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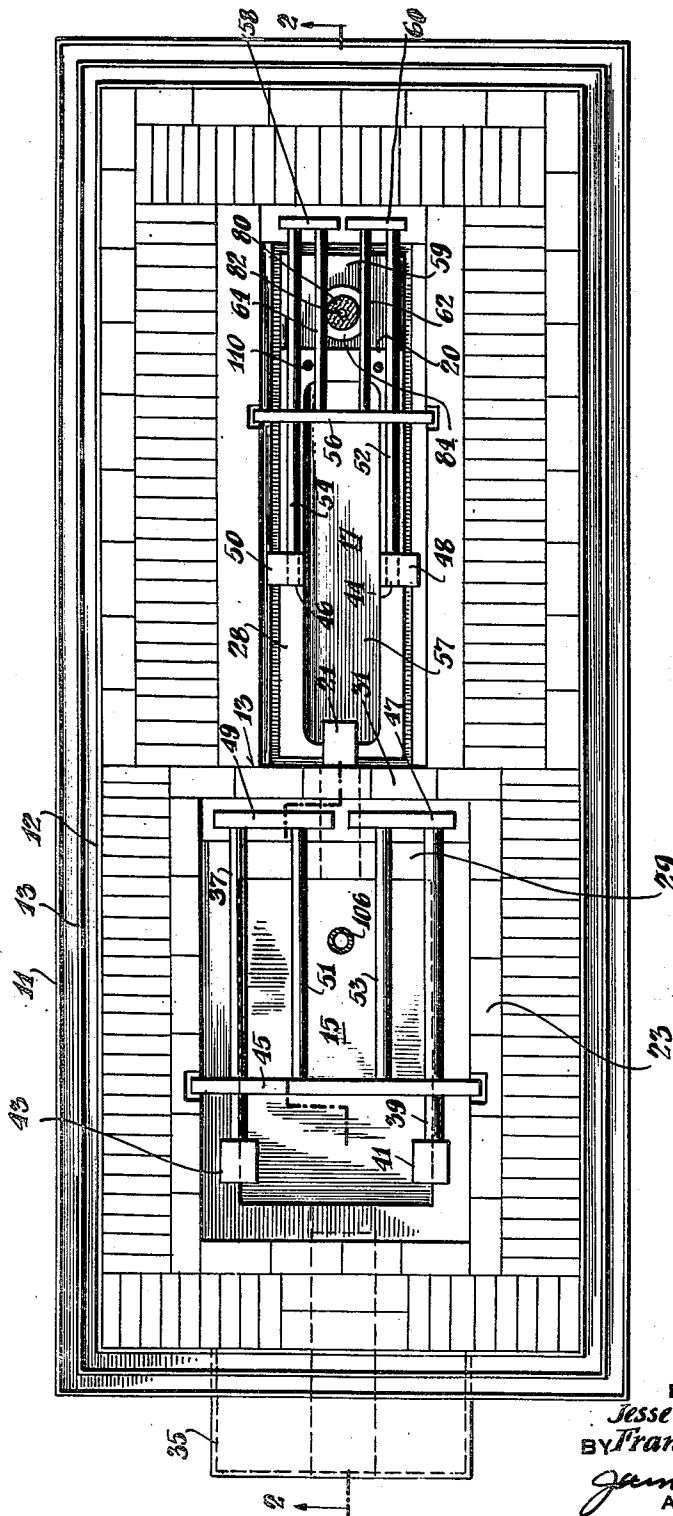
J. O. BETTERTON ET AL

2,264,289

PROCESS AND APPARATUS FOR CASTING METAL

Filed Aug. 22, 1939

2 Sheets-Sheet 1



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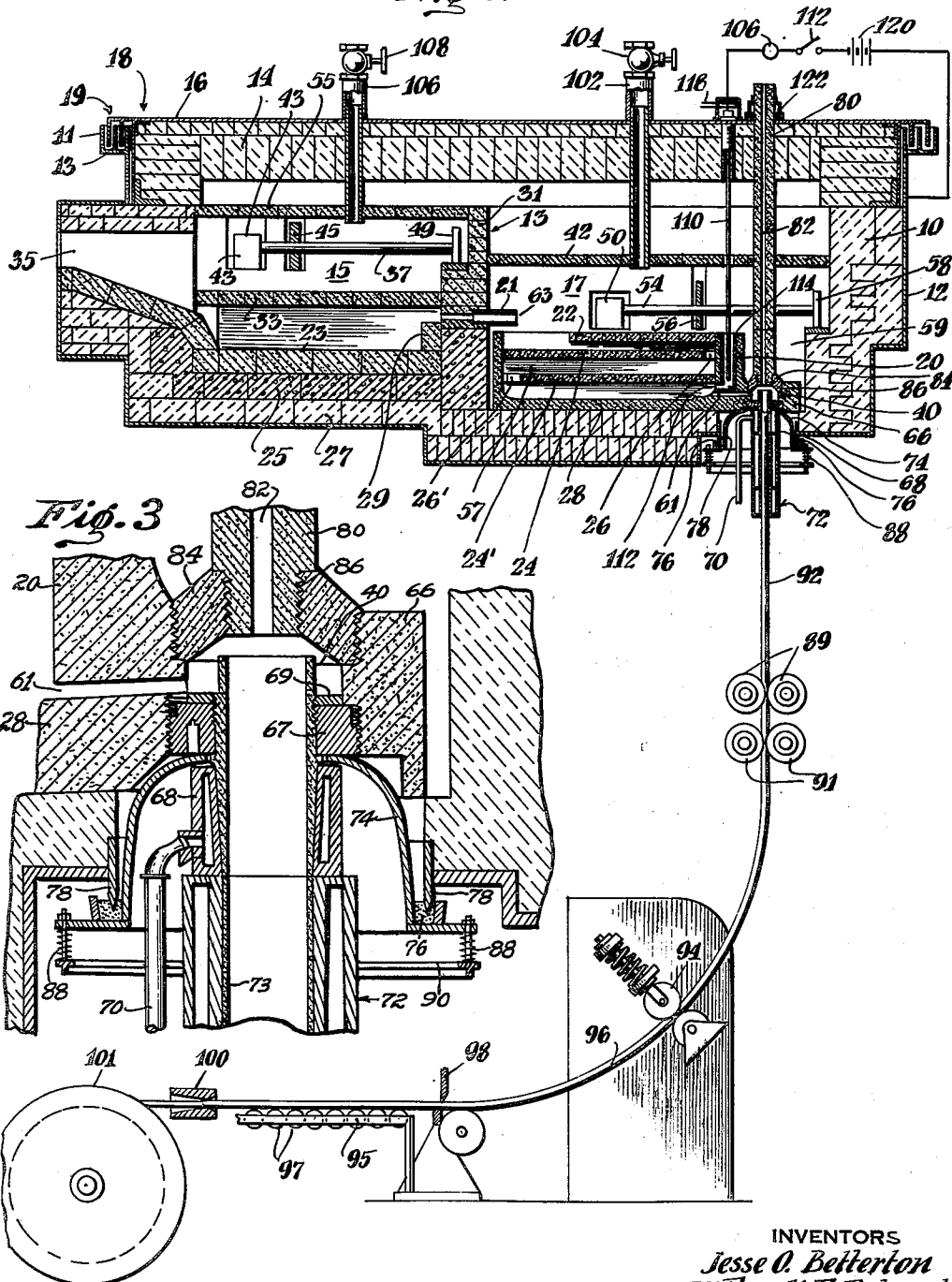
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Fig. 2



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2,264,289

PROCESS AND APPARATUS FOR CASTING METAL

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20 Claims. (Cl. 22—57.2)

The present invention relates to apparatus and method for continuously casting copper or copper-alloy rods for the manufacture of wire.

It has long since been proposed to introduce molten metal continuously into one end of a mold, solidify it therein, and continuously withdraw the solidified metal from the other end of the mold. Such operation is generally referred to as continuous casting and it is an object of the invention to provide an improved apparatus and process for its fulfillment.

In the practical operation of the continuous casting of copper, so that the process will be of a truly continuous character, it has been found by experience that certain definite factors and conditions must be observed. These factors and conditions include the following:

1. The metal (copper or copper alloys) must be properly prepared preliminary to its continuous casting; that is, the metal must be rendered substantially free from oxygen, and commercially gas-free.

2. There must be used a proper mold material in the part of the casting mold that is subjected to the molten copper.

3. There must be sufficient cooling of the mold and molten copper therein for effecting a rapid solidification of the copper in the mold inasmuch as the more rapid the solidification, the higher will be the casting speed with continuous production of sound rod.

4. The depth of the molten copper above the mold must be limited in proper manner for avoiding excessive depth thereof with resulting hydrostatic pressure upon the copper in the mold.

5. The speed of removal (casting speed) of the copper from the mold must be controlled properly.

6. A continuous supply of prepared copper must be led into the casting mold, additional prepared copper being fed thereto at a location remote from the mold opening to avoid turbulence of the molten copper in the mold.

In the commercial operation of the continuous casting process as applied to copper and copper alloys, it has been found that an important factor to be considered in the practical operation of the process is the presence of gases in the copper to be cast. Thus, for example, where electrolytic copper cathodes are being employed, there may be present gases such as hydrogen, water, and other gases, as well as salts from the electrolyte, so that if the cathodes were simply melted down and cast, the casting would exhibit a very porous structure.

Now, when copper is subjected to a continuous casting operation, the gases associated with the copper are liberated from the metal during solidification thereof and there is a very real danger of the liberated gases becoming entrapped in the metal being cast and causing the casting to break.

Therefore, in practice, it is necessary to subject the metal to refining operations for the elimination of the gases present therein, this refining being heretofore carried out in accordance with the usual refining operations, that is to say the copper is first blown with air until the hydrogen and sulphur has been expelled as completely as possible, and the metal is then poled in accordance with the usual practice until it reaches the point where the specific gravity of cast samples will be at least 8.50. The copper thus preliminarily refined and rendered commercially gas-free is introduced into the continuous casting furnace, in accordance with the prior practice, in which prior practice the above indicated refining and degasifying operations have been carried out in stations remote from the casting furnace.

The present invention has for one of its objects the provision of a process and apparatus whereby electrolytically deposited copper cathodes may be submitted directly to a continuous casting operation, notwithstanding the presence of the objectionable gases and other materials, such as those mentioned above.

A further object of the invention is to provide an apparatus for continuously casting copper, wherein the externally located refining stations are eliminated, and wherein the said preliminary refining and the continuous casting of the refined metal are performed in a single enclosure.

Other objects and advantages of the present improvements will become apparent as the description proceeds, and the features of novelty will be pointed out in particularity with the appended claims.

The particular application of the present invention is to provide a process and apparatus which will enable copper cathodes to be directly converted into a form which is immediately suitable for fabrication. Many attempts have been made in the past, and the economy of the proposal is well recognized by many investigators, to use such cathodes to cast directly final refined copper shapes. However, as has been mentioned above, these cathodes contain detrimental gases, such as hydrogen, water, and other gaseous materials, as well as salts from the electrolyte, sulphur, and the like, so that when they are melted down

and cast they yield a casting with a very porous structure. Again, in all these attempts to melt cathodes, or refined copper mill scrap, into refined copper shapes for sale, the metal always becomes contaminated, particularly with iron, and also with magnesium, aluminum, etc., from the refractories used in the furnaces, and here again there results a copper totally unfit for wire purposes in that the conductivity is far too low. This is the case even though the detrimental gases are removed, as has been described above, by separate and distinct operations for their elimination.

While the invention will be described with particular reference to the direct conversion of copper cathodes into oxygen-free refined copper by a continuous casting operation, it will be apparent that, if desired, other forms of copper, such as for example, wire bar copper may be utilized if desired in the present apparatus.

Although the features of novelty which are believed to be characteristic of this invention will be pointed out in particularity in the claims appended hereto, the invention itself, as to its objects and advantages, and the manner in which it may be carried out, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, and which show the construction of an apparatus which is designed to continuously cast oxygen-free copper directly from copper cathodes; and which apparatus also is designed to fulfill all of the above enumerated requirements for the commercial operation of the continuous casting process.

In the drawings—

Fig. 1 is a sectional plan view of one type of furnace which is suitable for the direct continuous casting of copper cathodes, with the cover removed, and parts omitted for clarity.

Fig. 2 is a sectional elevation of the furnace, the view being on the line 2—2 of Fig. 1, looking in the direction of the arrows, and including the structural elements omitted in Fig. 1.

Fig. 3 is an enlarged sectional elevation of the casting mold and adjacent structure shown in Fig. 2.

It will be understood that the particular furnace shown in the drawings is illustrative only, as the specific details of the construction may be varied widely; also that it is not to be limited in its use to the continuous casting of copper cathodes, but that it may be used similarly for the continuous casting of other kinds of copper, as well as other metals and alloys.

Referring more particularly to the drawings, the furnace is shown as comprising a refractory body 10 housed by a steel shell 12 and provided with a removal cover 18. This cover comprises a refractory body 14 enclosed in a steel shell 16 and has a double seal 19 extending around the whole top of the furnace and formed by cooperating flanged members 11 and 13 welded to shells 12 and 16, respectively. Sealing is appropriately effected by filling the compartments formed by flanges 11 with sand or an equivalent granular medium and with a non-volatile liquid such as a high petroleum distillate fraction, respectively.

Interiorly, the furnace is divided into two compartments, by a refractory vertical partition 13. One of these compartments, 15, is the melting and refining compartment, and the other compartment 17 is the casting compartment. Communication between the two compartments is afforded by duct 21.

The compartment 15 is lined with carbon blocks 23, this lining extending over the sides and bottom of the compartments, the blocks 23 resting on a thick layer of fire clay 25, which in turn rests on heat insulating bricks 27, which are adjacent to the shell 12. The lower part of partition 13 is fire clay with a carbon covering 29, the remainder of the partition 13 being built up of carbon blocks 31 to the top of the furnace body. The laboratory of the compartment 15 is covered by carbon slabs 33. The carbon lined intake 35 for the metal has a sloping bottom which opens beneath the cover 33, the slope of the intake bottom being sufficient to allow the cathodes or other metal shapes being charged to slide freely down the slope and into the laboratory of the compartment.

The compartment is heated to temperatures substantially above the melting point of the metal being cast by graphite resistor elements 37, 39, terminating interiorly of the furnace in terminal connector blocks 41, 43. The graphite resistors 37, 39 pass through holes in the graphite support plate 45 and connect the graphite blocks 41, 43 with graphite contact plates 47, 49, respectively, which plates are connected with the support plate 45 by shorter graphite resistors 51, 53.

The resistor elements are positioned above the carbon slabs 33, and below carbon slabs 55, which cover the compartment 15 and form a ceiling therefor. Additionally, the outer end of the intake 35 is closed with a gas-tight door, not shown, so that the interior of the furnace is sealed tightly against the outside atmosphere. With the furnace being filled with an inert gas, preferably nitrogen, during operation it will be apparent that the heating resistors and metal will be adequately protected against oxidation and contamination. Further, by reason of the close contact of the metal with its carbon environment on all sides, the metal becomes degasified sufficiently to enable it to be cast directly into oxygen-free metal suitable for direct fabrication. In this connection it will be noted that the duct 21 is positioned closely adjacent to the bottom of the carbon slabs 33 so that the metal fills almost up to these slabs and its surface almost contacts therewith so that the metal is enclosed entirely in a carbon environment, while becoming refined to a commercially gas-free condition.

The compartment 17 is provided with a graphite crucible 28, one end 20 of which subdivides the compartment 17 into a reservoir chamber 57 and a casting chamber 59. The passage or duct 21 in the wall 13 constitutes the path of flow for metal from the chamber 15 into crucible 28, and a port 61 in the crucible wall 20 constitutes the sole path of flow for metal from the chamber 17 into the mold or die 40.

Above the bottom of crucible 28 and supported by the sides of the crucible are spaced courses of graphite blocks, designated as 22, 24 and 24', which are in the nature of false bottoms in the crucible. The top course 22 of these blocks is made shorter than the remaining courses, it terminating short of spout 63 of duct 21 which delivers the refined metal from the refining chamber 15 to the crucible 28. At the right hand side of the course 24 as viewed in Fig. 2, there is provided an opening or port 26 which delivers metal to the lower course 24, this latter being provided with a similar opening or port 26' at its left hand side, through which metal flows to the bottom of the crucible 28, thence to port 61 and casting mold 40.

It will be seen therefore that on its way to the mold 40, the metal flows continuously in complete contact with carbon, i. e., it flows between the blocks 22 and 24, through port 26, then towards the left as viewed in Fig. 2, between the blocks 24 and 24', through port 26' onto the bottom of crucible 28, and then to the right again to the port 20, the metal flowing between the blocks 24' and the bottom of the crucible.

There are thus performed two functions, i. e. the turbulence of the metal, resulting from its intake from spout 63, is broken up, so that it flows quietly and steadily to port 61, and also the metal becomes further deoxidized before it reaches the casting mold 40, if it was incompletely deoxidized in the refining compartment. Turbulence in the metal in the mold is avoided further by arranging the port 61 to open below the mold intake.

The compartment 17 is heated electrically by graphite resistor elements horizontally positioned between the crucible and mold construction, to be described in detail hereinafter, and ceiling 42, which is made of graphite blocks or slabs and supported by channels in the furnace side walls. The heating elements comprise a pair of graphite resistor terminals 44, 46, terminating interiorly of the furnace in terminal connector blocks 48, 50. Graphite resistors 52, 54 pass through holes in the graphite support plate 56 and connect the connector blocks 48, 50 with graphite contact plates 58, 60, which plates are connected with the support plate 56 by shorter graphite resistors 62, 64.

It will be seen that the crucible 28 has an extension 66 extending from the bottom of the end 20 of the crucible, and this extension has a hole through its bottom for receiving the mold 40. This mold is machined from dense graphite which meets the specification of U. S. Letters Patent No. 2,136,394 dated November 15, 1938, granted to Frank F. Poland and Karl A. Lindner, and it is held in place by holder 67 and graphite washer 69, both of which are suitably threaded as is, also, a portion of the outside wall of the mold. The lower end of mold 40 is externally tapered towards its exit and is completely surrounded by a cooling jacket 68 of a metal with high heat conductivity, such as forged copper. The said jacket is provided with intake 70 and a suitable outlet, not shown, for circulation of cooling fluid therethrough, and the jacket is internally and inversely tapered to complement the external taper of the mold, and thus permit longitudinal movement of the jacket with respect to the mold.

Below this cooling jacket 68 there is provided a mold extension or auxiliary cooling jacket, indicated generally at 72, the structural details of which are not shown, it being sufficient to note in this connection that it is built up of a plurality of independent sections which when assembled are supported suitably in position, each section being composed of two separate complementary segments, which are joined yieldably by a conventional bolt and spring arrangement. Each segment has a suitable cooling fluid inlet and an outlet, and the segments are provided with liners 73 of ordinary graphite, which contact the cast rod.

These structural details are similar to the showing in the copending application of Betterton and Poland, Serial No. 267,688, filed April 13, 1939, for Apparatus for continuously casting

metals, of which this application is a continuation in part.

A seal is provided to prevent access of air to the otherwise exposed surface of the extension 66 of the crucible 28, and mold 40 by means of a shell 74 provided with a channel 76 filled with sand or other sealing medium into which extends sealing ring 78 when the mold assembly is in operative position. Non-oxidizing gas also may be introduced into the interior of the mold, as described in the aforesaid Betterton and Poland application in order to prevent oxidation of the new casting.

In view of the fact that the continuous casting process produces oxygen-free, gas-free metal, any gases remaining in the metal after the above described refining treatment, are liberated from the metal upon solidification thereof in the mold, and it is desirable to maintain such liberated gases out of contact with the metal coming to the mold in order to prevent reabsorption thereof in the metal, the presence of such gases in the metal being found in practice to cause serious operating difficulties, as has been mentioned above.

Consequently, means to vent the gas is provided. Such means include a stack 80, which is positioned directly above the intake of the mold 40 and extending through the furnace roof. The stack 80 has a vent opening 82 extending there-through, the stack being secured in a graphite base 84 by cooperating threads 86. The base 84 is in turn threadably mounted in the crucible extension 66. The vent opening 82 educts from the furnace the gases liberated from the copper as solidification thereof occurs in the mold, thereby reducing the sweeping action required by the inert atmosphere in the furnace. If the stack 80 opens in the furnace, the gases from the furnace stack enter the inert atmosphere and must be swept thereby from the furnace, for absolute prevention of reabsorption of the gases by the metal in the furnace. The entire mold assembly is resiliently mounted through springs 88 on a support 90, which support is mounted on any suitable means, not shown, which provides desired adjustment.

From the foregoing description of the furnace, it will be apparent that it greatly facilitates the fulfillment of the conditions which have been mentioned previously herein as being important in the performance of the process on a satisfactory commercial basis.

It will be recalled that where copper cathodes is the material being handled in the process, the operation must be conducted in view of the condition of the metal, which may be high in oxygen, for example. Consequently there must be an effective deoxidation of the cathode metal in the furnace before it reaches the casting mold, and the all-carbon surfaces with which the metal intimately contacts from the time it melts to the time it reaches the casting mold permit the metal to become deoxidized and commercially gas-free, the melting, refining and casting as carried out in the direct manner as is described herein effecting important operating economies over the use of the usual operations where the copper is transferred intermittently from the casting furnace from refining and holding units positioned at stations more or less remote from the casting furnace, the improved procedure eliminating rehandling of the metal during transfer operations and also the possibility of

gas absorption during the transfer, together with a substantial shortening of the time interval heretofore consumed between the melting of the metal and the casting thereof; while also avoiding the necessity of maintaining large reserves of molten metal for supplying the casting furnace. An inert atmosphere, such as nitrogen, is maintained continuously through the furnace to prevent oxidation of the carbon surfaces and resistors therein; and as nitrogen is not absorbed by copper, it does not introduce operating difficulties by its use.

All metal-contacting surfaces are of carbon, as is also true of the mold, so that from the time the metal, such as copper cathodes, is charged into the furnace and melted until the casting is withdrawn from the mold, it is in continuous contact, top, bottom and sides, with these carbon surfaces, and the time of passage of the metal through the furnace is such, that the metal, even where it is gaseous metal such as cathodes, is transformed into, and maintained in, the proper gas-free, deoxidized condition for direct conversion into a continuous cast shape.

It will be seen that the metal from the refining chamber 15 overflows from that chamber through passage 21 and spout 63 into the crucible 28, this latter forming a reservoir for the refined metal, which flows to the casting mold through the passage 61, thereby maintaining a continuous supply of metal in the mold.

By introducing the metal into the crucible through the spout 63 and allowing it to cascade over the false bottoms 22, 24, 24' there is avoided turbulence in the metal undergoing solidification in the mold, as well as completing the deoxidation of the metal, and the construction and operation of the process is such that the casting operation proceeds without interruption. There is maintained continuously a supply of metal being refined in the chamber 15, and a continuous reservoir of refined metal in the crucible 28, which flows continuously to the mold as the casting proceeds, the crucible being fed by overflow of refined metal from the laboratory of the refining chamber, this overflow being controlled, in turn, by the introduction of fresh cathodes into the charge through the carbon intake 35. The importance of thus being able to replenish the supply of molten metal in the crucible without disturbing the continuity of the casting operation is emphasized further when it is borne in mind that the head of metal above that undergoing solidification in the mold must not be too high at any time if imperfections in the casting are to be avoided.

It will be understood that prior to charging the furnace, a suitable plug is provided for the mold and mold extension which prevents the molten copper from running out of the mold prior to solidification therein. This plug ordinarily consists of the last part of the casting from a previous run and constitutes the starting rod for withdrawing the casting from the mold. To initiate the actual casting operation, water is circulated through the mold to solidify the copper therein and weld it to the plug or starting rod which then is withdrawn slowly, the speed of withdrawal being increased gradually, with proper attention being paid to the mold cooling rate until the full commercial casting rate is attained and thereafter continued without jerking of the cast rod. For this purpose there are provided multiple pairs of flanged guide rolls, indicated at 89, 91, the rolls of each pair

preferably being made self-adjusting with respect to each other to accommodate cast rods of different diameters and between which the rod 92 passes. Either roll of each pair may be power driven from a variable speed motor appropriately coupled to a speed reducer, the motor being responsive at all times to suitable rheostat control. After passing the rolls 89, 91, the rod 92 may be passed around a guide 94, preparatory to passing to reducing dies.

It will be borne in mind that the rod 92 is a casting suitable for direct production of wire by drawing. In order to produce a rod sufficiently long for wire drawing operations, the rod 92 is bent at a suitable distance above the casting floor at a guide roller 94, in a bend designated at 96, and in view of the rod 92 being a cast rod, the bend 96 preferably should be on an arc having a long radius, for example, a three-foot radius for a rod of, say, about one inch in diameter.

The horizontal portion of the rod 92, beyond the bend 96, rests on a table 95 provided with rollers 97, and when a suitable length of rod has been cast for wire drawing, it is severed by a shearing mechanism indicated at 98, which may be any one of several standard constructions. The rod is reduced in size for suitable shipment to wire manufacture, by passing it through one or more suitable reducing dies, such as that indicated at 100, which reduces the rod to $\frac{3}{4}$ inch diameter, for example, it then being coiled on a reel 101, also of large radius.

It has been noted previously that a nitrogen atmosphere is maintained in the furnace, the nitrogen being supplied to the furnace as substantially pure nitrogen gas, which is obtained in practice by burning out oxygen in carefully controlled quantities of air with city gas, butane or propane, the quantities being regulated so that combustion will be complete to water and CO₂ without leaving residual oxygen and no substantial amounts of carbon monoxide. The resulting nitrogen is passed through an absorbent for CO₂, e. g. triethanolamine, and the nitrogen is then dried, and passed to the furnace.

Additionally, it has been noted previously that the present invention results in important operating advantages. Previously to the present invention there were required at least two, and preferably three, furnaces in addition to the casting furnace. That is to say, the cathodes were charged into a melt-down furnace, and melted. The slag, resulting from the melting, which consisted principally of silicates and other components of the brick lining of the melt-down furnace, together with possibly fragments of brick, and the like was skimmed off. The melt-down furnace was heated usually by a fuel such as oil and the resulting products of combustion contaminated the copper with sulphur and other noxious materials, for the removal of which it became necessary to blow air through the molten charge, in order to burn out such contaminants. Incidentally some of the copper was oxidized. The blown copper is discharged into a tilting furnace, where it was poled to tough-pitch under coke or charcoal. This constituted the primary deoxidation treatment, further deoxidation being accomplished by deoxidizing under a carbon blanket in the ladle which transferred the copper from the poling (tilting) furnace to the casting furnace; or the copper was filtered through carbon. In order to have assured a continuous supply of refined copper available

for the casting furnace, it was highly desirable to provide two tilting furnaces, one containing refined copper, the other copper being poled. In addition to much labor, fuel costs, and repeated handling of the metal, this procedure resulted in a tie-up of some ten tons of copper for each casting mold.

The present procedure eliminates all of this. The cathodes are simply washed clean with water and charged into the electrically heated carbon furnace where they are melted and deoxidized in situ, while being swept by a current of nitrogen gas. Since there are no combustion products or brickwork in contact with the copper, the blowing and skimming steps of the standard refining practice are eliminated; and as the deoxidation takes place in the carbon furnace, the poling and secondary deoxidation in a ladle or by a carbon filter are avoided also, as well as the handling of molten metal which is necessary in the transfer of molten metal from the refining furnaces to the casting furnaces. In accordance with the present invention there is required only a single unit for each mold, in which unit both deoxidation and casting are accomplished, eliminating the various treatments and the multiple furnaces which were required previously to the present invention.

Of course, the invention contemplates making the refining section and the casting section, including the holding crucible, in separate parts, with independently connected resistors, whereby flexibility of operation may be gained, as repairs may then be made to the sections more readily, and a shut down of both of the resulting units is not necessitated for making such repairs. In such an installation, the deoxidizing unit may discharge into the casting unit by means of a metal overflow corresponding to the overflow 21, which discharges into the crucible in the casting unit. In such a modified construction, both units have a common gas system.

In accordance with the present invention, it has been found that 1500 lbs. of copper per hour can be readily cast directly from electrolytic cathodes using a one-ton capacity furnace in which there is a tie-up of only about one ton of copper for each casting mold, as compared with a tie-up of about ten tons of copper for each mold in accordance with the process as previously practiced.

A very important consideration in the production of sound continuously cast copper rod directly from the copper cathodes or other copper stock is the provision of the previously referred to inert sweeping atmosphere in the melting and casting units for the removal of noxious gaseous components which result from the melting of the cathodes.

Since solid cathodes are charged into the furnace without preliminary refining, the small but important amounts of contaminants in the cathodes go into the furnace in the metal. Such contaminants include chlorine from the hydrochloric acid addition agent used in the electrolyte; hydrogen from the hydrogen in the bath; glue and lignone from addition agents; grease from the starting sheet; sulphates from the bath; oxygen from exposure of the copper to air; and water included in the deposit.

During the melting, the chlorine is evolved from the metal as cuprous chloride fume; the hydrogen is driven off as such; the glue, lignone, and grease break down into miscellaneous gases; the water breaks down into hydrogen and car-

bon monoxide, in the presence of the carbon surfaces in the furnace; the sulphates break down into sulphuric acid anhydride and copper oxide. These gases are present over and in the molten copper all at once and, if permitted to remain in the copper, would result in any casting produced being porous and wholly unsuited for wire production.

Consequently these noxious materials must be removed from the furnace atmosphere and from the metal; and in accordance with this invention, such removal is accomplished by sweeping the molten metal in the melting and casting units with an inert atmosphere nitrogen gas being the preferred sweeping gas, as has been stated previously herein.

This nitrogen must be prepared very carefully to ensure its purity. The purer the nitrogen the better it is for this particular purpose, and in practice it is prepared by burning a carefully controlled mixture of air with illuminating gas, or such a mixture of air with pentane or butane, the proportion of air with the combustible gas being such that all of the oxygen of the air is burned out, principally to carbon dioxide with only, at most, traces of carbon monoxide, so that there results a mixture essentially composed of nitrogen, carbon dioxide and water. This mixture is passed through suitable gas absorbent equipment, wherein the carbon dioxide is removed by an efficient absorbent, such as an ethanolamine, for instance either mono-, di-, or triethanolamine, or a mixture thereof, which absorbs the carbon dioxide and any hydrogen sulphide or sulphur dioxide which may be present in the gas.

The thus-treated gas which now contains nitrogen, water, and possibly a little carbon monoxide and hydrogen is passed through activated alumina which extracts the water and lowers the dew point of the gas to -40°C . The resulting nitrogen contains generally not more than about 3% carbon monoxide, and generally not more than 3% of hydrogen; and in practice it is very easy to hold these impurities below 1.5%. As pointed out above, the purer the nitrogen is, the better.

The thus-treated gas, which now is essentially nitrogen, is passed through the furnace. Now, copper cathodes, in addition to oxygen, contain appreciable amounts of the contaminants mentioned above, there being enough of them normally present in the cathodes to defeat completely the continuous casting process, which is inoperative with respect to the direct casting of copper cathode metal unless these contaminants are removed from the environment of the metal. The nitrogen gas sweeps these contaminants out of the furnace, and transforms an inoperative proposal into a fully commercially operative process.

As has been mentioned above, during the melting of the cathodes in the melting unit, the chlorine contained in the cathodes is evolved as cuprous chloride and the hydrogen is liberated. Also the oxygen in the copper is converted into carbon monoxide, and the sulphates are decomposed into sulphur trioxide. The glue and grease are decomposed into miscellaneous gaseous materials. To a large extent such contaminating materials would not leave the copper, ordinarily, as they remain in the copper in equilibrium with the atmosphere of the environment, in accordance with their partial pressures. Now, by sweeping this atmosphere continuously with an inert gas,

this equilibrium is destroyed and in attempting to restore it, these contaminants, all of which are volatile at the temperature of the furnace, leave the metal and are swept out of the environment as fast as they leave the metal, so that the metal is freed substantially from such contaminants, only slight traces thereof being left in the copper for liberation when the copper becomes solidified in the mold into a rod which is very sound throughout, with a specific gravity closely approximating that of pure copper.

Only small amounts of nitrogen are required for sweeping purposes, and of course other gases strictly non-reactive and non-absorbable by the copper, for example, helium, may be used; nitrogen, being, however, the most available and the most practical gas for this purpose.

The sweeping gas is introduced into the furnace through the intake pipe 102, which is controlled by a valve 104; and it is educted from the furnace through pipe 106, controlled by a valve 108.

It has been mentioned before that it is important to maintain a low depth of metal over the mold 40, and in order to control such depth it is desirable to provide an indicating means for indicating the approximate suitable level of metal over the mold 40, beyond which level it is not desirable to go.

The indicating mechanism includes a carbon rod 110 positioned suitably in recess 114 formed by the extension 20 of the crucible 28, a port 112 positioned above the port 61 affording communication between the interior of crucible 28 and the interior of the recess 114, the lower end of the carbon rod 110 being positioned just above this port 112, at the approximate preferred depth of metal over the mold 40.

The rod 110 extends through the roof of the furnace, and it is in circuit with a lamp 116, or other equivalent indicating means, either visual or audible. A cooling coil 118 is provided for the upper end of the rod 110 and its connection with the indicating circuit, current from which is supplied from a suitable source 120, a switch 122 being provided in the circuit as control means. Consequently, when the metal level rises to where the metal contacts the rod 110, the switch 116 being closed, a circuit is completed and the lamp 116 glows, thereby indicating to an operator that the metal level is such that no more metal should be supplied to the mold 40 until the lamp is extinguished by the drop in the metal level.

It will be seen also that a seal 122 is provided around the top of stack 80, where this stack extends through the furnace top.

It will be apparent that, in its broader aspects, the present invention includes the direct conversion of copper cathodes into cast rod suitable for a direct drawing to wire, by melting the cathodes in a deoxidizing environment, sweeping away from the resulting molten metal, gaseous materials hostile to the production of sound rod, and continuously casting the swept metal into rod.

Since the rod is a cast rod, and not a forged rod, due precautions should be taken in handling it to avoid such sharp bends as might crack the rod, and consequently it is preferred to coil the rod on large drums, such as drum 101 after the rod goes through the reducing dies, the radius of the drum being sufficiently long to prevent the rod cracking during coiling and uncoiling of the rod.

From the foregoing description of the present invention, it will be apparent that the continuous casting of copper cathodes directly into sound

rod for wire manufacture is not a simple procedure, and in fact until the discovery of the causes for the invariable failures of the attempts to directly continuously cast copper rods and the discovery of the remedy therefor by sweeping the molten metal with an inert gaseous atmosphere, it was not possible to operate to cast copper cathode metal directly into sound rod, it being necessary to resort to the blowing and poling operations, which the present invention obviates, in order to condition the metal for commercial continuous-casting operation.

Obviously the same precautions are appropriately taken, as described in the foregoing description, if alloying elements are added to the copper cathodes, or other appropriate copper stock hereinbefore suggested, to produce copper-alloy rod.

What is claimed is:

1. Apparatus for continuously casting copper and copper alloy rod of high soundness for wire manufacture comprising furnace means defining metal-melting and metal-casting units, the metal-melting unit being adapted to receive solid copper and to melt the same, heating means in the said unit adapted to melt the copper without subjecting the copper to combustion gases, a continuous casting mold rigidly mounted in the metal casting unit for receiving molten metal from the receiving unit, and means enabling molten metal to pass directly from the melting unit to the casting unit and thence without turbulence to the mold, the said apparatus presenting a continuous surface of carbon to the copper passed therethrough.

2. Apparatus for continuously casting copper and copper-alloy rod of high soundness for wire manufacture comprising furnace means defining a metal-melting unit and metal-casting unit, means for heating the respective units, the said metal-melting unit being adapted to receive solid copper and to melt the same therein, overflow means from the melting unit to the casting unit for transferring molten copper from the melting unit to the casting unit, a continuous casting mold rigidly mounted in the casting unit for continuously receiving molten copper from the melting unit, the said apparatus presenting a continuous carbonaceous facing to the copper from the time it enters the melting unit until it leaves the mold, and means for indicating the depth of copper over the mold.

3. Apparatus for continuously casting copper and copper alloy rod of high soundness and density comprising a furnace interiorly divided into first and second compartments, means for introducing solid copper cathodes into the said first compartment, means for melting the said cathodes in the compartment, a continuous casting mold rigidly mounted in the second compartment, means for transferring molten copper from the first compartment to the second compartment, and means in the second compartment for holding a supply of molten copper from the first compartment and for continuously transferring the copper to the casting mold with the minimum of turbulence to the metal in the mold, all surfaces of said apparatus contacting the metal consisting of carbon.

4. Apparatus for continuously casting copper cathodes into copper rod of high density and high soundness comprising furnace means defining a metal-receiving unit and a metal-casting unit, the interior of each of the said units being completely surfaced with carbon, electric

heating means in the metal-receiving unit for melting copper cathodes introduced therein, and in the metal-casting unit for maintaining copper in the said metal casting unit at a temperature substantially above its melting to assure full fluidity of the copper, overflow means for the metal leading from the metal-receiving unit to the metal-casting unit, a continuous casting mold rigidly mounted in the metal-casting unit for continuously casting the metal in the said metal-casting unit, and means for supplying, substantially completely free from turbulence, the molten copper to the said mold.

5. Apparatus for continuously casting copper cathodes directly into sound and dense rod comprising a preliminary melting and deoxidizing chamber for the cathodes, a secondary deoxidizing and casting chamber in direct communication with the preliminary melting and deoxidizing chamber for directly receiving molten copper therefrom, continuous casting means in the secondary chamber, means in the chambers for deoxidizing the copper to be cast and for holding the said copper in substantially completely deoxidized condition until completely cast, means for preventing contact of gases liberated from the copper with the copper passing to the casting means and means for maintaining a circulating inert atmosphere over the copper in the chambers for sweeping out materials hostile to the production of sound rod.

6. Apparatus for the continuous casting of copper rod directly from copper cathodes comprising a melting chamber for receiving and melting the cathodes, means in the chamber for deoxidizing the resulting molten copper in situ in the chamber, a casting chamber for directly receiving deoxidized molten copper from the melting chamber, means in the casting chamber for continuously holding a pool of the deoxidized molten copper while maintaining the copper in substantially completely deoxidized condition, a continuous casting mold rigidly mounted in the casting chamber, means for continuously passing copper from the said pool to the casting mold in conformity with the casting speed of the copper passing through the mold, the said means preventing turbulence in the copper at the mold, and means for maintaining a moving atmosphere of inert gas over the copper in the said chambers.

7. Apparatus for continuously casting copper supplied from copper cathodes which comprises a furnace including a melting chamber and a casting chamber, both chambers being completely lined with carbon, electric heating elements in both chambers to maintain copper therein at temperatures substantially above its melting point, a carbon holder for the metal in the casting chamber, a passage for leading molten copper from the melting chamber into the carbon holder in the casting chamber, a plurality of spaced layers of carbon spaced above the bottom of the holder and forming a multiple-floored hearth therefor, ports in all upper floors disposed to cause copper flowing along the floors to cascade from one floor to the next below, and to reverse its direction of flow along each succeeding floor, thereby moving in a tortuous path completely enclosed, with carbon, a continuous casting mold rigidly mounted in the casting chamber for continuously receiving copper from the holder, means for continuously leading copper from a pool thereof in the holder to the mold, means for preventing turbulence of the copper at the mold, and means for maintaining a moving at-

mosphere of unabsorbable gas over the copper in the chambers.

8. The method of continuously casting copper supplied from copper cathodes which comprises introducing solid cathodes into a melting and deoxidizing environment, effecting the melting and deoxidizing of the cathodes in situ in the environment, directly passing the resulting molten copper from the said environment into a continuous casting environment, and continuously casting the copper, while rendering the copper in the said environment substantially completely oxygen-free and gas-free by continuously sweeping the copper with an inert gas unabsorbable by the copper.

9. The method of continuously casting copper supplied from copper cathodes which comprises introducing the cathodes into a melting and deoxidizing environment, effecting the melting and deoxidizing of the cathode copper in situ in said environment, overflowing the resulting molten deoxidized copper into a casting environment, maintaining a supply of the said molten deoxidized copper in the said casting environment while holding the copper in substantially completely deoxidized condition, and continuously supplying the copper without turbulence and in substantially gas-free condition to continuous casting means as solidified copper is continuously withdrawn therefrom.

10. The method of continuously casting copper supplied from copper cathodes which comprises introducing the cathodes into a carbon-lined melting environment and melting the cathodes, holding the resulting molten copper in said environment until substantially completely deoxidized, directly passing the deoxidized molten copper into a casting environment, and continuously casting the copper from this latter environment while continuously maintaining the copper in substantially completely deoxidized and gas-free condition by continuously sweeping the copper with a moving atmosphere of an inert gas unabsorbable in the copper.

11. The method of continuously casting copper supplied from copper cathodes which comprises introducing the cathodes into a carbon-lined melting environment, melting the cathodes therein, holding the resulting copper in said melting environment until substantially completely deoxidized, overflowing the copper from said environment directly into a carbon holder positioned in a carbon lined casting environment, maintaining an inert atmosphere in both environments, forming a pool of the said copper in said casting environment, and continuously casting copper from the said pool while maintaining the latter and while sweeping the copper in the melting and casting environment with an inert gas unabsorbable in the copper, thereby rendering the copper in substantially completely in both oxygen-free and gas-free condition for casting.

12. The method of directly converting copper cathodes into sound copper rod for wire manufacture which comprises melting copper cathodes, leading the molten copper directly and without turbulence to a continuous casting mold, and continuously casting the copper into rod while continuously sweeping the copper during melting and casting with an inert gas to remove contaminants of the copper from its environment to produce sound cast rod.

13. The method of directly casting copper

cathodes into sound rod for wire production which comprises melting copper cathodes in a melting unit, directly flowing the resulting copper from the melting unit to a casting unit while avoiding turbulence in the copper in the casting unit, controlling the depth of the copper in the casting unit, and continuously casting the copper into rod while continuously maintaining the molten copper in complete contact with carbon surfaces and while maintaining a moving atmosphere of inert gas in contact with the copper in the units to free the copper from, and to sweep from its environment, contaminating materials.

14. The method as claimed in claim 13 wherein the inert gas is substantially pure nitrogen.

15. The method of converting copper cathodes directly into sound and dense rod, suitable for wire production, which comprises melting the cathodes in a deoxidizing environment while sweeping the resulting molten copper with an inert gas to degasify and remove from contact with the said copper materials hostile to the production of sound rod, and directly continuously casting the swept metal into rod, while continuously maintaining the molten copper in intimate contact with the deoxidizing and degasifying environments.

16. The method of producing dense, sound copper castings which comprises establishing melting and casting environments, forming a pool of molten copper in said melting environment and replenishing the pool by charging copper stock to the pool and melting it therein, passing molten copper from the pool into the casting environment and continuously casting the copper there-

from, and continuously removing gaseous contaminants from said environments by sweeping same with an atmosphere non-absorbable by copper.

17. The method according to claim 16 in which the sweeping atmosphere is nitrogen.

18. The method according to claim 16 in which the sweeping atmosphere is helium.

19. The method of producing a sound, continuous copper casting from copper stock containing gaseous impurities which comprises charging such stock to a first deoxidizing environment, supplying heat thereto without introducing any deleterious gases from the heating source, sweeping said environment with a gas non-absorbable by the copper, passing the copper into a second deoxidizing environment, and continuously casting the copper from said latter environment.

20. The method of producing a sound, continuous copper casting from copper stock containing gaseous impurities which comprises charging such stock to a first deoxidizing environment, supplying heat thereto without introducing any deleterious gases from the heating source, sweeping said environment with a gas non-absorbable by the copper, passing the copper into a second deoxidizing environment, continuously casting the copper from said second deoxidizing environment, and venting the gases constantly released from the copper being continuously cast in a manner preventing the entrance of such gases into said second deoxidizing environment.

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