

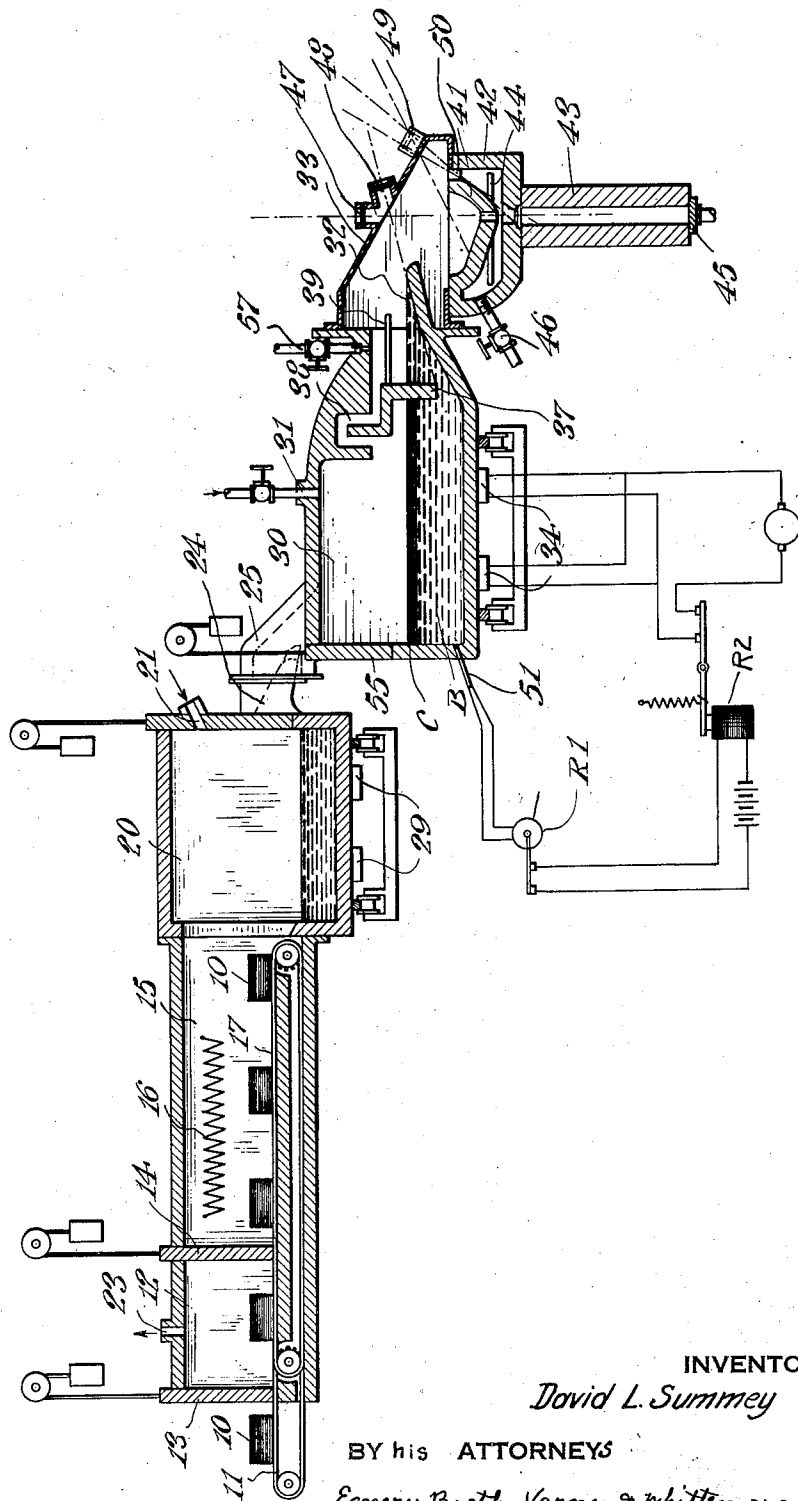
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PROCESS FOR TREATING METALS

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PROCESS FOR TREATING METALS

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The present invention relates to a method of refining metals, particularly copper and similar metals which readily oxidize in the molten condition and retain the resulting oxides upon solidification with undesirable effect on the metal.

including both ferrous and non-ferrous metals, but for the sake of brevity and clarity the following discussion will be limited to copper.

Among the objects of the invention are the production of copper, or other metals, in commercially workable condition, free from objectionable gas cavities, and substantially free from combined oxygen. In carrying out the invention there may advantageously be used a carbonaceous reducing process followed by unique commercially practicable procedure which will prevent the readmission of oxygen until the metal has cooled to the point where oxygen will not be reabsorbed upon exposure to the air.

Copper must be used for many purposes where its workability, strength and electrical conductivity become extremely important qualities. For example, copper wire is often drawn down to very fine sizes for electrical purposes and if the metal has harmful porosity or is mixed with impurities the wire will be weak and of poor conductivity. It has long been known that oxygen is one of the causes of unsoundness in copper produced by the usual reverberatory furnace practice; that if too much is present there is an excess of copper oxide which depresses the strength and conductivity of the metal even though there may be no porosity; and that if too little is present there will be excessive porosity. According to present practices which do not keep cast metal free from oxygen, the amount of oxygen which will produce the best copper varies somewhat with the amount of other impurities but is generally given as about .03% to .04%; but normally the quality of the metal varies because it is necessary to rely upon the judgment of skilled operators as to the amount of oxygen which should be left in each batch of metal.

Further objects of the invention are to provide a method of removing sulphur or similar impurities, for preheating the metal when necessary or desirable and for rapidly and efficiently subjecting all of the metal in a molten bath or pool to contact with the reducing agent to thoroughly remove the oxygen.

Other objects and advantages of the invention will be apparent to those skilled in the art as the description proceeds.

The apparatus used for carrying out the present process is described and claimed as a general combination in my copending application, Serial Number 619,474, filed June 27, 1932, which is a continuation in part of the present application. The oscillating furnace (referred to herein by the numeral 20) is described and claimed in my copending application, Serial Number 596,980, filed March 5, 1932; the pour hearth (referred to herein by the number 30) is described and claimed in my copending application, Serial Number 605,147, filed April 14, 1932; the pouring enclosure and strainer (referred to herein by the numerals 33 and 41) is described and claimed in my copending application, Serial Number 608,177, filed April 29, 1932; and the billet molding and discharging mechanism (referred to in part herein by the numeral 43) is described and claimed in my Patent No. 2,030,482, granted February 11, 1936.

There have been many theories as to why copper which contains less than .03% oxygen is unsound. Up to the present time there is no theory which is accepted by all; but a theory which has lately been widely accepted may be stated substantially as follows: Whenever the oxygen content of the copper is high, for example, above 0.1%, the amount of hydrogen permitted to be present is so small, for example, 0.00002%, as to be incapable of causing serious unsoundness. Metal containing these impurities in these proportions contracts on freezing and the ingots produced have a sunken surface. But during poling as the oxygen content of the metal falls, the hydrogen content of the metal increases, and since the hydrogen reacts with the oxygen during solidification to generate steam, causing porosity, the ingots from poled metal are less sound. The surface depression becomes less noticeable, until a point is reached at about .035 to .05% oxygen where the porosity resulting from the reaction will be found to be just sufficient to counteract the normal contraction of the metal on solidification and give an ingot with a level surface. Reducing the oxygen content of the metal beyond this point by further poling causes a rapid increase in the hydrogen content of the metal.

There are a number of metals used for industrial purposes which are seriously impaired by porosity and impurities and from which it is very difficult to eliminate these objectionable characteristics. Copper, aluminum, nickel, zinc, magnesium and their alloys are some of the more important non-ferrous metals included in this group. The present invention insofar as applicable is intended for the entire group

It is estimated that the quantity of hydrogen present is doubled in lowering the oxygen content by 0.02%. From this it appears that a very slight further poling beyond a critical point causes a noticeable increase in the porosity of the ingot.

This theory, and most others as a matter of fact, assume that oxygen is the cause of the trouble and that some oxygen will always be present. Even minute quantities can cause harmful porosity. Based upon this assumption there have been many attempts to produce copper which is so free from oxygen that the reaction causing porosity cannot occur. Several elements and compounds such as phosphorus, calcium, barium, calcium boride and the like have been found to completely remove oxygen but these substances are themselves objectionable. They are very expensive and if not used with the utmost precision will not give satisfactory results. If too little is used the oxygen is not completely removed; and if too much is used the excess will injure the copper by rendering it brittle, by lowering its conductivity, or otherwise. Even if the amount is accurately calculated there will be both oxygen and reducing agent left in the metal due to incomplete mass action. Moreover, some of the products of the reaction, which usually are undesirable, remain in the metal. Slags such as calcium chloride have been said to be efficient agents for removing cuprous oxide from molten copper. Their action is totally different from that of the group mentioned above, since their efficacy depends upon the absorption of cuprous oxide rather than the chemical reduction of the oxide. It is probable that their commercial use is limited by practical difficulties, since it was observed during a commercial scale experiment with barium chloride on the molten copper that the slag was extremely volatile at the normal temperatures encountered and evaporated with such rapidity that an adequate depth could not be maintained in spite of frequent additions of fresh material.

I have found that all of the oxygen can be removed without using these oxide-absorbing slags or reducing agents which leave a harmful residue in the metal. This is effected by a carbonaceous or other non-metallic reducing agent which is chemically active but which does not adversely affect the quality of the resultant oxygen-free copper by alloying with or leaving a solid residue in the product. I have also found that if the oxygen is not present at the beginning, it can be kept out by the carbonaceous or other reducing agents or even by certain inert substances which produce no harmful results upon the metal. This is accomplished by employing the method and apparatus which I have devised.

It is, of course, known that carbon will reduce the oxygen content of metal. It has long been used in poling copper. It may under some conditions remove all of the oxygen in a carefully protected bath. However, so far as is known no oxygen-free metal, particularly no copper, has been produced in the solid cast condition by this method. Nor have there been any commercial processes devised which would be applicable to the continuous production of cast metal free from oxygen and solid deoxidizing agents. By "cast metal" herein is meant a metal which is produced by a pyrometallurgical melting process, whether the metal be cooled in the molds or be cooled while it is being worked into certain shapes.

According to my invention it is possible to produce oxygen-free copper in the solid state in the usual commercial shapes by apparatus and process which are entirely practicable and commercially economical. I have succeeded in producing many tons of copper in this manner and I will now describe my procedure to enable others to duplicate my results.

The process according to this invention may be practiced with various forms of apparatus but for the purpose of illustration I have shown a form which I at present prefer.

The single figure of drawing is a diagrammatic sectional elevation of such apparatus. This does not show all of the details but indicates the nature and arrangement of various devices which may be used sufficiently to enable a person skilled in the art to build the apparatus and to practice the process.

Assuming that the metal taken for treatment is sufficiently pure at the start, it is only necessary to keep it pure during the subsequent pyrometallurgical refining process. Cathode or electrodeposited copper which generally will be taken is usually of this purity except that in some cases and for certain purposes it may contain harmful amounts of occluded sulphur and other impurities. The process which I practice is adapted to keep the metal pure and, in case the metal should be contaminated with certain impurities, is also adapted to remove them. Considering the process in certain aspects in connection with the particular apparatus illustrated, the metal is charged through the door 55 into the pouring furnace 30, the apparatus shown to the left of the furnace 30, including the connecting hood 25, being considered as not present for the moment. The furnace is made to hold a relatively large quantity of metal to avoid changes of temperature in the metal being poured caused by the metal being charged.

A carbon covering such as charcoal C is maintained on the bath B of metal to remove the oxygen therefrom. If the metal is oxygen-free when charged the carbon covering alone or even an inert atmosphere to prevent the admission of air will be sufficient and no particular effort need be made to obtain extended contact between the carbon and the metal. For example, the metal may be charged in solid shapes such as cathodes which are substantially pure or may be charged pure in molten condition from a prior refining process. It is only necessary to apply sufficient heat to melt the metal or to keep it molten as may be required. Any heating means may be employed provided it does not introduce harmful impurities. For this reason heating means such as open flames which give off ordinary fuel combustion gases are to be avoided.

I prefer to heat the metal by electrical induction heaters 34 for these not only avoid contamination entirely but may be used in such manner as also to effect a thorough circulation of the metal. For example, the heaters 34 on the furnace 30 are arranged in such a way as to bring all the metal to the surface frequently. It is highly important when carbon or some other floating agent is used for removing impurities from the metal that the metal be circulated properly beneath it. Carbon is a strong deoxidizing agent but in many instances it has failed to remove all of the oxygen because intimate contact with the metal was not obtained. For example, a bath of molten metal may have a

carbon cover maintained thereon for a great length of time without being deoxidized if adequate circulation is not produced. Induction heating may be availed of to assist in producing extremely rapid circulation and efficient deoxidation of the metal.

When oxygen is to be removed from the metal of the bath I prefer to have the space above the bath within the closed vessel filled with a gaseous deoxidizing agent which may be supplied from outside sources or be generated by the action of the carbon placed on the bath of metal. The metal which is to be charged into the furnace may be taken in either solid or liquid condition and preferably with sulphur and metallic impurities removed. For example, metal may be taken from a reverberatory furnace subsequent to the usual blowing stage, the present process as so far disclosed being principally suited for the removal of oxides. One way of providing this gaseous agent is to generate carbon monoxide outside and introduce it into the furnace. Or a composite gas comprising carbon monoxide, nitrogen and harmless amounts of carbon dioxide may be similarly obtained and will be somewhat less expensive. Or carbon dioxide or limited and closely controlled amounts of air may be introduced which by reaction with the carbon covering produce carbon monoxide. A regulable inlet 31 may be utilized for the introduction of any of these gases.

If the deoxidizing or inert gases are constantly supplied and permitted to escape from the furnace they will reduce the amount of hydrogen which may be present in the metal as well as the oxygen. This is effected by the tendency, aided by circulation of the metal, of the hydrogen to escape from the bath and mix with or dilute the other gas and be removed with it. As long as fresh hydrogen-free gas is supplied the hydrogen from the bath will mix with it and the removal of hydrogen by dilution can proceed.

If the furnace is enclosed, as shown, and gas is maintained under pressure therein, either by injection or by generation of gas in the furnace, there will be some outflow of gases, either by openings provided therefor or by leakage.

Having provided oxygen-free metal in the furnace it is next necessary to obtain it in solid condition whether in the form of rods, plates, tubes, bars, billets, slabs or such other form as may be desired. This part of the process must be conducted with the very greatest caution for the reabsorption of oxygen into the metal proceeds with extreme rapidity and even slight amounts of oxygen are sufficient to spoil the metal. Previous processes have exposed the metal to the air at some point or other and this is not permissible. The metal must be fully and completely protected until it has cooled to the point where it will not reabsorb harmful gases. Oxygen will not be reabsorbed after the metal solidifies, so it is necessary to protect it down to this point at least.

I have found that the required protection can best be furnished by a structural enclosure together with an enclosed gas envelope for the metal while being poured and by a structural enclosure or a protecting covering while the metal is cooling. In effect, the structural enclosure and the gas protection will be so complete that no air can reach the metal, either by direct inflow, by admixed eddy currents, or otherwise. Preferably the structural enclosure is in the form of a conduit adapted to surround the pouring

stream. This not only permits access and inspection by operators which would not be possible, for example, with enclosures which are adapted to house the entire casting apparatus as a unit, but effects a proper application and conservation of the protecting gas. It also protects the operators in the fullest measure from harmful gases.

The structural pouring enclosure preferably is articulated to accommodate the tilting movements of the furnace during pouring. Herein the pouring spout 32 is arranged at one side of the central vertical plane of the cylindrical furnace and metal is poured from the spout when the furnace is rotated upon its supports. The articulation in this case is provided by facing plates on the furnace 30 and the stream-protecting hood 33 respectively. The plates are held together by any suitable and preferably resilient means.

In some cases the hood may be extended and arranged to seal directly with a billet mold 43 but a strainer 41 may sometimes be desirable, especially when pouring into small openings, so this has been illustrated. The strainer is enclosed within casing 42 which is sealed with the billet mold when pouring and connected with the hood 33. Either the casing and hood or the mold are provided for a slight vertical movement for making and breaking contact before and after pouring whereby one mold may be removed and replaced by another.

It is desirable for the operator to be able to inspect the pouring operations at all times so for this purpose sight openings having tight glass windows are provided in the pouring conduit. In the present instance three sight openings 47, 48, 49 are provided giving lines of sight as indicated by the dot and dash lines to the pouring spout, the strainer, the stream from the strainer, and the top of the mold.

A skimmer 37 may be provided in the furnace for holding back the slag. Electrical resistor heaters 39 and 44 or other heating means which cause no contamination of the metal may be employed in the spout and at the strainer respectively for keeping the metal molten at these points where otherwise it would tend to solidify between pours.

The mold and structural conduit connecting it with the furnace are filled with an inert or deoxidizing gas such as carbon monoxide, or nitrogen, or a mixture of the two, above atmospheric pressure whereby some outward leakage may occur, but at least so no inward leakage of air may occur. The composite gas mentioned above comprising carbon monoxide, nitrogen and harmless amounts of carbon dioxide may, of course, be used in the mold and conduit if desired. The proportion of carbon dioxide in the mixture must be kept within limits and preferably as low as practicable, since if the composite gas contained too much carbon dioxide it would exert an oxidizing effect under the conditions described. These gases have been found suitable for protecting copper. For other metals it may be necessary to use other gases, the gas used in any case being one which will not injure the metal for its desired uses.

This gas may be introduced from the furnace, may be generated in the mold or conduit or may be introduced into the mold or conduit from sources other than the furnace. When supplied from the furnace the gases travel through a bypass conduit 38 past the skimmer into the hood

and from there through corner openings 50 past the strainer into the mold. Before pouring commences the bottom 45 of the mold is removed to allow the gases to force the air therefrom. When the gases are separately supplied to the conduit they may be injected through an inlet 46 in the strainer casing, in which case the by-pass conduit 38 may be closed unless it is desired to have the gases pass upward into the furnace from below. The latter method (with the by-pass conduit plugged up) has some advantages since dust from the furnace when present is not permitted to follow the metal into the molds.

When the metal in the furnace is initially free from oxygen, as when electrodeposited copper is charged, it will be found that an inert gas alone may be used to protect the metal if conditions are carefully maintained. Ordinarily it is preferred to establish a deoxidizing atmosphere simply as an added insurance against oxidation.

Before the metal is poured into them the billet molds are thoroughly cleaned inside and coated with a suitable material to produce a smooth surface on the billets and to prevent them from sticking to the molds, the coating material preferably having a non-oxidizing or deoxidizing effect upon the metal. One material which has proved suitable for this purpose is bone-black.

The billets are preferably cast in deep vertical molds and the pouring is conducted slowly enough to induce freezing from the bottom upward when chill, i. e., fluid-cooled molds are used to cause the gases to be forced upward without being entrapped in the metal to cause unsoundness. With chill molds the temperature and hence the rate of cooling can be closely controlled and hence the depth of molten metal and the evolution of gases can be closely regulated.

It is important to maintain a uniform pouring temperature and for this purpose the current switch to the heating elements 34 is controlled by a pyrometer 51 and suitable relays R1, R2, etc. in the well known manner of controlling power switches from pyrometers. In the drawing the pyrometer is shown in the charging end of the furnace 30 instead of in the pouring end but in this case it is presumed that all of the metal in the furnace 30 will be in purified condition, as it would be when electrodeposited metal is charged or when the metal has been purified in a preceding furnace. The pyrometer must be encased in a suitable refractory cover such as a silica-alumina tube closed at the inner end to protect it from the metal. No suitable encasing material is known which will withstand the action of oxygen in molten oxygen-bearing copper; but I am enabled to use the pyrometer for the control because the metal in the furnace at the place where the pyrometer is located is so free of oxygen as to permit a refractory tube and hence a pyrometer to be used. In addition to the accurate control of the temperature of the metal as it is being poured, the heaters 39 and 44 insure the maintenance of the metal in a molten condition as it passes to the molds even though it may be poured at a temperature only slightly above the melting point.

After pouring and before the protecting gas has escaped, the billets are covered to prevent oxidation, assuming that the molds are moved forward from beneath the hood before all the metal has solidified. A covering such as finely powdered charcoal, barium chloride, calcium chloride or a heavy gas is used, the charcoal being preferred. The covering is allowed to remain un-

til the metal cools below the point at which it will absorb gases from the atmosphere.

While the induction furnace as used herein is best for producing clean heating and thorough circulation of the metal it may not be the most economical when used as the sole source of heat. For this reason it may be desirable to supply part of the melting heat to the metal before it enters the furnace 30. If the impurities in the metal are high it may also be desirable to melt and partly refine the metal before it is introduced into the furnace 30. For these purposes I provide a preheater 15 employing electrical heating means such as resistance heaters 16 and, in some cases provide a melting furnace 20 which is heated inductively.

The preheater, besides supplying heat economically, may be employed for removing sulphur when that is present. For example, after a charge 10 of crude metal has been passed through the door 13 into the lock chamber 12 by the conveyor 11 the door 14 is raised and a gas such as hydrogen (for copper) may be injected at the inlet 21 to reduce the sulphur and some of the oxygen also as soon as the metal becomes heated sufficiently. For other metals and for removing other impurities I may, of course, employ other gases, for example, carbon monoxide for brass, aluminum, etc. The gases of combustion escape by the outlet 23. While being heated the charges are moved by the conveyor 17 and finally are discharged into the melting furnace 20, when that is used.

When hydrogen is used the bath in furnace 20 is left uncovered and there the action continues due to the circulation of the metal. The process carried out in furnace 30 is suited for the removal of a portion of the hydrogen if left in the metal. In any event, the subsequent treatment is adequate for the removal of enough of the hydrogen so it will not produce unsound metal during casting.

A spout 24 protected against the outflow of the covering material like the spout 32 and also heated by non-contaminating means may be employed for passing the metal to the furnace 30. An articulated hood 25 provides an enclosure for deoxidizing or inert gases flowing toward furnace 20 from the furnace 30 to protect the metal while being poured.

Instead of using hydrogen to remove sulphur, air may be used if the bath in furnace 20 is protected by a suitable covering such as carbon. When air is used the inner door 14 is left open permanently and after a charge has been introduced the outer door 13 is left open a slight amount to admit the small quantity of air required. Exhaust fumes may escape by way of the opening 21 or by some other vent which may be provided near the furnace end of the preheating chamber, the other vent 23 being closed for this operation.

The air, of course, will form additional oxides in the metal but these will be reduced beneath the carbon covering in the bath of furnace 20 and any remaining will be completely removed in the furnace 30.

It may be desirable to cover the bath in furnace 20 with carbon even when hydrogen gas is used in the preheater for removing sulphur and oxygen. In this case if the original oxygen content was low it may be found that the carbon has removed all the residue of oxygen or has reduced it to a very low amount and that the metal may be poured directly from the furnace 20 into the

molds. When this is done the protection during and after pouring will be provided as described for pouring metal from furnace 30.

In all variations of the method described above the metal is treated in an inert or reducing atmosphere. The reducing atmosphere for copper, which is taken as a specific example, is usually maintained in part at least by a carbon covering on the bath. Also the metal is melted or maintained in a molten state within an electric induction furnace. Circulation of the metal is desirable both to bring all the metal to the surface frequently for contact with the carbon or the reducing atmosphere and also to promote the evolution of gases absorbed or dissolved in the metal. This is accomplished by the electrical effects of the induction heating or by mechanical movement of the vessel or both.

The assurance of obtaining pure metal in the final condition is provided by the extreme care taken to protect the molten stream by enclosing casings and gas contact as the metal cascades during pouring and also by covering the metal in the molds until it changes from the molten to the solid condition. In this manner the interaction of hydrogen and oxygen in the molten metal in the final stage is avoided and sound metal is formed. Any fine holes formed by such gases as remain may readily be welded together by virtue of their oxygen-free surfaces by hot working the metal in the solid state.

The resulting metal may be formed into various shapes. When pouring the metal into shapes which will be subsequently worked I prefer to use deep molds poured vertically, as mentioned above. The particular shapes preferred are round billets, wire bars with parallel sides and at least one pointed end and cakes with all sides substantially parallel.

The terms "vessel", "device", and "instrument" where they appear in the specification and claims are used synonymously and in their broadest sense to refer to any form of instrumentality or means which is capable of confining molten metal and accomplishing the other functions required of it. The terms "oxygen-free" and "free from metallic oxides" used herein as descriptive of metals and alloys are considered synonymous and mean free from the oxides of the metal or the metals of the alloys. When, for example, copper is characterized as "oxygen-free", it means that the copper does not contain any copper oxide, although it may contain some oxygen in the form, for instance, of carbon monoxide, which is not oxidizing to copper.

While specific embodiments of my invention have been described in detail in order to furnish a clear conception of the invention it is to be understood that the invention is not limited thereby but may have other embodiments within the limits of the prior art and the scope of the subjoined claims.

What I claim is:

1. In the art of refining copper, the method which comprises continuously charging into a bath of molten copper fully protected from the air in a heating vessel, increments of copper which is substantially free from sulphur and other contaminating substances such as are found in the gases of fuel heating flames; continuously maintaining the bath of copper in a molten condition in the vessel by the application of heat free from contaminating gases of fuel heating flames; continuously maintaining the space within the vessel adjacent the metal free from atmos-

pheric air, oxidizing gases and other contaminating substances; continuously maintaining directly upon the copper, a covering of carbon and an atmosphere composed principally of carbon monoxide which are capable of completely removing any oxygen which the copper may contain; and continuously maintaining at a given point within the vessel a body of the copper protected from the atmospheric air and ready for removal from the vessel.

2. In the art of refining copper, the method which comprises continuously charging increments of copper into a bath of molten copper confined in an electric heating furnace; continuously maintaining the bath of copper in a molten condition in the furnace by the application of electric heating; continuously maintaining the space within the furnace adjacent the copper free from atmospheric air, oxidizing gases and other contaminating substances; continuously maintaining in contact with the metal in the furnace a covering of carbon and an atmosphere composed principally of carbon monoxide capable of completely deoxidizing the copper and which leave no injurious residues in the copper; and continuously maintaining at a given point within the furnace a body of the copper at a uniform temperature ready for removal by automatically regulating the application of heat by the electric heating elements of the furnace by and in accordance with the temperature of the copper as registered by a temperature responsive element immersed in the copper bath.

3. The method of refining and casting metals which comprises, establishing and continuously maintaining within a pouring vessel a body of substantially deoxidized metal in a molten condition ready to pour while maintaining within the vessel and in contact with the metal a non-oxidizing medium to the exclusion of atmospheric air and other contaminating gases; pouring the metal from the pouring vessel in a falling stream into a receiving vessel while maintaining about the stream and the metal in the receiving vessel at super-atmospheric pressure a body of gas which is positively and completely isolated against the inflow and intermingling therewith of atmospheric air, the gas being free from contaminating gases of fuel heating flames and incapable of causing oxidizing reactions during pouring, and maintaining about the metal in the receiving vessel a protecting medium which completely excludes atmospheric air until the metal has solidified to the extent that oxygen of the air will not readily attack it.

4. The method of refining and casting copper which comprises, continuously maintaining within a pouring vessel a body of deoxidized and desulphurized copper in a molten condition ready to pour while maintaining about the metal a harmless deoxidizing carbonaceous medium to the exclusion of atmospheric air and the contaminating gases of combustion heating flames; pouring copper from the pouring vessel in a falling stream into a receiving vessel while maintaining about the stream and the metal in the receiving vessel at super-atmospheric pressure a body of deoxidizing carbonaceous gas which is positively and completely isolated against the inflow and intermingling therewith of atmospheric air, the gas being free from contaminating gases of fuel heating flames; and maintaining about the copper in the receiving vessel a protecting medium which completely excludes atmospheric air until

the copper has solidified to the extent that oxygen of the air will not readily attack it.

5 5. The method of refining and casting metals which comprises, continuously maintaining within a pouring vessel a body of substantially de-
oxidized metal in a molten condition ready to
pour, adding additional metal to maintain the
supply, while maintaining within the vessel and
10 in contact with the metal a non-oxidizing medium to the exclusion of atmospheric air and contaminating gases of fuel heating flames; pouring the
metal from the pouring vessel in a falling stream
into a receiving vessel while maintaining about
the stream and the metal in the receiving vessel
15 at superatmospheric pressure a non-oxidizing medium particularly free from contaminating
gases of fuel heating flames which positively isolates the metal from the air; and maintaining
about the metal in the receiving vessel a non-
20 oxidizing medium which completely excludes atmospheric air until the metal has solidified to the extent that oxygen of the air will not readily attack it.

6. The method of refining and casting metals
25 which comprises continuously maintaining within a pouring vessel a body of substantially de-oxidized metal in a molten condition ready to pour while maintaining within the vessel and in
contact with the metal a non-oxidizing medium
30 to the exclusion of atmospheric air and contaminating gases of fuel heating flames; pouring the
metal from the pouring vessel in a falling stream into an intermediate pool and from the pool in a
falling stream into a receiving vessel where it
35 solidifies, while maintaining about the streams and the metal in the pool and receiving vessel at
super-atmospheric pressure a body of gas which is positively and completely isolated against the
inflow and intermingling therewith of atmospheric air, the gas being free from contaminating
40 gases of fuel heating flames and incapable of causing oxidizing reactions during pouring; and
maintaining about the metal in the receiving vessel a protecting medium which completely ex-
45 cludes atmospheric air until the metal has solidified to the point where oxygen of the air will not readily attack it.

7. The method of refining and casting metals which comprises, establishing and continuously
50 maintaining within a pouring vessel a body of substantially deoxidized metal in a molten condition ready to pour while maintaining within the
vessel and in contact with the metal a non-oxidizing medium to the exclusion of atmospheric air
55 and other contaminating gases; pouring the metal from the pouring vessel in a falling stream into
a receiving vessel while maintaining about the stream and the metal in the receiving vessel at
super-atmospheric pressure a body of gas which
60 is positively and completely isolated against the inflow and intermingling therewith of atmospheric
air, the gas being free from contaminating gases of fuel heating flames and incapable of causing
oxidizing reactions during pouring; maintaining
65 a constant control of the temperature of the metal where it leaves the bath and during its passage
to the receiving vessel; and maintaining about the metal in the receiving vessel a protecting medium which completely excludes atmospheric air
70 until the metal has solidified to the extent that oxygen of the air will not readily attack it.

8. The method of refining and casting metals which comprises, establishing and continuously
75 maintaining within a pouring vessel a body of substantially deoxidized metal in a molten condi-

tion ready to pour while maintaining within the vessel and in contact with the metal a non-oxidizing medium to the exclusion of atmospheric air and other contaminating gases; pouring the
5 metal from the pouring vessel in a falling stream into an intermediate shallow pool and thence into a receiving vessel while maintaining about the
stream and the metal in the receiving vessel at super-atmospheric pressure a body of gas which is positively and completely isolated against the
10 inflow and intermingling therewith of atmospheric air, the gas being free from contaminating gases of fuel heating flames and incapable of causing
oxidizing reactions during pouring; maintaining a constant control of the temperature of the metal
15 where it leaves the bath, in the pool during its passage to the receiving vessel, and in the receiving vessel; and maintaining about the metal in
the receiving vessel a protecting medium which completely excludes atmospheric air until the
20 metal has solidified to the extent that oxygen of the air will not readily attack it.

9. In the art of refining and casting metals, the method of obtaining a product substantially
25 free from oxides of the metal and objectionable gas cavities upon casting from a molten bath, which comprises maintaining a bath of molten
metal substantially free from metallic oxides in a pouring vessel free from atmospheric air and
30 other contamination adjacent the metal, pouring the metal in a falling stream, while completely
protected structurally from the pouring vessel into a receiving vessel; maintaining the metal
at a constant temperature where it leaves the pouring vessel; and delaying the beginning of
35 solidification until the metal reaches the receiving vessel by applying heat along the stream without subjecting the metal to the contaminating
products of combustion of fuel heating flames.

10. In the art of refining and casting metals, 40
the method of obtaining a product substantially free from oxides of the metal and objectionable
gas cavities upon casting from a molten bath, which comprises maintaining a bath of molten
45 metal substantially free from metallic oxides in a pouring vessel free from atmospheric air and
other contamination adjacent the metal, pouring the metal in a falling stream, while completely
protected structurally, from the pouring vessel into a receiving vessel; maintaining the metal at
50 a constant temperature where it leaves the pouring vessel; delaying the beginning of solidification until the metal reaches the receiving vessel
by applying heat along the stream without subjecting the metal to the contaminating products
55 of combustion of fuel heating flames; and controlling the rate of cooling of the metal in the receiving vessel by controlling the rate of pouring
and the temperature of the receiving vessel to prevent the entrapment of gases in the solidifying metal.

11. In the art of refining and casting metals, the method of obtaining a product substantially
free from oxides of the metal and objectionable
65 gas cavities upon casting from a molten bath, which comprises maintaining a bath of molten
metal substantially free from metallic oxides in a pouring vessel free from atmospheric air
adjacent the metal, pouring the metal in a falling stream from the pouring vessel into a shallow
70 pool and thence into a receiving vessel while completely protected structurally; maintaining
the metal at a constant temperature where it leaves the pouring vessel; and delaying the beginning
of solidification until the metal reaches 75

the receiving vessel by applying heat to the stream and pool without subjecting the metal to the contaminating products of combustion of fuel heating flames.

12. The method of refining and casting metals which comprises, establishing and continuously maintaining a body of substantially deoxidized metal in a molten condition ready to pour within a pouring vessel while maintaining within the vessel and in contact with the metal a non-oxidizing medium to the exclusion of atmospheric air and other contaminating gases; pouring the metal from the pouring vessel in a falling stream into a receiving vessel while maintaining about the stream and the metal in the receiving vessel at super-atmospheric pressure a body of gas which is positively and completely isolated against the inflow and intermingling therewith of atmospheric air, the gas being free from the contaminating gases of fuel heating flames and incapable of causing oxidizing reactions during pouring; and maintaining about the metal in the receiving vessel a protecting medium which completely excludes atmospheric air until the metal has solidified to the extent that oxygen of the air will not readily attack it, the gas for positively protecting the metal in the pouring vessel and along the stream being supplied in considerable excess of the amount required for any chemical action which it may have whereby it will constantly flow outward away from the metal at all points of escape and remove certain gaseous contents of the metal by dilution.

13. The method of refining and casting metals which comprises, continuously maintaining a body of deoxidized and desulphurized metal in a molten condition ready to pour from a pouring vessel while maintaining about the metal a deoxidizing medium to the exclusion of atmospheric air and the contaminating gases of fuel heating flames; bringing metal receiving molds successively into position to receive metal poured from the pouring vessel; connecting the molds as they halt in position with the pouring opening of the pouring vessel by a tight structural enclosure but leaving the remote portion of the mold open; maintaining in the structural enclosure at super-atmospheric pressure a deoxidizing gas which is free from contaminating gases of fuel heating flames; permitting the gas from the enclosure to flow through the mold connected thereto until all of the air and other original gases have been purged therefrom and then closing the remote opening of the mold; successively pouring portions of the metal from the pouring vessel into the molds in a free stream or cascade through the enclosure and the enclosed body of protecting gas; and maintaining about the metal in the molds a protecting medium which completely excludes atmospheric air until the metal has solidified to the extent that oxygen of the air will not readily attack it.

14. The method of refining metals, the oxides of which readily destroy the refractory coverings of pyrometers immersed therein, which comprises, subjecting the metal to a treatment adapted to remove oxides therefrom in a first furnace, passing the metal while completely enclosed from the atmosphere and surrounded by a non-oxidizing gas at super-atmospheric pressure to a second furnace, subjecting the metal to a treatment adapted to substantially eliminate all of its oxides in the second furnace, maintaining the metal completely enclosed free from oxygen and protected by a non-oxidizing

gas under super-atmospheric pressure in the second furnace; and maintaining a uniform pouring temperature of the metal in the second furnace by a refractory-encased pyrometer immersed in the metal at a point where it is substantially free from its oxides.

15. The method of refining metals, the oxides of which readily destroy the refractory coverings of pyrometers immersed therein, which comprises maintaining at one point in a melting apparatus a body of the metal in a molten condition, subjecting the metal to a treatment which will insure substantially complete freedom from its oxides; passing the oxygen-free metal while fully protected from oxidizing effects to a point of delivery; and maintaining the metal at a substantially uniform temperature ready for delivery by a refractory-encased pyrometer immersed in the body of molten oxygen-free metal.

16. The method of refining copper to produce sound castings which comprises, charging the metal into a molten bath of copper in an electric furnace which is completely enclosed structurally from the atmospheric air; maintaining a covering of carbon in contact with the bath in the furnace; and maintaining in the furnace enclosure at super-atmospheric pressure a protecting body of de-oxidizing gas composed principally of carbon monoxide.

17. The method of refining copper to produce sound castings which comprises, maintaining a bath of molten copper in an electric furnace which is completely enclosed structurally from the atmospheric air; charging into the bath increments of copper which is free from the harmful effects of the gases of fuel heating flames; maintaining a covering of carbon in contact with the bath in the furnace; and maintaining in the furnace enclosure at super-atmospheric pressure a protecting body of deoxidizing gas composed predominantly as to active constituent of carbon monoxide.

18. The method of refining copper to produce sound castings which comprises, maintaining a bath of molten copper in an electric furnace in the presence of carbon; charging into the bath increments of copper which is free from the harmful effects of the gases of fuel heating flames; maintaining in contact with the metal a protecting body of deoxidizing gas composed principally of carbon monoxide; and pouring the pure metal from the furnace into a receiving vessel while protecting the metal by an envelope of a protecting body of deoxidizing gas composed predominantly as to active constituent of carbon monoxide fully confined structurally against the atmospheric air, the gas being maintained at super-atmospheric pressure whereby any leakage is outward.

19. The method of refining copper to produce sound castings which comprises, maintaining a bath of molten copper in an electric furnace in the presence of carbon; charging into the bath increments of copper which is free from the harmful effects of the gases of fuel heating flames; maintaining in contact with the metal a protecting body of deoxidizing gas composed principally of carbon monoxide; and pouring the pure metal from the furnace into a receiving vessel while protecting the metal by an envelope of a protecting body of deoxidizing gas composed predominantly as to active constituent of carbon monoxide fully confined structurally against the atmospheric air, the gas being maintained

at super-atmospheric pressure whereby any leakage is outward, and being supplied in considerable excess above the amount required for chemical reaction whereby to further insure that any leakage of gas will be outward away from the metal and to remove hydrogen and other gases, which do not react chemically with the protecting gas, by dilution.

20. The method of refining copper to produce sound castings which comprises, maintaining a bath of molten copper in an electric furnace in the presence of carbon; charging into the bath increments of copper which is free from the harmful effects of gases of fuel heating flames; maintaining in contact with the metal a protecting body of deoxidizing gas composed principally of carbon monoxide; pouring the pure metal from the furnace into a receiving vessel while protecting the metal by an envelope of a protecting body of a deoxidizing gas composed predominantly as to active constituent of carbon monoxide fully confined structurally against the atmospheric air, the gas being maintained at super-atmospheric pressure whereby any leakage is outward; and maintaining the pouring temperature of the copper substantially constant by regulating the application of heat to the metal in the furnace through the electric heating elements thereof by and in accordance with the temperature registered directly by the bath of metal.

21. The method of refining copper to produce sound castings which comprises, maintaining a bath of molten copper in an electric furnace in the presence of carbon; charging into the bath increments of copper which is free from the harmful effects of the gases of fuel heating flames; maintaining in contact with the metal a protecting body of deoxidizing gas composed principally of carbon monoxide; pouring the pure metal from the furnace into a receiving vessel while protecting the metal by an envelope of a protecting body of deoxidizing gas composed predominantly as to active constituent of carbon monoxide fully confined structurally against the atmospheric air, the gas being maintained at super-atmospheric pressure whereby any leakage is outward; causing metal in the receiving vessel to solidify while further metal is being poured therein; and positively protecting from the atmospheric air any unsolidified metal remaining after the pouring ceases until it has cooled to the point at which oxygen of the atmosphere will not contaminate it.

22. The method of refining copper to produce sound castings which comprises, maintaining a bath of molten copper in an electric furnace in the presence of carbon; charging into the bath increments of copper which is free from the harmful effects of the gases of fuel heating flames; maintaining in contact with the metal a protecting body of deoxidizing gas composed principally of carbon monoxide; pouring the pure metal from the furnace into a receiving vessel while protecting the metal by an envelope of a protecting body of deoxidizing gas composed predominantly as to active constituent of carbon monoxide fully confined structurally against the atmospheric air, the gas being maintained at super-atmospheric pressure whereby any leakage is outward; and applying heat to the flowing stream by a heating medium having no contact with the metal to keep the metal in molten condition until it reaches the receiving vessel.

23. In the art of refining copper to produce sound castings, the method which comprises,

heating the copper charges to a high temperature below the melting point by electrical resistor heating devices in the presence of a gas capable of combining with sulphur if present and removing it while keeping the metal free from the contaminating gases of fuel heating flames; transferring the copper charges to an electric induction furnace and melting them beneath a covering of carbon to remove substantially all of the oxygen if present while keeping the metal free from contaminating gases of fuel heating flames; and pouring the metal while completely and positively excluding atmospheric air by a carbon monoxide gas envelope maintained at super-atmospheric pressure and structurally separated from the air.

24. In the art of refining copper to produce sound castings, the method which comprises, heating the copper charges at a high temperature below the melting point in the presence of hydrogen and free from the contaminating gases of fuel heating flames; transferring the charges to an enclosed melting vessel and melting them free from the harmful gases of fuel heating flames, in contact with carbon; and maintaining in the vessel in contact with the metal and at super-atmospheric pressure a constantly replenished supply of a deoxidizing gas consisting largely of carbon monoxide which removes oxygen by chemical reaction and hydrogen by dilution.

25. In the art of refining metals to produce sound castings, the method which comprises, heating the metal charges at a high temperature below the melting point in the absence of the harmful gases of fuel heating flames; transferring the charges to a melting furnace and melting them free from contaminating gases of fuel heating flames while positively protected from atmospheric air by a non-oxidizing gas at super-atmospheric pressure; and pouring the metal while completely and positively protected from atmospheric air by a non-oxidizing gas envelope maintained at super-atmospheric pressure and structurally separated from the air.

26. In the art of refining copper to produce sound castings, the method which comprises, desulphurizing copper cathodes in the solid condition, melting them free from contact with sulphur in an electric induction furnace beneath a covering of carbon and in contact with carbon monoxide whereby the metal is circulated by the inductive heating into frequent and intimate contact with the carbonaceous reducing agents to remove oxygen from the metal if present.

27. The method of refining copper which comprises, taking charges of electro-deposited or cathode copper which is approximately free of sulphur and introducing these charges into a bath of molten copper in a fully enclosed electric melting furnace; maintaining a carbon covering upon and in contact with the bath; maintaining the space within the furnace above the metal positively free from atmospheric air by maintaining within the furnace a non-oxidizing gas at super-atmospheric pressure; and transferring molten copper from the furnace to a mold while keeping the metal positively protected by an enclosed body of non-oxidizing gas at superatmospheric pressure.

28. The method of treating metals which readily oxidize upon exposure to air while molten and which are injuriously affected in the final stages before solidifying by the gases of hydrocarbon fuel heating flames, which comprises, continuous-

ly adding increments of metal into a vessel; continuously maintaining the metal in the vessel in a molten condition free from contaminating gases of fuel heating flames; continuously maintaining in contact with the metal in the vessel, a medium which protects the metal from oxidation and delivers it completely free from metallic oxides, the medium being of such a nature that it leaves no harmful residues in the metal; and continuously maintaining at a delivery point in the vessel a body of deoxidized metal positively protected against oxidation by a body of gas which is substantially enclosed from the atmospheric air and maintained under sufficient pressure to cause any flow of gases to be outward away from the metal and toward the atmospheric air.

29. The method of treating non-ferrous metals which readily oxidize upon exposure to air while molten and which are injuriously affected in the final stages before solidifying by the gases of hydrocarbon fuel heating flames, which comprises, continuously charging increments of metal into a pouring vessel; continuously maintaining the metal in the pouring vessel in a molten condition free from the contaminating gases of fuel heating flames; continuously maintaining in contact with the metal in the vessel a medium which protects the metal from oxidation and delivers it completely free from metallic oxides, the medium being of such a nature that it leaves no harmful residues in the metal; and pouring oxygen-free metal from the pouring vessel while positively and completely protecting it with a harmless gas containing carbon monoxide, the gas being substantially enclosed and under sufficient pressure to cause any leakage to be outward away from the metal, whereby the access of air and other contaminating substances to the metal is prevented.

30. The method of treating non-ferrous metals which readily oxidize upon exposure to air while molten and which are injuriously affected in the final stages before solidifying by the gases of hydrocarbon fuel heating flames, which comprises, continuously charging increments of metal into a pouring vessel; continuously maintaining the metal in the pouring vessel in a molten condition free from contaminating gases of fuel heating flames; continuously maintaining in contact with the metal in the vessel a medium which protects the metal from oxidation and delivers it completely free from metallic oxides, the medium being of such a nature that it leaves no harmful residues in the metal; and pouring the oxygen-free metal from the pouring vessel while positively and completely protecting it with a harmless gas containing carbon monoxide, the gas being substantially enclosed and under sufficient pressure to cause any leakage to be outward away from the metal, whereby the access of air and other contaminating substances to the metal is prevented, the receiving instrument into which the metal is poured being completely scavenged of all air and other injurious substances before the metal is poured into it and the metal being protected against the air and other injurious substances until the metal is solidified.

31. The method of treating electro-deposited copper, to render it workable, which comprises, melting cathode copper in an electric furnace while protecting it by a non-oxidizing medium in contact therewith, transferring the metal from the furnace to a solidifying instrument while keeping the metal protected by an enclosed body of non-oxidizing gas maintained at super-atmos-

pheric pressure to prevent the inward leakage of air and other contaminating gases to the metal, and solidifying the metal while protecting it from the air and other contamination.

32. The method of treating electro-deposited copper to render it workable, which comprises, melting cathode copper in an electric furnace while protecting it by a non-oxidizing medium in contact therewith, transferring the metal from the furnace to a solidifying instrument while keeping the metal protected by an enclosed body of non-oxidizing gas maintained at super-atmospheric pressure to prevent the inward leakage of air and other contaminating gases to the metal, and solidifying the metal while protecting it from the air and other contamination, the solidifying instrument being purged by filling the entire space to be occupied by the metal with a non-oxidizing gas at super-atmospheric pressure thereby removing all the air before the metal is transferred into it.

33. The method of treating copper which comprises, melting it in a first device in contact with a harmless carbonaceous reducing agent, passing the copper to a second device while protecting it with a harmless gas containing carbon monoxide, purging the space to be occupied by the metal during solidification by filling it with a non-oxidizing gas at super-atmospheric pressure thereby removing all the air therefrom before the metal is transferred into it, and solidifying the copper while protecting it from the air and other contamination.

34. The method of refining non-ferrous metals which readily oxidize upon exposure to the air, which comprises, melting the metal in a fuel-fired furnace, and transferring the metal to an electric furnace and there thoroughly contacting all of the metal with a harmless carbonaceous reducing agent to remove substantially all of the metallic oxides which may be present while protecting the metal at the point of delivery from the furnace from the air and other contaminating influences by a non-oxidizing gas at super-atmospheric pressure.

35. The method of refining non-ferrous metals which readily oxidize upon exposure to the air, which comprises, melting the metal in a fuel-fired furnace, transferring the metal to an electric furnace and there thoroughly contacting all of the metal with a harmless carbonaceous reducing agent to remove substantially all of the metallic oxides which may be present while protecting the metal at the point of delivery from the furnace from the air and other contaminating influences by a non-oxidizing gas at super-atmospheric pressure, and withdrawing the metal from the furnace and solidifying it while protecting it from oxidizing influences and from the contaminating gases of fuel heating flames by a non-oxidizing gas at super-atmospheric pressure.

36. The method of refining copper which comprises, melting the copper in a fuel-fired furnace which tends to oxidize the metal, transferring the metal to a treating vessel and there subjecting it in molten condition to a complete reaction with a harmless carbonaceous reducing agent by bringing all of the metal into thorough contact with the reducing agent while keeping the metal protected from the air and the contaminating products of combustion of fuel heating flames to perform a complete reducing action on the metal, and pouring the oxygen-free copper while protecting it from air by a gas composed principally as to active constituent of carbon monoxide, the

protecting gas for pouring being confined at super-atmospheric pressure within a structural enclosure.

37. The method of producing sound copper forms by a pyrometallurgical melting process, which comprises, subjecting molten copper to a contact reaction with a harmless carbonaceous reducing agent, free from effective quantities of the contaminating gases of hydrocarbon fuel heating flames, the reaction being sufficiently complete to produce molten copper which is substantially free from metallic oxides, and casting the oxygen-free copper while protecting it from oxidizing substances by a harmless carbonaceous reducing agent free from effective quantities of the contaminating gases of hydrocarbon fuel heating flames.

38. The method of treating metals which readily oxidize in the molten state to produce sound solid objects thereof, which comprises, subjecting the metal in the molten state in a first device to a complete contact reaction with a reducing agent the reaction product of which can escape without leaving harmful residues in the metal, whereby to provide a supply of the molten metal entirely free from oxides and harmful residues of the reducing agent, passing the metal to a second device where it solidifies while positively protecting it from oxidizing and other contaminating influences by a non-oxidizing gas which leaves no harmful residues in the metal, the gas being confined at super-atmospheric pressure with the metal in a structural enclosing device, and positively protecting the metal from the air until solid.

39. The method of treating copper to produce sound solid objects thereof, which comprises, subjecting the copper in the molten state in a first device to a complete contact reaction with a carbonaceous reducing agent the reaction products of which can escape without leaving harmful residues in the metal, whereby to provide a supply of molten copper entirely free from oxides and harmful residues of the reducing agent, passing the copper to a second device where it solidifies, while positively protecting it from oxidizing and other contaminating influences by a non-oxidizing gas which leaves no harmful impurities in the metal, the gas being confined with the metal at super-atmospheric pressure, and positively protecting the metal from the air until solid.

40. The process of producing sound copper castings which comprises, subjecting cathode copper in the solid state to a desulphurizing treatment, melting the copper, subjecting the metal in the molten state to a sufficiently complete and thorough contact with carbon to insure substantial freedom from all metallic oxides in the metal, and protecting the metal during the deoxidizing treatment against atmospheric air and contaminating combustion gases of fuel heating flames.

41. The process of producing sound copper castings which comprises, subjecting cathode copper in the solid state to a desulphurizing treatment, melting the copper, subjecting the metal in the molten state to a sufficiently complete and thorough contact with carbon to insure substantial freedom from all metallic oxides in the metal, protecting the metal during the deoxidizing treatment against atmospheric air and contaminating combustion gases of fuel heating flames, and pouring the oxygen-free metal and protecting it during pouring by a harmless carbonaceous reducing agent.

42. The process of producing sound copper castings which comprises, subjecting cathode copper in the solid state to a desulphurizing treatment, melting the copper, subjecting the metal in the molten state to a sufficiently complete and thorough contact with carbon to insure substantial freedom from all metallic oxides in the metal, protecting the metal during the deoxidizing treatment against atmospheric air and contaminating combustion gases of fuel heating flames, and pouring the oxygen-free metal into solidifying instruments and protecting it during pouring by an enclosed body of harmless carbonaceous reducing gas.

43. The process of producing sound copper castings which comprises, subjecting cathode copper in the solid state to a desulphurizing treatment, melting the copper, subjecting the metal in the molten state to a sufficiently complete and thorough contact with carbon to insure substantial freedom from all metallic oxides in the metal, protecting the metal during the deoxidizing treatment against atmospheric air and contaminating combustion gases of fuel heating flames, and pouring the oxygen-free metal into solidifying instruments and protecting it during pouring and until it has solidified by a harmless carbonaceous reducing agent.

44. The method of treating metals which in their molten state are subject to the attack of atmospheric gases, which comprises, preparing a body of molten metal which is substantially free from metallic oxides and injurious effects of fuel heating flames, pouring the metal outside of the confines of the pouring vessel into a receiving instrument while protecting the metal during pouring by an enclosed body of harmless gas at super-atmospheric pressure which completely envelops the flowing metal, and further protecting the metal from the air until it has solidified.

45. The method of treating metals which in their molten state are subject to the attack of atmospheric gases, which comprises, preparing a body of molten metal which is substantially free from metallic oxides and injurious effects of fuel heating flames, pouring the metal outside of the confines of the pouring vessel into a receiving instrument while protecting the metal during pouring by an enclosed body of harmless gas at super-atmospheric pressure which completely envelops the flowing metal, and further protecting the metal from the air until it has solidified, the metal being passed during pouring through a shallow pool within the enclosed body of gas to promote the release of gases therefrom.

46. The method of treating metals which in their molten state are subject to the attack of atmospheric gases, which comprises, preparing a body of molten metal which is substantially free from metallic oxides and injurious effects of fuel heating flames; pouring the metal outside of the confines of the pouring vessel into a receiving instrument while protecting the metal during pouring by an enclosed body of harmless gas at super-atmospheric pressure which completely envelops the flowing metal, the metal being poured into deep vertical molds slowly enough to permit solidification from the bottom upward whereby the pool of metal in the mold is kept relatively shallow and the gases are permitted to escape from the solidifying metal, and further protecting the metal from the air until it has solidified.

47. The method of pouring metals which in

the molten state are subject to the attack of atmospheric gases which comprises, pouring the metal from a pouring vessel into a receiving instrument while the stream is surrounded throughout its passage from the pouring vessel to the receiving instrument by a structural enclosure which in effect forms a connecting conduit between the pouring vessel and the metal receiving portion of the receiving instrument and in which is maintained at super-atmospheric pressure a non-contaminating body of gas which is non-oxidizing toward the metal, whereby the metal is positively protected against contamination through contact with the atmosphere.

48. The method of pouring metals which in the molten state are subject to the attack of atmospheric gases which comprises, pouring the metal from a pouring vessel into a receiving instrument while the stream is surrounded throughout its passage from the pouring vessel to the receiving instrument by a structural enclosure in which is maintained at super-atmospheric pressure a non-contaminating body of gas which is non-oxidizing toward the metal, the enclosed body of gas being composed predominantly as to active constituent of carbon monoxide.

49. The process of treating copper cathodes, which consists in roasting and concurrently preheating the solid cathodes, in melting the cathodes and in exposing the melted copper to thorough contact with a reducing agent free from hydrogen.

50. The process of treating copper, which consists in roasting and concurrently preheating the solid charges, in melting the charges, in exposing the molten copper to thorough contact with a reducing agent free from contamination with substances rich in hydrogen, in casting the copper and in protecting the copper from air during casting by an atmosphere having a sufficiently low partial pressure of oxygen so as not to contaminate the copper with oxygen.

51. The process of treating copper to produce castings free from cuprous oxide and objectionable gas cavities, which consists in removing cuprous oxide from the copper by exposing the copper in molten condition to contact with carbon in the absence of contamination with air and harmful gases of combustion from hydrocarbon fuel and in casting the copper surrounded by a harmless gas containing carbon monoxide and having a sufficiently low partial pressure of oxygen so as not to contaminate the copper with oxygen or its compounds other than carbon monoxide.

52. The method of treating copper to make castings free from objectionable gas cavities, which consists in desulphurizing the copper, in removing cuprous oxide from the copper by exposing the copper in molten condition to contact with carbon in the absence of contamination with the atmosphere, in casting the copper and in protecting the copper during casting by an envelope of harmless gas containing carbon monoxide.

53. The method of treating copper to make castings free from objectionable gas cavities, which consists in desulphurizing copper cathodes in the solid state, in melting the cathodes, in

removing cuprous oxide from the molten copper by exposing the copper to contact with carbon in the absence of contamination with the atmosphere and with harmful gases of combustion from hydrocarbon fuel, in casting the copper and in protecting the copper during casting by an envelope of harmless gas containing carbon monoxide.

54. The method of treating copper to make castings free from objectionable gas cavities, which consists in removing cuprous oxide from the copper by exposing the copper in molten condition to contact with carbon in the absence of contamination with air and harmful gases of combustion from hydrocarbon fuel and in casting the copper while shielding it from the atmosphere by an envelope of harmless gas containing carbon monoxide.

55. The process of preparing copper castings free from excessive gas cavities, which consists in completely deoxidizing the metallic oxides in molten copper by a harmless carbonaceous reducing agent, free from objectionable contamination with hydrogen, in casting the copper in pure condition, and in protecting the copper from air during casting by surrounding the copper with carbon monoxide free from substances which will cause the liberation of carbon dioxide, hydrogen or steam in the solidifying copper.

56. The process of producing copper castings free from cuprous oxide and objectionable gas cavities, which consists in melting copper, in deoxidizing the molten copper to render it substantially free from cuprous oxide, in casting the copper in pure condition and in maintaining a reducing gaseous atmosphere free from hydrogen-contaminating substances around the copper from the time the copper is deoxidized until it is cast and during casting.

57. The method of treating copper to produce castings substantially free from cuprous oxide and objectionable gas cavities which comprises, continuously charging increments of solid copper into a melting furnace, continuously melting the increments of copper, continuously subjecting the molten copper to a sufficiently complete contact reaction with a harmless carbonaceous reducing agent to insure substantial freedom from metallic oxides, while keeping the copper free from contamination by the harmful gases of fuel heating flames, continuously maintaining a body of the treated copper in a non-oxidizing environment substantially free from intermingling with untreated metal and free from contamination with air and the harmful gases of fuel heating flames, and withdrawing and solidifying the treated copper from the non-oxidizing environment while protected from contamination by the air and the harmful gases of fuel heating flames.

58. The method of treating metals which comprises, continuously maintaining a body of molten metal, continuously subjecting the metal to a treatment which will insure substantially complete freedom from metallic oxides, continuously maintaining the treated metal at a substantially uniform temperature ready for delivery by a heat-responsive device immersed in the oxygen-free metal, and withdrawing and solidifying the oxygen-free metal.

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