

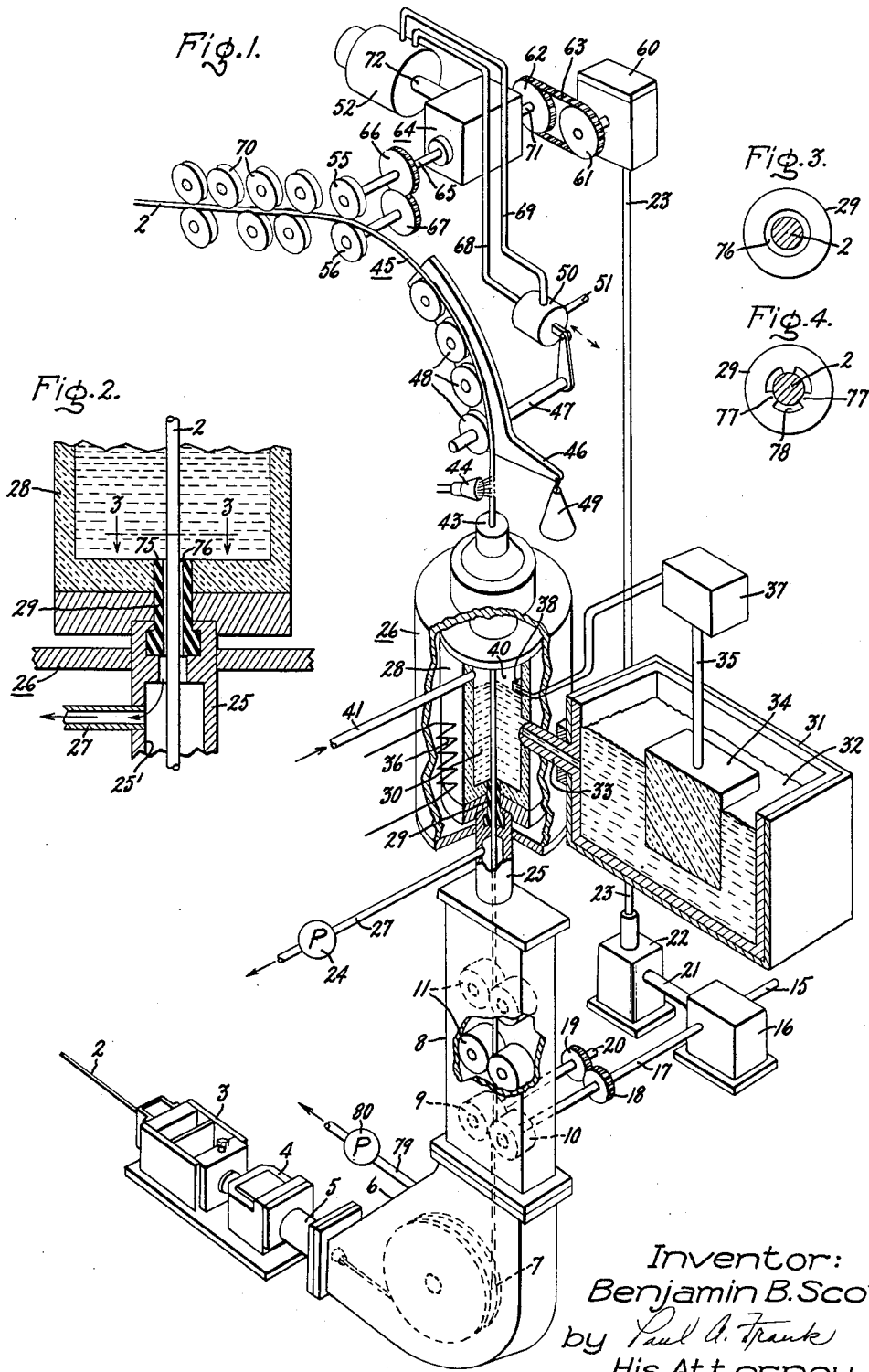
Oct. 23, 1962

B. B. SCOTT

3,060,056

METHOD AND APPARATUS FOR CONTINUOUSLY ACCRETING MOLTEN MATERIAL

Filed Sept. 21, 1960



Inventor:
Benjamin B. Scott,
by Paul A. Frank
His Attorney.

1

3,060,056

METHOD AND APPARATUS FOR CONTINUOUSLY ACCRETING MOLTEN MATERIAL

Benjamin B. Scott, Louisville, Ky., assignor to General Electric Company, a corporation of New York
Filed Sept. 21, 1960, Ser. No. 57,487
6 Claims. (Cl. 117—51)

This invention relates to a method and apparatus for accreting molten material on a moving member, and more particularly, to a method and apparatus wherein a member having a copper sheath is continuously produced by accretion.

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

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. This general method is further disclosed and claimed in a more specific and particular form in copending application Serial No. 55,469, filed September 12, 1960, in the names of Roland P. Carreker, Jr., and Robert M. Parke and entitled "Method and Apparatus for Accreting Molten Copper on a Moving Member." These applications and this patent were assigned to and are presently owned by the assignee of the present invention. By this means, the use of intermediate steps such as reheating, rolling, pickling, etc., is obviated thereby achieving lower production costs based on lower equipment costs and lower operating costs.

In practicing dip forming processes as that described in the Carreker patent applications, the problem of gas contamination may manifest itself in causing the creation of a product which may be non-homogeneous having an undulating outer surface further affected by the presence of cracks, voids, and fissures therein. The presence of contaminant gases influences the heat exchange between the core member and the molten material causing these irregularities and also harmfully affecting the bond between the accreted material and the core member.

The sources of gases resulting in a defective product have been identified to include three categories: impurities in the molten material which is accreted, surface impurities of the core rod, and impurities within the core rod. Taking, for example, copper, it has been found that with increasing temperature in the solid state and to a greater degree in the molten state, pure copper readily absorbs gas, reacts chemically, and alloys with most materials. Contamination which is present even in the high grade copper refined by the best conventional methods may include gases such as hydrogen, oxygen,

2

carbon dioxide, carbon monoxide, and nitrogen, copper compounds such as oxides and sulfides; and include other materials such as carbon. These contaminants are absorbed by the molten copper from residual plating contamination present in the cathode material, furnace linings, carbon electrodes, and from the furnace atmosphere. Moisture, sulfur dioxide, and hydro-carbons found in furnace atmospheres are especially troublesome since the molten copper disassociates and separately absorbs the basic constituents of the contaminants which include oxygen, hydrogen, sulfur, and carbon while releasing carbon monoxide. At solidification, the excess of these contaminants are forced into granule and core interfaces where entrapped gases create damaging voids. Also at solidification, further defects are formed due to chemical reactions. Void producing gases released internally at solidification may be molecular in size, not capable of passing through the hot copper lattice and may include hydrogen, carbon monoxide, carbon, dioxide, methane, sulfur dioxide and steam.

The actual gases formed depend upon the random proximity of impurities at solidification and also upon the reactions which may occur between the contaminants at these high temperatures. The nature of these reactions may change with decreasing temperatures since condensation of certain gases may occur.

Surface impurities on copper core material may include moisture, cupric and cuprous oxides, cleaning solutions, water, oil vapor, and lubricant residues. These impurities may be flashed into gaseous form prior to and during the interval of contact with the molten material in the crucible. The released gases are similar to those set forth above with the addition of certain hydro-carbon gases and gasified cleaning compounds which may include chlorides, carbonates, sulfates, nitrates, etc.

The external impurities in copper core materials may be similar to the impurities found in molten copper. The effect of these impurities is dependent to a great extent on the thermal penetration of the molten metal into the core material.

The chief object of the present invention is to provide an improved method and apparatus for continuously accreting molten material on a moving member.

Another object of the invention is to provide an improved method and apparatus for accreting molten material wherein dissolved gases in the molten liquid which are precipitated at the time of accretion are removed to permit substantial bonding of the accreted material to the member.

A still further object is to provide an improved method and apparatus for accreting molten material on a moving member wherein contaminant gases and gasifiable impurities are precipitated in the area of accretion and discharged from the area of accretion and from the crucible.

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

Briefly stated, the present invention relates to a method and apparatus wherein a moving core rod is introduced into a nozzle located in the lower portion of a crucible containing molten material, the nozzle opening being of a size and shape to provide a clearance between the rod and at least a portion of the nozzle to permit gas to flow between the rod and the nozzle opening, the rod passing through the molten material in the crucible having material accrete thereon, solidification of the molten material precipitating dissolved gases which are removed from the area of accretion by being discharged through the nozzle in counterflow relation to the moving rod to provide a product having the accreted material bonded to the core rod. The term "rod" as used herein denotes elongated

bodies having various cross-sections which may be either solid or hollow.

The attached drawings illustrate preferred embodiments of the invention in which:

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

FIGURE 2 is a sectional view of a portion of the crucible shown in FIGURE 1 illustrating the means for removing gases from the area of accretion;

FIGURE 3 is a sectional view taken through line 3—3 in FIGURE 2.

FIGURE 4 is a sectional view of another embodiment of a nozzle taken through line 3—3 shown in FIGURE 2.

In FIGURE 1, there is shown a preferred embodiment of an apparatus for practicing the present invention in which wire 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 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. 13, 1960, entitled, "Method and Apparatus for Accreting Molten Material on a Moving Member." If desired, other cleaning means, such as chemical 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 described seal between the shaving cutter and the rod, is provided to minimize the possibility of additional surface contamination and to assure that the surface of the rod is free from oxidation when the accretion process occurs. Core rod 2 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 evacuate passage because rod drawing apparatus 3 and rod shaving apparatus 4 require that the rod be pulled there-through.

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 connected 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 shaft 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.

In housing 8 there is also located a plurality of pulleys 11 which engage the rod to perform a supporting and straightening function before the rod is introduced into crucible 26. The rod passes from housing 8 into tube 25 which may have connected thereto exhaust tubes 27 and 29 and evacuating pumps 24 and 30 to maintain a vacuum in the passage defined by members 5, 6, 8, and 25. Nozzle 29 which extends into crucible 26 is located at the upper end of tube 25. Nozzle 29 performs the function of supplying rod 2 into crucible 26 and also incorporates the function of removing gases from the crucible in a manner described more fully hereinafter. It can be seen from FIGURE 1 that core rod 2, having been suit-

ably cleaned to provide a clean surface thereon, is maintained in an evacuated passage to minimize contact with a contaminating atmosphere until after the accretion process has been performed.

Crucible 26 may be insulated to maintain the temperature of molten material 30 located in liner 28 which may be fabricated of graphite. In order to maintain the temperature of the crucible at a desired level, heating means such as electric induction heater 36 may be utilized. The material supplied to the crucible may be provided by a furnace 31 having heating means (not shown) for melting the copper or other material to be accreted. If desired, gases such as oxygen may be removed from the copper by means of graphite pieces placed in the melt which unite with the gases permitting the production of copper having low oxygen content. An inert atmosphere may also be utilized above the melt in furnace 31 to reduce oxidation of the melt. In the case of copper it has been found desirable in practice to maintain the oxygen in the molten copper to a minimum practicable amount to insure a good product. The molten material, such as copper, is supplied to crucible 26 by means of a spout 33 which extends into liner 28 of crucible 26. The level in the liner may be sensed by a suitable control means 38 which may also incorporate therein means to sense the temperature in the crucible, said control means 38 regulating servo motor 37 which is connected by means of rod 35 to graphite piece 34. This graphite piece is of such size that movement thereof in the body of molten material 32 in furnace 31 controls the level and feed of material into crucible 26. 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 introduce molten material into the crucible, graphite piece 34 may be immersed into the body of material 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 September 12, 1960, now Patent No. 3,060,055 entitled, "Method and Apparatus for Accreting Molten Material."

In accreting material on the rod, it is desirable to maintain an inert atmosphere above the level of the liquid to minimize contamination. This may be achieved by introducing through line 41 an inert gas, such as nitrogen, above the level of the melt. The rod as it passes through the melt extracts heat from the molten material. This molten material accretes or freezes thereon causing the rod to increase in diameter also thermally expanding the rod.

FIGURE 2 illustrates an enlarged view of the entrance portion of crucible 26 shown in FIGURE 1. As rod 2 passes through opening 25' of tube 25 and is introduced into nozzle 29 suitable clearance space 76 shown in FIGURE 3 is provided between rod 2 and the nozzle surface. At the discharge end 75 of nozzle 29 hydraulic pressure of the molten material in the crucible combined with the vacuum in opening 25' brings the solidified material into the clearance 76. Continuous solidification of molten material at discharge end 75 of the nozzle substantially prevents molten material flowing into nozzle to impede the successful operation of this continuous accretion process.

FIGURE 2 shows that discharge end 75 of nozzle 29 by means of clearance space 76 and the opening 25' of tube 25 is in communication with exhaust tube 27. As previously mentioned, the change of the state of the molten copper in the crucible from liquid to solid at the point of accretion is accompanied by the precipitation of large volumes of dissolved gases from the material. These precipitated gases are drawn through the clearance 76 which is in communication with exhaust tube 27 to permit the removal of these gases from crucible 26. The removal of these gases permits the bonding of the accreted material on the core rod to form a substantially

5

uniform product substantially free from internal and surface defects.

In FIGURE 4 there is shown another embodiment of nozzle 29 in which the inner surface of the nozzle comprises a plurality of lands 72 which are designed to support the rod passing through the nozzle. Lands 77 and core rod 2 define a plurality of clearance spaces 78 through which precipitated gases may be passed in counterflow relation to core rod passing through nozzle 29. Lands 77 in the embodiment of FIGURE 4 provide support for the rod passing therethrough while the clearance 76 in FIGURE 3 is of a nature which permits relative lateral motion of the rod in the nozzle opening. The rod is discharged from crucible 26 through nozzle 43. If desired, suitable cooling means 41, such as spray nozzles, may be utilized to cool the highly heated core rod as it leaves the crucible.

The rod emerging from the crucible is in a highly heated state and is weak in mechanical properties. In order to prevent rupture of the rod, a suitable shock isolation loop or tensioning arrangement 45 may be provided. This construction may change the direction of the rod an angle greater than 90°. Tensioning arrangement 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.

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 substantially increased and compensating means must be incorporated in the driving means for removing the rod from the discharge side of the crucible to prevent tensile or compressive failure in the mechanically weak product. 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 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 drive roll 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 pulleys 55 and 56.

In the operation of the apparatus shown in FIGURES 1 and 2, a continuous rod is introduced into drawing apparatus 3 and into shaving apparatus 4 which incorporates cleaning means wherein the surface of the rod has the oxide coating or other contaminant 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 nozzle 29. The rod may pass through tube 5 which is in sealing engagement with shaving apparatus 4 and housing 6. The rod moves through housing

6

6 around pulley 7 and is engaged by drive rolls 9 and 10 in housing 8. These pulleys urge the rod up through the housing 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 to prevent bending caused by crucible entrance forces. Core rod 2 enters tube 25 and into nozzle 29 with its surface not only substantially free from oxidation and other contamination but the surface of the rod is also substantially degassed.

As the rod enters the crucible filled to a predetermined level with molten material 30 it has accreted thereon a layer of molten material thus forming a rod of greater diameter with the accreted material substantially bonded thereto. As previously mentioned contaminant gases are precipitated from molten copper at the time of solidification. A substantial portion of this gas may be hydrogen which has been introduced into the molten metal with oxygen formed from moisture disassociates. Oxygen may also be absorbed into the copper from the furnace atmosphere, if present. The oxygen content of the molten copper may be lowered by utilizing graphite or other form of carbon in the furnace or in the crucible. Preferably, the crucible is graphite lined. The graphite unites with the oxygen in solution to form carbon monoxide to lower the oxygen content in the accreted material. Other sources of contaminant gas may be carried into the accretion zone by the core rod including moisture, pump oil, lubricant traces, and inter-granular impurities. Moisture coming into direct contact with liquid copper may be disassociated and be absorbed separately as oxygen and atomic hydrogen. Lubricants which may be in vapor form are thermally decomposed into hydrogen which is absorbed by the molten solution, free carbon, carbon dioxide which is reduced to cuprous oxide and carbon monoxide which is generally released by the molten copper without absorption. Further at the time of accretion, oxygen is released from cuprous oxide which reacts with hydrogen and carbon that is present. Cuprous oxide may be also forced into the grain boundaries of the product where it reacts with the carbon and hydrogen to form steam, carbon dioxide, and carbon monoxide. These gaseous products which are internally generated in the accreted structure possess substantial pressure which the mechanically weak accreted structure cannot withstand. The gas tends to form pockets resulting in voids or to escape from the surface of the product forming irregularities such as fissures and crevices, both on the surface and internally, resulting in an inferior product.

In the present invention at the time of solidification these gases (see FIGURE 2) are drawn from the area adjacent discharge end 75 of nozzle 29 through the clearance space in the nozzle construction which is placed in communication with exhaust tube 27 connected to evacuating pump 24. In this manner the gases which are precipitated are immediately removed from the area of accretion and placed into counterflow relation to the rod being supplied into the crucible and the contaminant gas is removed from the crucible.

The core rod emerging from molten material 30 is in a highly heated glowing state. An atmosphere of inert gas is maintained above the molten material 30 to prevent oxidation and formation of slag in the crucible. Rod 2 passes through nozzle 43 and is discharged from the crucible. If desired, suitable cooling means 44, such as spray nozzles, may be employed at this point 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 pulleys 55 and 56 which attempts to remove the rod as it is discharged from the crucible. Be-

cause of the fragile nature of the rod at this point, the driving speed of pulleys 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 shaft 71 which is the driving shaft to the 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 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 pulleys 55 and 56 is less or greater than the speed of the pulleys 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 material on a moving rod to form a substantially uniform product having the accreted material substantially bonded to the rod. This is achieved by providing means for withdrawing dissolved contaminant gases and other gasified impurities in the molten material as they are precipitated at the time of accretion from the crucible so that these gases are not permitted to harmfully affect the accretion process resulting in creating a rod having internal and external defects. It will be appreciated that the core rod may be the same material as the accreted material or if desired different combinations of metal may be used, for example, the core rod may be iron or aluminum.

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

1. In a method for accreting molten material on a continuously moving core rod, the steps which consist in passing the core rod from the atmosphere into an evacuated passage, introducing the moving rod from the evacuated passage into a nozzle located in the lower portion of a crucible containing molten material, passing the moving core rod through such molten material causing accretion of molten material on the rod precipitating dissolved gases in the area of accretion, removing a substantial portion of the precipitated gas from the area of accretion and from the crucible, and discharging the rod from the crucible.

2. In a method for accreting molten material on a continuously moving core rod, the steps which consist of passing the 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 material, the nozzle opening being of a size and shape to provide a clearance between the rod and at least portions of the nozzle opening, passing the core rod through the molten material at a speed sufficient to substantially prevent the passage of molten material into the clearance between the nozzle and the core rod while molten material accretes on the moving rod, solidification of the molten material on the rod precipitating dissolved gases in the area of accretion, passing a substantial portion of the precipitated gas from the

area of accretion through the clearance between the nozzle and the moving core rod in counter-flow relation thereto to remove the precipitated gas from the crucible and discharging the rod from the crucible.

3. In an apparatus for accreting molten material on a moving core rod the combination of means defining an evacuated passage, a crucible, means for passing the core rod from the atmosphere into said evacuated passage, a crucible, means for maintaining a desired level of molten material in said crucible, nozzle means located in the lower portion of the said crucible and being connected to the evacuated passage adapted to introduce the core rod into the crucible, means for removing a substantial portion of the gases precipitated as the molten material accretes on the moving core rod being introduced into the crucible, and means for maintaining an inert atmosphere in the crucible above the level of the molten material.

4. In an apparatus for accreting molten material on a moving core rod the combination of means defining an evacuated passage, means for passing the core rod from the atmosphere into said evacuated passage, a crucible, means for maintaining a desired level of molten material in said crucible, nozzle means located in the lower portion of said crucible and being connected to the evacuated passage adapted to introduce the core rod into the crucible, evacuating means, passage means connecting the discharge side of the nozzle to the evacuating means for removing a substantial portion of the gases precipitated as the molten material accretes on the moving core rod being introduced into the crucible.

5. In an apparatus for accreting molten material on a moving core rod the combination of means defining an evacuated passage, means for passing the core rod from the atmosphere into said evacuated passage, a crucible, means for maintaining a desired level of molten material in said crucible and being connected to said evacuated passage adapted to introduce the core rod into said crucible, said nozzle having an opening of a size and shape to provide a clearance between the core rod and portions of the nozzle opening, evacuating means in communication with said clearance space for removing a substantial portion of the gases precipitated as the molten material accretes on the moving core rod being introduced into the crucible, said precipitated gas being passed into said clearance in counterflow relation to the rod.

6. In an apparatus for accreting molten material on a moving core rod the combination of means defining an evacuated passage, means for passing the core rod from the atmosphere into said evacuated passage, a crucible, means for maintaining a desired level of molten material in said crucible, nozzle means located in the lower portion in said crucible and being connected to said evacuated passage adapted to introduce the core rod into said crucible, said nozzle being provided with a plurality of lands to support the rod and to define suitable clearances therebetween, evacuating means in communication with said clearance spaces for removing a substantial portion of the gas precipitated as the molten material accretes on the core rod being introduced into the crucible, said precipitated gas being passed into said clearance in counter-flow relationship to the rod and being discharged from said crucible.

References Cited in the file of this patent

UNITED STATES PATENTS

2,543,936	Reynolds	Mar. 6, 1951
2,959,829	Brennan	Nov. 15, 1960