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METHOD AND APPARATUS FOR ACCRETING MOLTEN COPPER ON A MOVING MEMBER

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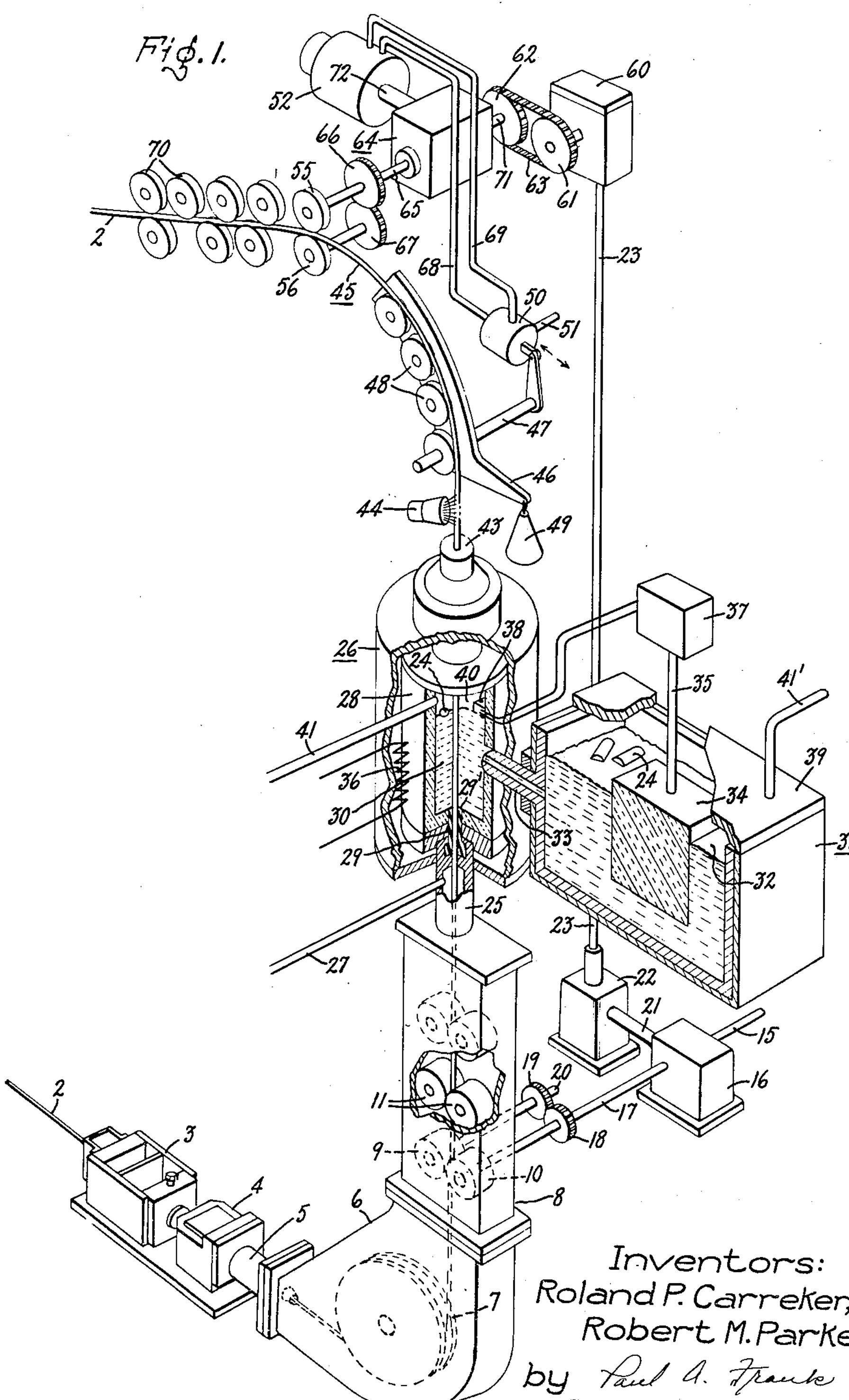

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METHOD AND APPARATUS FOR ACCRETING MOLTEN COPPER ON A MOVING MEMBER

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This invention relates to a method and apparatus for accreting molten copper on a moving member, and more particularly, to a method and apparatus wherein molten copper accretes on, and is bonded to, a moving member.

A large portion of the cost of manufacturing stock materials such as rod, tube and sheet is incurred in the manufacture of the primary and intermediate forms of material from which the stock material is ultimately manufactured. In the manufacture of wire stock from copper, special equipment such as melting furnaces, large casting apparatus, reheating furnaces, roll equipment, pickling equipment, etc., are utilized to produce intermediate core wire stock which is drawn into wire or other shapes.

An apparatus and a method for continuously depositing by accretion, molten material upon an elongated body having a first cross-sectional configuration of a material having substantially the same composition as the molten material whereby there is formed an elongated body having a second cross-sectional area greater than the first, are disclosed in and said apparatus is claimed in U.S. Patent No. 3,008,201, which issued from copending application of Roland P. Carreker, Jr., Serial No. 530,283, filed August 24, 1955. The method is claimed in copending application of Roland P. Carreker, Jr., Serial No. 98,087, filed March 24, 1961, as a continuation-in-part of said application Serial No. 530,283 and assigned to the assignee of said patent and of the present invention. By this means, the intermediate steps of reheating, rolling, pickling, etc., are avoided to achieve lower production costs based on the lower equipment costs and lower operating costs.

In practicing the teaching of the Carreker application, the problem of gas contamination may manifest itself in the creation of a product wherein the accreted material may not be bonded to the core material and the outer surface of the accreted material may be undulating in shape and also may be affected by the presence of cracks and fissures. The presence of contaminant gases, either as a precipitated gas or in combined form with the material to be accreted, affects the heat exchange between the core material and the molten material which causes these irregularities and also harmfully influences the bond between the accreted material and the core material.

Contaminant gases may originate from the core member upon which the accretion occurs or as an impurity in the material to be accreted. In the case of the impurity originating in the core member, this may be as surface dirt such as grease or as a gas which is introduced by viscous friction of the moving surface of the member into the crucible wherein accretion takes place. When these impurities enter the crucible, the liquid and solid impurities are vaporized creating expanding gases. Gaseous impurities on the surface of the core member are similarly expanded by the high temperature. In the case of gaseous impurities in the copper melt which is to be accreted on the core member, the present invention recognizes that the gas contaminant is usually oxygen. It is further recognized that in the event the copper being accreted on the core member has an oxygen content of greater than approximately 20 parts per million, precipitation of the gas occurs at the time of accretion harmfully affecting the product. Gases appearing in the area of accretion tend to harmfully affect the heat exchange between the molten material and core member. Also, the oxygen may combine with the molten material to form copper oxide which harmfully affects the heat exchange process during accretion forming an unsuitable product. Such erratic or uneven heat exchange may cause uneven accretion of material thereby providing an undulating surface on the product and also affecting the bond between the molten material and the core member. The term "bond" as utilized herein denotes sufficient cohesion to permit reduction of cross-section of the product, for example, by drawing, without severing the connection between the core material and the accreted material.

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The chief object of the present invention is to provide an improved method and apparatus for continuously accreting molten copper on a moving member to form a substantially uniform product wherein the accreted material is substantially bonded to the core member.

Another object of the invention is to provide an improved method and apparatus for accreting molten copper on a moving core member wherein sources of gas contaminants are removed from the core member and molten copper at the time of accretion to provide a uniform product having the accreted material substantially bonded to the core member.

These and other objects of our invention will be more fully described hereinafter.

Briefly stated, the present invention relates to a method and apparatus wherein a moving core rod is substantially cleaned and degassed before being introduced through a nozzle located in a lower portion of a crucible containing molten copper, the oxygen content of the molten copper which is accreted onto the core member being maintained less than approximately 20 parts per million whereby the accreted material is substantially bonded to the core member. The term "rod" as used herein denoted elongated bodies which may have various cross-sections being either solid or hollow.

The attached drawing illustrates a preferred embodiment of the invention in which:

FIGURE 1 is a perspective view partially in section of an apparatus for practicing the present invention.

In FIGURE 1 there is shown an apparatus for practicing the invention in which core rod **2** is supplied to a drawing apparatus **3** located adjacent a suitable shaving apparatus **4**. The dies of apparatus **3** may support the rod as it is introduced into a shaving cutter which removes a thin layer of metal from around the entire periphery of the rod to remove the oxide coating or other surface contaminants therefrom and also to be in sufficiently intimate contact therewith to form a seal between the shaving cutter and the rod. The construction and manner of operation of drawing apparatus **3** and shaving apparatus **4** are more fully described in the copending application of J. A. Russell and G. Carlson, Serial No. 55,470, filed Sept. 20, 1960, and entitled, "Method and Apparatus for Accreting Molten Material on a Moving Member." If desired, other cleaning means such as the chemical cleaning means may be utilized for removing the oxide coating and other contaminants from the surface of the rod.

Core rod **2** having been cleaned enters into a passage partially defined by tube **5**. This passage, which is maintained in an evacuated condition by the previously mentioned seal between the shaving cutter and the rod, is provided to assure that the surface of the rod is free from oxidation when the accretion process occurs. The rod passes into idler pulley housing **6** which has located therein a rotatably mounted pulley **7** which changes the direction of rod **2** permitting it to pass into housing **8** wherein is located suitable drive means for urging the rod through the evacuated passage defined by tube **5**, housings **6** and **8** and tube **25**. This drive means which includes drive rolls **9** and **10** is located in the evacuated passage because rod drawing apparatus **3** and rod shaving apparatus **4** require that the rod be pulled therethrough.

Rotative motion is applied to the drive rolls by suitable drive means (not shown) connected to shaft **15** extending from gear reducer **16**. One output from gear reducer **16** is shaft **17** which is connected to pulley **10**. Pulley **9** is mounted upon shaft **20** and is conected by means of gears **18** and **19** to shaft **17**. By this means pulleys **9** and **10** rotate in opposite directions to urge rod **2** in an upward direction. Suitable shaft seals (not shown) may be provided around shafts **17** and **19** to maintain the evacuated condition of the passage.

Gear reducer **16** has a second output shaft **21** connected to gear box **22** having an output shaft **23** which is connected to a second drive means more fully described hereinafter.

A plurality of pulleys **11** which engage the rod to perform a supporting and straightening function before the rod is introduced into crucible **26** are located in housing **8**. The rod passes from housing **8** into tube **25** which may have connected thereto an exhaust tube **27** being in communication with a suitable pump to maintain a vacuum in a passage defined by members **5**, **6**, **8**, and **25**. Nozzle **29** which extends into crucible **26** is mounted at the upper end of tube **25** and performs the function of supplying rod **2** into crucible **26**. At the discharge end **29'** of nozzle **29**, core rod **2** comes into contact with molten copper in a manner wherein the copper accretes onto the rod in a manner more fully described hereinafter.

The molten copper which is supplied to crucible **26** is provided by furnace **31** which may be heated by suitable heating means such as electric induction heaters (not shown). The material supplied to furnace **31** preferably is copper of low oxygen content such as cathode copper. If copper is supplied having greater than approximately 20 parts per million of oxygen, reducing means must be utilized to lower the oxygen content of the copper. The reducing means may be located in either furnace **31** or crucible **26** or in both. The reducing means may take the form of materials placed in intimate contact with the molten copper which unite with the oxygen therein forming a gaseous product which is precipitated from the molten copper. Preferably the reducing means is a form of carbon, such as graphite, or in the event that low conductivity copper is being produced, phosphorous may be utilized. In the present embodiment the furnace lining may be of graphite and substantial amounts of graphite or charcoal particles **24** may be floated in the melt, this graphite uniting with the oxygen to reduce the content to less than approximately 20 parts per million. While melting the copper in furnace **31** the furnace preferably is enclosed by cover **39** and the surface of the melt preferably is covered with a blanket of inert gas such as nitrogen supplied through line **41'**.

The molten copper is supplied to crucible **26** by means of a spout **33** which extends into liner **28** of crucible **26**. The level in liner **28** may be sensed by a suitable control means **38** which may also incorporate therein means to sense the temperature in the crucible. Control means **38** regulates servo motor **37** which is connected by means of rod **35** to a graphite piece **34**. The size of graphite piece **34** is such that movement thereof in the body of molten material **32** in furnace **31** controls the level and the rate of supply of material into liner **28**. Before initiation of the accretion process, this piece of graphite **34** is substantially removed from the body of material **32**. When it is desired to supply molten material into the crucible, the graphite piece may be immersed into the copper melt **32** by servo motor **37** in response to control means **38**. The manner of initiating and terminating the accretion process is more fully described in the copending application of H. H. Bixler, Serial No. 55,471, filed Sept. 12, 1960, and entitled, "Method and Apparatus for Accreting Molten Material."

Crucible **26** includes a liner **28** adapted to contain molten material **30** and which preferably is fabricated of graphite. Particles of graphite **24** may also be floated on the surface of the melt to unite with any oxygen in the melt to maintain or achieve lower oxygen content. To prevent further oxidation of the molten copper, an inert gas, such as nitrogen, may be supplied through line **41** to maintain an inert gas atmosphere above the melt.

As previously noted, rod **2** which is supplied into the crucible has been cleaned by apparatus **4**, passed into an evacuated passage which not only maintains the surface of the rod remote from an oxidizing atmosphere but acts to remove any gases which may have been introduced into the passage by viscous friction of the moving rod so that the rod supplied nozzle **29** is substantially clean and substantially degassed.

The copper introduced adjacent the rod at the discharge end of the nozzle **29** is of a low oxygen content. In the event the copper supplied to furnace **31** is of low oxygen content, for example, lower than approximately 20 parts per million and preferably between 4 and 10 parts per million, the reducing agents and the inert atmosphere above the melt maintain the low oxygen content by preventing oxidation which may occur due to leakage. In the event that the oxygen content of the copper supplied to furnace **31** is of a higher oxygen content, the reducing agents in furnace **31** and also in crucible **26** act to reduce the oxygen content so that at the point of accretion the oxygen content is within tolerable limits so that substantially no gases are precipitated during solidification of the copper.

It has been found that to achieve proper accretion without deterioration of rod **2** and also to avoid backflow of copper into the clearance between rod **2** and nozzle **29** the speed of rod **2** should exceed a predetermined value depending upon the physical characteristics of the apparatus. The rod passes through the melt in the crucible extracting heat from the molten material which accretes or solidifies thereon causing the rod to increase in diameter and also causing the thermal expansion thereof. At discharge end **29'** of nozzle **29**, hydraulic pressure of the molten copper in the crucible urges the molten copper to pass into the clearance between the nozzle and rod. However, due to combined effect of rod speed with the continuous solidification of molten copper there is no counter-flow of molten copper into the nozzle to the extent of impeding the operation.

The rod, as molten material accretes thereon, becomes greater in diameter and finally passes through the inert gas blanket located above the melt and is discharged from the crucible through nozzle **43**. If desired, suitable cooling means **41**, such as spray nozzles, may be utilized to cool the highly heated rod as it leaves the crucible.

The rod emerging from the crucible is in a highly heated state and is extremely fragile. In order to prevent rupture of the rod a suitable shock isolation loop **45** may be provided. This construction may change the direction of the rod through an angle greater than 90° Shock isolation loop construction **45** comprises a suitable arm **46** which pivots about a shaft **47**. The arm has located thereon a plurality of pulleys **48** which because of counter weight **49** located on an extension of arm **46** causes a bias on the rod. The reaction of the moving rod causes rotation of arm **46** in a manner whereby valve **50** is actuated. Pneumatic valve **50** is connected by means of line **51** to a suitable source of pneumatic pressure and is adapted to control an air motor **52** associated with second drive means for driving the rod from the isolation loop in a manner more fully described hereinafter.

As previously mentioned, the rod emerging from the crucible is of an increased cross-sectional area because of the accretion of metal thereon. Because of thermal expansion, the rod length is substantilly increased and compensating means must be incorporated in the driving means for removing the rod from the discharge side of the crucible. The previously described arm **46** with its connection to valve **50** comprises a sensing means associated with drive rolls **55** and **56** located adjacent the shock isolation loop. Power is supplied to drive rolls **55** and **56** through the previously described shaft **23** which is associated with the first drive means including drive rolls **9** and **10**. Rotation of shaft **23** is transmitted through gear box **60**, through pulleys **61** and **62** which are connected by a suitable belt **63**. Pulley **62** is mounted on driving shaft **71** which drives differential mechanism **64**. The output of differential mechanism **64** is connected to shaft **65** upon which is mounted pulley **55**. Drive roll **56** is driven by shaft **65** through gears **66** and **67**. In order to vary the speed of drive rolls **55** and **56**, air motor **52** is associated with differential mechanism **64** through driving shaft **72**. The speed of air motor **52** is controlled by the previously mentioned valve **50** connected to the air motor by means of lines **68** and **69**. Manipulation of valve **50** causes rotation of shaft **72** in either direction to control the speed of drive rolls **55** and **56**. The nature of this differential mechanism is more fully described in the previously mentioned copending application of Russell and Carlson. For purposes of support, a plurality of pulleys **70** are provided adjacent drive rolls **55** and **56**.

In the operation of the apparatus shown in FIGURE 1, a continuous rod **2** is introduced into drawing apparatus **3** and into shaving apparatus **4** wherein the surface of the rod has the oxide coating or other material removed from the surface thereof, the intimate contact of the cutter with the rod forming a seal between the atmosphere and the evacuated passage starting at tube **5** and terminating at tube **25**. The rod passes through tube **5** which is in sealing engagement with shaving apparatus **4** and housing **6**. The rod passes through housing **6** round pulley **7** and is engaged by drive rolls **9** and **10** in housing **8**. These pulleys urge the rod up through housing **8** and also pull the rod through the drawing and shaving operations previously described. As the rod passes through housing **8** it is supported by suitable pulleys **11**. The rod enters tube **25** and into nozzle **29** having the surface thereof clean and substantially degassed.

As the rod enters the crucible filled to a predetermined level with molten material **30**, it has accreted progressively thereon a layer of molten copper thus forming a rod of greater diameter wherein the molten material is substantially bonded to the core member. This bonding is achieved because the rod introduced into the crucible is substantially free of all gas, solid and liquid contaminants which at elevated temperatures could vaporize to harmfully affect the accretion process. Further, because of the furnace and crucible construction utilizing an inert gas blanket and utilizing reducing agents such as graphite or phosphorous, the oxygen content of the molten copper supplied at the point of accretion is sufficiently low so that substantially no gas is precipitated at the time the liquid copper solidifies. Rod **2** passes through nozzle **43** and is dicharged from the crucible. If desired, suitable cooling means **44**, such as spray nozzles, may be employed to lower the temperature of the rod.

The rod encounters shock isolation loop **45** which because of the bias of counter weight **49** urges pulleys **48** mounted on the arm to engage the high temperature rod whose length has been increased by thermal expansion and whose cross-sectional area has been increased by accretion. Opposing the bias of counter weight **49** is the driving effect of drive rolls **55** and **56** which attempt to remove the rod as it is discharged from the crucible. Because of the fragile nature of the rod at this point, the driving speed of drive rolls **55** and **56** is varied in response to the force applied to pulleys **48** by the rod in the shock isolation loop. Movement of the pulleys causes rotation of shaft **47** which controls valve **50**. Air from valve **50** passes through lines **68** and **69** which varies the speed and direction of rotation of output shaft **72** of motor **52**.

As previously noted rotational motion is transmitted from shaft **15** through shaft **23**, gear box **60**, and pulleys **61** and **62** to driving shaft **71** of differential mechanism **64**. If air motor **50** is not in operation there may be no increase or decrease in the rotational speed of driven shaft **65** over the speed of driving shaft **71**. Passage of air through either line **68** or **69** determines the direction of rotation of air motor **52**. The direction of rotation of output shaft **72** of air motor **52** determines whether the speed of drive rolls **55** and **56** is less or greater than the speed of the drive rolls **9** and **10**. The rod is guided through pulleys **70** to a suitable storage area from whence the rod is directed to other drawing apparatus as desired.

The present invention provides a method and apparatus for continuously accreting molten copper on a moving core rod to form a product wherein the accreted material is substantially bonded to said core rod. This is achieved by providing means for substantially cleaning and degassing the surface of the core rod supplied to the crucible and further substantially reducing the oxygen content of the molten copper accreted on the core rod to less than 20 parts per million. It will be appreciated that the core rod may be copper or other metal such, as nickel or steel, upon which it is desired to accrete copper.

While we have described a preferred embodiment of the invention it will be understood that the invention is not limited thereto since it may be otherwise embodied within the scope of the appended claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a method for accreting molten copper on a continuously moving core rod the steps which consist in cleaning the surface of the core rod, passing the core rod from the atmosphere into an evacuated passage, introducing the moving core rod from the evacuated passage into a nozzle located in the lower portion of a crucible containing molten copper, passing the core rod through said molten copper, supplying molten copper containing less than approximately 20 parts per million of graphite-removable oxygen adjacent the core rod to accrete molten copper on the moving core rod to form a rod having a greater thickness, said accreted copper being substantially bonded to said core rod.

2. In a method for accreting molten copper on a continuously moving core rod the steps which consist in cleaning the surface of the core rod, substantially degassing the surface of the core rod, introducing the moving degassed core rod into a nozzle located in the lower portion of a crucible containing molten copper, passing the core rod through said molten copper, supplying molten copper containing less than approximately 20 parts per million of graphite-removable oxygen adjacent the core rod to accrete molten copper on the moving core rod and supplying an inert atmosphere above the molten material in the crucible to maintain the low oxygen content of the copper in the crucible, to form a rod having a greater thickness, said accreted copper being substantially bonded to the core rod.

3. The method of continuously casting copper rod which comprises the steps of heating and melting copper to provide a molten mass of copper for contact with an elongated core rod as a continuous casting substrate body, reducing the graphite-removable oxygen content of the resulting copper melt to less than approximately 20 parts per million, and then running core rod through the copper melt and continuously accreting copper on the core rod while maintaining the graphite-re-

movable oxygen content of the said melt at less than approximately 20 parts per million.

4. In an apparatus for accreting molten copper on a continuously moving core rod the combination of means for cleaning the surface of the core rod, means defining an evacuated passage, a crucible, nozzle means located in the lower portion of said crucible connected to said evacuated passage and being adapted to introduce the core rod into the crucible, means for passing the core rod from the atmosphere through said evacuated passage and into said crucible, means for supplying to the crucible molten copper having a graphite-removable oxygen content less than 20 parts per million, means for maintaining the graphite-removable oxygen content of the molten copper in the crucible less than approximately 20 parts per million, the molten copper accreting on the moving core rod to form a rod having greater thickness, said accreted copper being substantially bonded to said core rod.

5. In an apparatus for accreting molten copper on a continuously moving core rod the combination of means for cleaning the surface of the core rod, means defining an evacuated passage, a crucible, nozzle means located in the lower portion of said crucible connected to said evacuated passage and being adapted to introduce the core rod into the crucible, means for passing the core rod from the atmosphere through said evacuated passage and into said crucible, means including a furnace vessel for supplying molten copper to the crucible, means comprising carbonaceous bodies in the furnace vessel for reaction with oxygen in molten copper to be delivered to the crucible, means for maintaining an inert atmosphere above the molten copper in the crucible and reducing means located in said crucible for maintaining the graphite-removable oxygen content of the molten copper less than approximately 20 parts per million, the molten copper accreting on the moving core rod to form a rod having greater thickness, said accreted copper being substantially bonded to said core rod.

6. In an apparatus for accreting molten copper on a continuously moving core rod the combination of means for cleaning the surface of the core rod, means defining

an evacuated passage, a crucible, nozzle means located in the lower portion of said crucible connected to said evacuated passage and being adapted to introduce the core rod into the crucible, means for passing the core rod from the atmosphere through said evacuated passage and into said crucible, means for supplying molten copper into said crucible and means to reduce the graphite-removable oxygen content of the molten copper to less than approximately 20 parts per million prior to its introduction into the crucible, the molten copper accreting on the moving core rod to form a rod having greater thickness, said accreted copper being substantially bonded to said core rod.

7. In an apparatus for accreting molten copper on a continuously moving core rod the combination of means for cleaning the surface of the core rod, means defining an evacuated passage, a crucible, nozzle means located in the lower portion of said crucible connected to said evacuated passage and being adapted to introduce the core rod into the crucible, means for passing the core rod from the atmosphere through said evacuated passage and into said crucible, means including a furnace vessel for supplying molten copper to the crucible, means comprising graphite bodies in the furnace vessel for reaction with oxygen in molten copper to be delivered to the crucible means for maintaining an inert atmosphere above the molten copper in the crucible and graphite means located in said crucible for maintaining the oxygen content of the molten copper less than approximately 20 parts per million, the molten copper accreting on the moving core rod to form a rod having greater thickness, said accreted copper being substantially bonded to said core rod.

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