplying a combustible mixture to the burner in the furnace to practice the method of the invention;

FIG. 4 is a cross sectional view of the supply mechanism for supplying noncombustible cooling to the furnace to practice the method of the invention;

FIG. 5 is an enlarged fragmentary elevational view, partially broken away, of the receiving member shown in FIG. 1C and of the casting wheel to illustrate the method of the invention;

FIG. 6 is a cross section of the receiving member taken on lines 6—6 of FIG. 5;

FIG. 7 is a schematic diagram of the control circuit for controlling the environment in the furnace to practice the method of the invention;

FIG. 8 is a fragmentary elevational view of the rolling mill in a second embodiment of the invention to practice the method of the invention; and,

FIG. 9 is an elevational view taken on the line 9—9 of FIG. 8.

These figures and the following specification disclose a specific embodiment of the invention, but the details disclosed herein in no way limit the invention since it may be embodied in other equivalent forms.

Referring to the accompanying drawings, one apparatus to practice the invention is seen to comprise a receiving member 10, a temperature regulating furnace 11, a rolling mill 12 having a cover 14 thereon and a cooling member 15. A metal bar 16 cast in a casting machine 18 of known type shown in FIGS. 5 and 6 is enclosed by the receiving member 10 immediately upon delivery from the casting machine 18. As the metal bar 16 moves through the receiving member 10 shown in FIG. 1C, it is enveloped by a controlled environment, preferably reducing, but in any event nonoxidizing in accordance with the method of the invention. Thus, in the receiving member 10, any oxide coating on the bar 16 is removed and/or its formation is substantially prevented. From the receiving member 10, bar 16 enters the temperature regulating furnace 11 where it is heated or cooled by a controlled environment which reduces and/or prevents from forming any oxide coating on the bar 16. Upon leaving the furnace 11, the metal bar 16 is received by the rolling mill 12 without intermediate exposure to the ambient oxidizing atmosphere. In the mill 12 the bar is again enveloped by a controlled environment which also reduces any oxide coating as well as prevents the formation of a new oxide coating while being rolled into rod 86. The metal rod 86 is then cooled below its oxidation temperature in the cooling member 15 by a controlled environment that reduces any oxide coating and prevents the further oxidation of the metal.

Referring more particularly to FIG. 1C, the receiving member 10 is seen to comprise an extractor chamber 19, a transfer chamber 20, and a flexible connector 21. The extractor chamber 19 is an arcuate member substantially square in cross-section as is best shown in FIGS. 5 and 6, the sides 24a of which extend adjacent a casting wheel 22 of the casting machine 18 and up and over the wheel 22. Cover members 24 extend between the sides 24a from just outwardly of the outer periphery of the casting wheel 22 thereby completing a channel 25 through which the metal bar 16 may move upon being extracted from

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the casting wheel 22. A slot 26 in the outer cover member 24 allows a metal band 28, which encircles the casting wheel 22 to form a casting mold, to pass out of the channel 25 through the extraction chamber 19 so that the metal bar 16 may be extracted from the casting wheel 22 into the channel 25 of the extraction chamber 19 without contacting the outside atmosphere. Seals 29 adjacent the metal band 28 as it passes through the slot 26 prevent the atmosphere outside of the extraction chamber 19 from entering the channel 25 in the extraction chamber 19. At the lower end of the outer edge member 24 as viewed in FIG. 5 is a seal 30 which also serves to help keep the outside atmosphere from the channel 25.

The flexible connector 21 is a hollow bellows member attached to the upper free end of the extractor chamber 19 along a centerline collinear with that of the extractor chamber 19 at its one end and with that of the transfer chamber 20 at its other end. The connector 21 allows the metal bar 16 to pass from the extractor chamber 19 to the transfer chamber 20 without contacting the atmosphere outside the receiving member 10. The connector 21 also allows the extraction chamber 19 to be moved to a plurality of positions with respect to a support member 30 by the operation of an adjusting cylinder 31 attached to the extractor chamber 19 and the support member 30 while allowing the transfer chamber 20 to remain stationary.

The transfer chamber 20 is a cylindrical hollow member, the centerline of which is substantially horizontal, comprised of a metal side wall 32 having a circular metal end 32a bolted thereto and having insulation 34 on the interior thereof to substantially prevent the transfer of heat from the metal bar 16 to the environment outside the receiving member 10. The metal bar 16 passes from the connector 21 into a channel 35 of the transfer chamber 20, through an opening 36 through the end 32a and the insulation 34, where it is received by rolls 38 which keep the metal bar 16 aligned for passage into the transfer chamber 20. A plurality of support rolls 39 transfer the metal bar 16 through the transfer chamber 21 while maintaining the metal bar 16 substantially straight. Pinch rolls 40 receive the metal bar 16 at the delivery end 41 of the transfer chamber 20 and align the bar 16 for passage through an opening 42 in the furnace 11.

An inert or reducing environment is introduced into the channel 35 of the transfer chamber 20 through a supply pipe 44 joining the channel 35 with an inert or reducing environment supply (not shown) such as a gas generator. A valve 45 regulates the rate at which the inert or reducing environment is introduced into the channel 35. The inert or reducing environment flows around the metal bar 16 in the channel 35, through the opening 36 into the flexible connector 21, through the connector 21 and the extraction chamber, and out of the extraction chamber 19 adjacent the sides of the casting wheel 22. Thus, the metal bar 16 is enveloped by an inert or reducing environment from the time it leaves the casting machine 18 and while it passes through the receiving member 10.

Attached to the delivery end 41 of the transfer chamber 20 is the temperature regulating furnace 11 shown in FIG. 1B, the centerline of which is collinear with that of the transfer chamber 20. The furnace 11 comprises generally a tubular side wall 46 and circular end plates 48 attached to each end of the side wall 46. A refractory lining 49 covers the inside of the side wall 46 and the end plates 48 to prevent deterioration of the side wall 46 and the end plates 48 due to the heat of a direct flame within the furnace 11. An opening 42 in each end plate 48 and the lining 49 allows the metal bar 16 to pass from the transfer chamber 20 through a channel 51 defined by the refractory lining 49.

In order to properly maintain the metal bar 16 at a uniform temperature at the entrance to the rolling mill 12, it is necessary at times to add heat to the metal bar

16, and at other times to cool the metal bar 16. It is also necessary that any oxide coating that may have formed on the metal bar 16, in the absence of or despite the receiving member 10, during passage from the casting machine 22 to the furnace 11 be reduced or removed from the metal bar 16 before passage into the rolling mill 22.

Heat to raise the temperature of the metal bar 16 is supplied to the furnace 11 by a conventional gas burner 52 positioned within the channel 51 of the furnace 11, said burner having a tubular wall 54 with apertures 55 therethrough to allow reducing a combustible gas mixture to enter the channel 51 for combustion. This reducing mixture reduces any oxide on metal bar 16 as the mixture burns. A supply line 50 communicating with the burner 52 and a supply pump 56 supplies the burner 52 with the reducing combustible mixture. The pump 56 receives the reducing combustible mixture at a constant air-fuel ratio from a metering system 58 such as an industrial carburetor which furnishes a constant air-fuel ratio mixture regardless of the gas supply. By regulating the output of the pump 56, as will be explained later, the amount of mixture entering the burner 52 and therefore the amount of heat produced by the burner 52 can be regulated. Thus, the reducing combustible mixture supplied to the burner 52 by the metering system 58 reduces any oxide on the metal bar 16 as it passes through the furnace 11 so that only the original cast metal of the bar 16 is left after passage through the furnace 11.

In order to impart to the furnace 11 the ability to cool the metal bar 16 while still reducing any oxide coatings on the metal bar 16, a reducing environment comprised of the products of combustion is supplied through a pipe 59 and a manifold 60. The reducing environment is produced in a precombustion chamber 61 external of the furnace 11 and is supplied with a combustible mixture having an air-fuel ratio such that the products of combustion will reduce oxide coatings. This reducing mixture is supplied to the precombustion chamber 61 through a constant air-fuel ratio burner 62 of known type. The reducing combustible mixture is then burned in the chamber 61 and the products of combustion, which are also reducing, are pumped into the furnace 11 by a transfer pump 64 of known type through the pipe 59. A water jacket 66 around the pipe 59 serves to cool the products of combustion as they flow through the pipe 59 to the pump 64. A water pump 68 of known type provides a regulated water supply to the water jacket 66 and a discharge pipe 69 allows the water to be removed from the water jacket 66. The regulation of the amount of flow through the burner 62, the transfer pump 64 and the water pump 68 will be explained in the following discussion on the control system for the furnace 11.

In practice, the reducing atmosphere has been produced by the combustion of an oxygen straved mixture of air and natural gas. Other fuel may, of course, be substituted. The combustion of this rich mixture is, of course, incomplete in the absence of additional oxygen, thus producing a reducing environment. In the present method and apparatus, additional oxygen is supplied by the oxide of the metal which, in supplying the oxygen for more complete oxidation, is reduced to the pure metal.

Referring to FIG. 7, the control system for the furnace 11 of the present invention is seen to comprise a voltage regulator 121, a pressure switch 122 and a temperature limiting switch 120. The voltage regulator 121 is connected to a constant voltage input which is standard line voltage and varies the output voltage therefrom in accordance with the voltage produced by a thermocouple 123 positioned within the channel 51 in the furnace 11; the pressure switch 122 activates the transfer pump motor 64' when the voltage drop across a pressure pickup 124 positioned within the channel 57 of the furnace 11 be-

comes sufficiently great; and the temperature limiting switch 120 starts or stops the supply pump motor 56', the burner motor 62', transfer pump motor 64' and the water pump motor 68' in accordance with the voltage output from a thermocouple 125 as will be explained later. The thermocouples 123 and 125 are the voltage sources of radiation pyrometers of known type and are positioned so that the temperature of the metal bar 16 is indicated just as it enters the furnace 11. If the temperature of the metal bar 16 is below a certain predetermined temperature, then the voltage output from the thermocouple 125 activates the supply pump motor 56' through the switch 120. The pump 56 then supplies a reducing combustible mixture to the burner 52 in accordance with the voltage output from the voltage regulator 121, an increase in fuel being supplied varying inversely with an increase in the temperature of the bar 16. The voltage output from the voltage regulator 121 is regulated by the voltage output from the thermocouple 123 and, if the temperature of the metal bar 16 is above the predetermined temperature, the voltage from the thermocouple 125 causes the switch 120 to turn the supply pump motor 56' off, thereby stopping combustion within the furnace 11 due to fuel starvation.

If the temperature of the metal bar 16 is above the predetermined temperature, the voltage output from the thermocouple 125 activates the burner 62, the water pump 68 and the transfer pump 64 through the switch 120. The voltage output from the thermocouple 123, through the voltage regulator 121, controls the speed of the constant air-fuel ratio burner motor 62' in order to control the burning rate in the burner 62, the water pump motor 58' in order to control the flow of water through the water jacket 66 and the transfer pump motor 64' to control the rate of flow of the gases of combustion from the precombustion chamber 61 into the furnace 11. The flow of water through the water jacket 66 cools the gases of combustion sufficiently so that they will cool the bar 16 to the predetermined temperature before reaching the rolling mill 12. Therefore, the higher the temperature of the metal bar 16, the more flow of water that is produced by the pump 68 in order to cool the metal bar 16 to the predetermined temperature. If the temperature of the metal bar 16 drops below a predetermined temperature, the voltage output from the thermocouple 125, through the limiting switch 120, turns off the motors 62', 68' and 64'. In case of failure of one of the pumps 56' or 62', a voltage from the pressure pickup 124 activates the transfer pump motor 64' to clear the furnace 11 of combustible gases that may result in an explosion if allowed to remain in the channel 51.

The furnace 11, then, supplies heat to the metal bar 16 by burning a combustible mixture supplied to the channel 51 by the burner 52 that produces a reducing environment in the channel 51 around the metal bar 16 if the metal bar 16 is below the predetermined temperature and in addition reduces any oxidation that may be present on the metal bar 16. Furthermore, the furnace 11 supplies cooled gases to the channel 51 if the metal bar 16 is above the predetermined temperature that not only cool the metal bar to the predetermined temperature but also reduce any oxide coating that may be present on the metal bar 16. Moreover, the furnace 11 may be used to present an oxide free metal bar 16 to the rolling mill 12 at a predetermined temperature to the exclusion of the receiving member 10 if a sufficient amount of reducing gases is introduced into the channel 51. This requires the use of an uneconomical amount of fuel, however, resulting in a need for the transfer member 10.

In order to remove any flash material from the corners of the metal bar 16, a plurality of flame scarfers 131 are provided within the furnace 11. The flame scarfers 131 comprise a plurality of nozzles 132 protruding through the side wall 46 and refractory lining 49 of the furnace 11, a plurality of mixture supply pipes 133 communicat-

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ing with the nozzles 132, a manifold 134 which distributes a combustible mixture to the pipes 133, and a valve 135 in the manifold 134 which regulates the flow of mixture to the nozzles 132. The nozzles 132 are positioned so that the jet of flame from the nozzle 132 is directed against the corners of the metal bar 16 and burn the flash metal away.

A pair of pinch rolls 70 enclosed within a metal tube 71 extending between the end plate 48 and an end panel 72 of the rolling mill 12 receive the metal bar 16 as it exits the furnace 11 through the opening 42 in the end plate 48 and guide it through the passage 74 in the end panel 72 to the rolling mill 12. The metal tube 71 serves to prevent any contact of the heated metal bar 16 with the environment outside the present apparatus and provides support for the pinch rolls 70.

The rolling mill 12 shown in FIG. 1A is of generally conventional type with a cover 14 installed thereon to allow a slight fluid pressure to be exerted on the inside thereof. The cover 14 comprises a plurality of L-shaped hoods 75 extending out and over the roll stands 76 of the rolling mill 12 and seated at their ends against the base of L-shaped transmission housing 78 of the rolling mill 12, and end panels 72 at the entrance end 80 and the exit end 81 of the rolling mill 12. The hoods 75 are hinged, as at 79, at their upper ends to the top of the housing 78 as seen in FIG. 2 and have handles 32 adjacent their lower ends so that each hood 75 can be easily raised by hand in order to work on the roll stands 76. The hoods 75 are mounted adjacent each other so that there is very little opening between their edges 84, thus permitting little flow of environmental gases to or from the inside of the cover 14. The end panels 72 are mounted on the transmission housing 78 so that they communicate with the hoods 75 to form a substantially closed chamber 85 through which the metal bar 16 passes. The passages 74 in the end panels 72 allow the metal bar 16 to enter the rolling mill 12, be rolled in the rolling mill 12, and exit from the rolling mill 12 as rod 86.

A lubricating coolant manifold 88 extends along the length of the rolling mill 12 above the roll stands 76 as viewed in FIGS. 1A and 2 and serves to distribute a lubricating coolant to the rolls 89 of the rolling mill 12 and the metal bar 16 through nozzles 92 as the bar 16 passes through the rolling mill 12. The coolant is supplied to the manifold 88 by a pipe 90 having a valve 91 interposed therein to regulate the flow of coolant through the manifold 88 and the nozzles 92. A low pressure is created within the chamber 85 by the vaporization of the coolant by the heat of the metal bar 16 and the rolls 89. However, a manifold 94 having a plurality of nozzles 95 spaced therealong allows a reducing mixture, as above referred to, to be introduced under pressure into the chamber 85, thus producing an even greater differential between the pressure in the chamber 85 and the pressure of the outside atmosphere. A supply pipe 96 having a flow rate control valve 98 delivers the reducing mixture to the manifold 94 in regulated amounts. Thus, no external atmosphere is permitted to enter the chamber 85 within the hoods 75.

Referring to FIGS. 8 and 9, the second embodiment of the rolling mill 12 shown in FIG. 1A is seen to comprise a rolling mill 12' wherein the metal bar 16 is received from the furnace 11 by a transfer tube 71'. The metal bar 16' is then rolled in the rolling mill 12' in the usual manner with the metal bar 16 being transferred between roll stands 76' through additional transfer tubes 71'. The flow of coolant is provided by a coolant manifold 88' having a plurality of nozzles 92' therealong, a supply pipe 90', and a valve 91'. The flow of coolant from the nozzles 92' is sufficient to envelope the bar 16 as it is being rolled so as to preclude the outside environment from contacting and oxidizing the metal bar 16 as it is being rolled. Heat from the roll stands 76' and the metal bar 16 causes the coolant to be oxidized during the

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rolling of the bar 16 which, in turn, reduces any oxides that might be present on the metal bar 16.

As the rolled rod 86 leaves the rolling mill 12, it is received by a cooling tube 99 having three segments 99a, 99b and 99c, each having a passage 98 therethrough. The first segment 99a communicates with the chamber 85 through the passage 74 in the end panel 72 at one end and with a catch basin 100 at its other end. The catch basin 100 is a hollow rectangular member provided with a drain pipe 101 at its lower end for draining any fluid caught in the catch basin 100. The second segment 99b of the cooling tube 99 communicates with the catch basin 100 opposite from the first segment 99a so that the passage 98 in the first segment 99a and the passage 98 of the second segment 99b are collinear. A trumpet shaped entrance to the passage 98 in the second segment 99b facilitates the entrance of the rod 86 into the second segment 99b.

The extending end of the second segment 99b communicates with an injection block 105 having a central passageway 106 therethrough. An annular recess 108 in the block 105 communicates with the passageway 106 and a plurality of coolant inlet pipes 107 for supplying coolant to the annular recess 108. A conical recess 110 extends from the annular recess 108, along the central passageway 106 towards the second segment 99b. Threadedly inserted into the block 105 and extending into the conical recess 110 is a metering pin 111 which has a tapered end 112 corresponding to the conical recess 110. A central channel 113 through the metering pin 111 is aligned with the central passageway 106 so that the rod 86 may pass therethrough.

Adjusting the metering pin 111 so that the tapered end 112 extends into the conical recess 110 regulates the amount of coolant allowed to flow along the recess 110 into the central passageway 106 from the annular recess 108. Thus, the flow velocity of coolant into and along the central passageway 106 and along the passageway 98 of the second segment 99b toward the rolling mill 12 is regulated by turning the metering pin 111 within the block 105. Decreasing the spacing between the recess 110 and the end 112 of the metering pin 111 increases the velocity of the flow of coolant into the central passageway 106, and increasing the spacing between the recess 110 and the metering pin 111 decreases the velocity of the flow of coolant into the central passageway 106. The coolant flows along the passageway 98 of the segment 99b and into the catch basin 100 where it is removed. The coolant within the cooling tube 99 is oxidized by the heat of the metal rod 86 thereby producing a reducing atmosphere which reduces any minute oxide coatings that may have reformed on the metal rod 86 subsequent to rolling.

Another catch basin 100' similar to the catch basin 100 is attached to the opposite end of the block 105 and communicates at its opposite side with an air wipe block 116. The opposite end of the metering pin 111 has a tapered shoulder 114 thereon which extends into a conical recess 115 of the air-wipe block 116. The air-wipe block 116 has a plurality of angularly disposed ports 118 therein communicating with a rod passageway 119 through the block 116 at their one end and a plurality of air supply tubes 120 at their other end. The ports 118 are positioned so that air or some other similar gas flowing from the supply tubes 12 through the ports 118 is directed along the passageway between the shoulder 114 on the metering pin 111 and the conical recess 115 and against the rod 86 so that any coolant remaining on the rod 86 is removed. Therefore, any coolant on the rod 86 as it leaves the central channel 113 through the metering pin 111 is blown away from the rod 86 and into the catch basin 100 by the fluid flowing from the ports 118 and along the passage between the metering pins 111 and the recess 115.

The rod 86 then enters the third segment 99c of the cooling tube 99 cooled below its oxidation temperature. The rod 86 also possesses desired hot rolled characteristics

due to the temperature control and is therefore ready for subsequent drawing, coiling, or storing operations in an unoxidized condition.

Operation

In operation, the metal bar 16 enters the channel 25 of the extraction chamber 19 from the casting wheel 22 where it is immediately enveloped by an inert or reducing environment flowing oppositely along the channel 25 to the direction of motion of the metal bar 16. Thus, the metal bar 16 is not subjected to environmental conditions which tend to oxidize the metal bar 16 as it is extracted from the casting wheel 22 of the casting machine 18 and/or with a reducing medium scale which may be formed on the bar during casting will be reduced. It is also understood that the extraction chamber 19 may be easily modified to receive the metal bar 16 as it is cast by other types of casting machines known in the art and thereby prevent oxidation of the metal bar 16 as it is delivered from such other types of casting machines.

The metal bar 16 passes along the extraction chamber 19, through the flexible connector 21 and into the transfer chamber 20 where it is grasped by the rolls 38, all the while being enveloped by the inert or reducing environment supplied by the pipe 44 to the transfer chamber 20. The metal bar 16, after leaving the rolls 38, passes along the transfer chamber 20 on the support rolls 39, is received by the pinch rolls 40 and aligned for entrance into the temperature control furnace 11. Radiant heat loss from the bar 16 is substantially prevented during the passage of the bar 16 through the transfer chamber 20 by the insulation 34 on the inside of the transfer chamber 19. Thus, both oxidation and radiant heat loss from the bar 16 are substantially prevented during the passage of the metal bar 16 through the receiving member 19 by the inert or reducing environment and the covering 34.

The metal bar 16 enters the furnace 11 where it is heated or cooled until the predetermined hot working temperature is reached, and the flash metal on the edges thereof is removed by the scarfers 131. The thermocouples 123 positioned at the entrance of the furnace 11 sense the temperature of the metal bar 16 as it enters the furnace 11 and transmits an electrical signal to the voltage supply 121 which regulates the voltage to the motors 62', 64', 56' and 68' in accordance with the temperature of the bar 16. The temperature limiting switch 120 activates the motors 62', 64' and 68', while stopping the motor 56' if the temperature of the metal bar 16 is above the predetermined temperature and activates the motor 56', while stopping the motors 62', 64' and 68' if the temperature of the metal bar 16 is below the predetermined temperature. Thus, the temperature of the metal bar 16 is automatically regulated as it passes through the furnace 11. Also, any oxidation that may have formed on the metal bar 16 is quickly and effectively reduced so that the bar 16 enters the rolling mill 12 via the pinch rolls 70 in an oxide free state, thereby alleviating the problems encountered when the rolling is performed on oxide coated bars. The furnace 11 is capable of reducing the oxide coating on the metal bar 16 even if no oxidation prevention is provided by a means between the casting machine 22 and the furnace 11 if large quantities of fuel are added to the furnace 11, although this is uneconomical and is only used if a failure develops in the receiving member 19.

The metal bar 16 is aligned by the pinch rolls 70 and enters the rolling mill 12 for rolling. The bar 16 is then rolled into rod 86 by the rolls 89 while coolant is supplied by the nozzles 92 to maintain the temperature of the metal bar 16 at the proper rolling temperature during the rolling operation. The coolant is partially oxidized by the heat from the metal bar 16 and the rolls 89 and creates a slight pressure differential across the cover 14. Thus, oxidation of the metal bar 16 is prevented. Moreover the pressure within the chamber 85 can be supplemented by the reducing environment introduced under

pressure by the nozzles 95. Since the burning of the coolant produces a reducing environment in the vicinity of the surface of the metal bar 16, this prevents the formation of oxide coatings while the bar 16 is being rolled and also reduces minor oxidation that may be encountered on the surface of the bar 16.

The rod 86 leaves the rolling mill 12 at an elevated temperature and passes into the cooling tube 99 wherein an environment which is reducing envelopes the rod 86 and cools it below its minimum oxidation temperature. The coolant flows from the recess 108 along the space between the recess 110 and the metering pin 111 and envelopes the rod 86 as it flows along the central passageway 106 and the passageway 98 oppositely to the motion of the rod 86 to the catch basin 100 where it is removed.

The rod 86 extends past the air-wipe block 116 wherein the air blast from the ports 118 removes any of the coolant remaining on the rod 86. The rod 86 is then ready for subsequent coiling or drawing operations without danger of oxidation.

In using the second embodiment of the present invention, all of the apparatus for the process is the same except the rolling mill 12' in place of the rolling mill 12. The rolling mill 12' receives the cast bar 16 from the furnace 11, rolls the bar 16 into rod 86 while enveloping the bar 16 and rod 86 with a reducing environment supplied by the burned coolant from the manifold 88 and nozzles 92 and discharges the rod 86 into the cooling tube 99 for cooling in the aforementioned manner.

The rod 86, then, is received from the third segment 99c of the cooling tube 99 in an oxide free state and possessing the desired hot rolled characteristics as to strength, ductility and conductivity as a result of proper temperature control supplied by the present invention.

It will be obvious to those skilled in the art that many variations and applications may be made in the embodiments chosen for the purpose of illustrating the present invention without departing from the scope thereof as defined by the appended claims.

What is claimed as invention is:

1. A method of producing a hot-formed product comprising casting molten metal to obtain cast metal, hot working said cast metal into a hot-formed product, and substantially enclosing said cast metal in an oxide reducing environment during said hot working.

2. The method of claim 1 including adjusting the temperature of said cast metal between said casting and said hot-working.

3. The method of claim 1 including substantially enclosing said cast metal in a non-oxidizing environment between said casting and said hot-working.

4. The method of claim 1 including passing said cast metal through an oxide-reducing environment between said casting and said hot-working.

5. The method of claim 1 including cooling said hot-formed product substantially immediately subsequent to said hot-working.

6. The method of claim 1 including cooling said hot-formed product in a non-oxidizing environment substantially immediately subsequent to said hot-working.

7. The method of claim 1 including conveying said cast metal from a means for said casting directly to a means for said hot-working.

8. The method of claim 1 including passing said cast metal through an oxide reducing environment between said casting and said hot-working, and cooling said hot-formed product in an oxide-reducing environment substantially immediately subsequent to said hot-working.

9. A method of producing a hot-formed product comprising casting molten metal to obtain cast metal, passing said cast metal through an oxide-reducing environment to a means for hot-working said cast metal, and hot-working said cast metal into a hot-formed product in said means for hot-working.

10. The method of claim 9 including substantially

11

enclosing said cast metal in a non-oxidizing environment
during said hot-working.

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