Sept. 23, 1941. P. M. HULME ET AL 2,256,481

PRODUCING FLAT-SET COPPER SHAPES

Filed Oct. 30, 1940 2 Sheets-Sheet 1

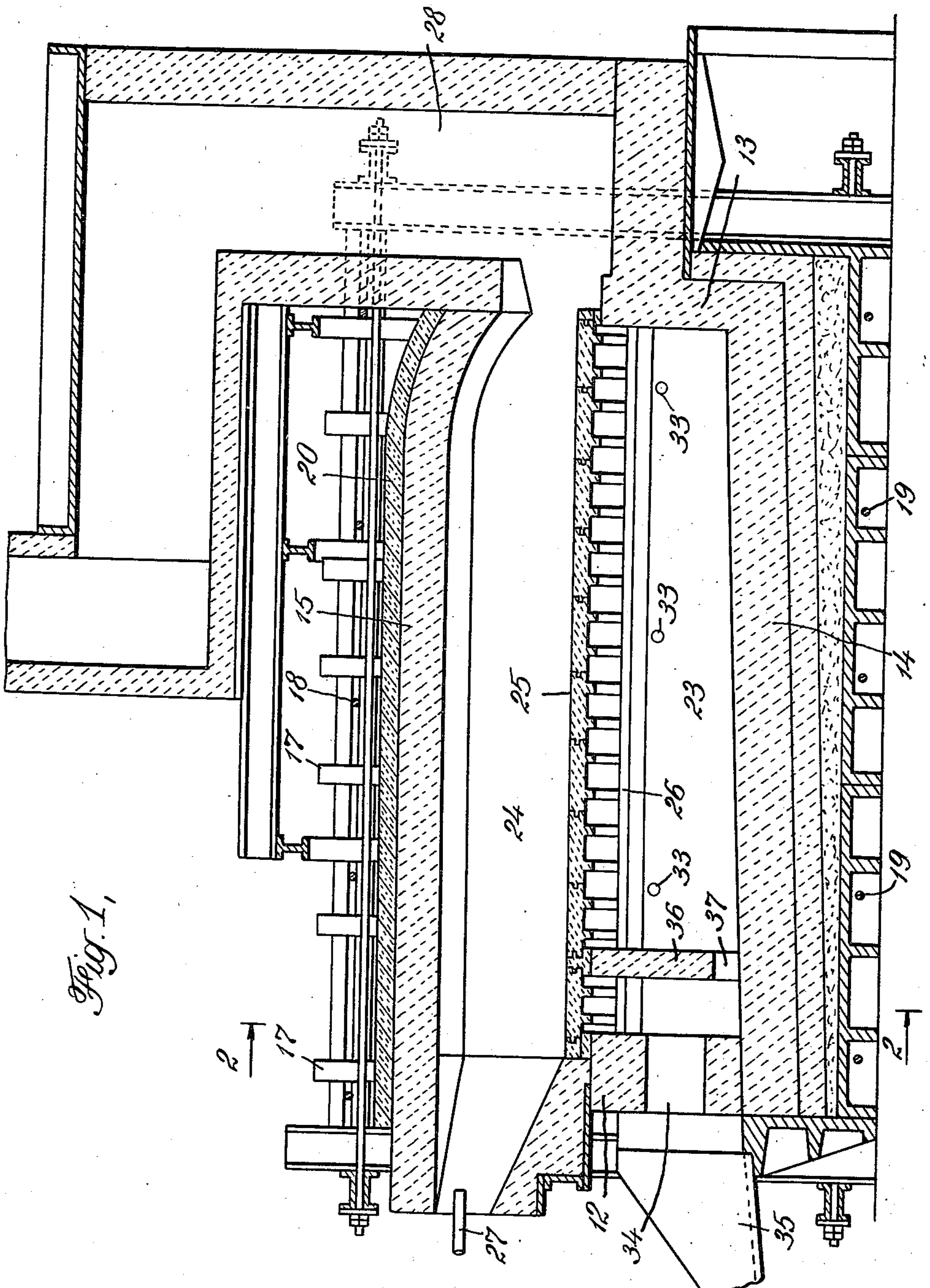

Fig. 1.

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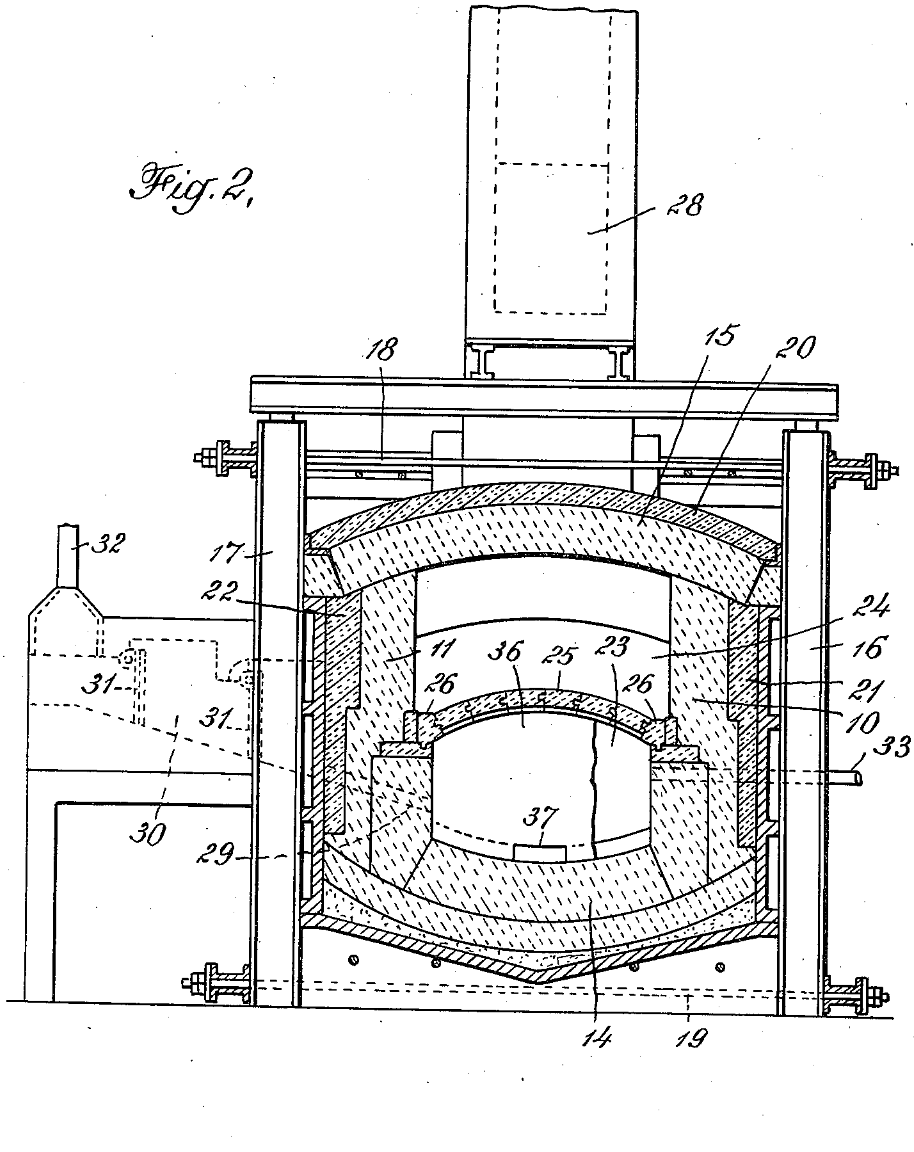
Fig. 2,



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PRODUCING FLAT-SET COPPER SHAPES

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9 Claims. (Cl. 75—76)

This invention relates to the production of substantially flat-set cast copper shapes, and has for its object the provision of an improved method for producing such shapes.

Most of the copper being produced commercially at the present time is electrolytically refined. Such copper is very pure, but physically it is unsuited for rolling, drawing, or other fabricating operations for producing commercial articles. Accordingly, it is necessary to melt the cathode copper produced by electrolytic refining methods and cast it into wire bars, billets, cakes, or other shapes from which commercial articles may be made.

The common practice for melting and casting electrolytic cathode copper heretofore has followed the old Welsh process for fire-refining, and is in fact known as a "refining" process. It involves first melting the copper in a fuel-fired furnace, skimming any slag formed, oxidizing the molten charge, skimming the oxidized impurities, and then poling the charge to reduce cuprous oxide. During the melting operation the copper is in contact with the gaseous combustion products of the fuel, and some of these gases are absorbed in and contaminate the copper. To remove these contaminants and other impurities, the molten copper is blown with air and then skimmed. In this manner impurities in the copper are largely removed, but some copper oxide is unavoidably formed and remains in the molten copper. The molten copper, therefore, is next covered with coke and subjected to a poling operation by plunging wooden poles below the surface of the molten metal. As a result of this operation, the cuprous oxide in the molten metal is reduced and the metal is conditioned for casting.

The progress of the poling operation is carefully watched by taking frequent samples and casting them into blocks. Whether or not the poling operation has proceeded to a sufficient extent is determined by observing the nature of the "set" or "pitch," that is, the condition of the exposed surface of these cast samples upon cooling. When the test samples show a proper set, poling is stopped and the molten copper is cast into suitable shapes.

The cast product solidifying in the mold with a substantially flat or slightly crowned surface, or "set," is known as "tough-pitch" or "flat-set" copper. This copper invariably contains a small amount of oxygen (0.01 to 0.05%), as the presence of a small amount of oxygen is necessary to insure the flat-set desired for rolling and drawing operations. The precise manner in which the oxygen functions to produce a flat-set is not fully understood, but it is generally believed that the oxygen reacts with very small amounts of impurities (particularly sulphur) present even in cathode copper, and forms a gas which comes out of solution as the copper cools. This gas expands and counteracts the tendency of metallic copper to shrink upon freezing by forming minute cavities in the casting in sufficient amount to prevent the formation of a shrinkage cavity or "pipe." If insufficient gas is evolved, the surface will be depressed, or if there is too much, the surface will raise and may even be broken by a spew of metal forced through the frozen surface scum. The former is known as "low-set" copper and the latter as "crown-set" copper, or "over-poled" copper where metal has been forced or spewed through the frozen scum. Only the flat-set or slightly-crowned copper is properly called tough-pitch copper, since by long usage the term "tough-pitch" has come to designate copper which upon casting solidifies with this desirable set. Although true tough-pitch copper invariably contains about 0.01% to 0.05% oxygen, the term "tough-pitch" may not properly be applied to any copper containing this amount of oxygen, for in some cases (depending upon the amounts of impurities, such as sulphur, in the copper) the presence of oxygen within these limits will not produce the flat-set or slightly crowned set required for commercial purposes.

Because of the commercial importance of producing true tough-pitch copper castings, the poling operation of the refining process must be very closely watched, and the melting and casting of copper by this process is truly an art requiring long experience to master, rather than a process subject to scientific control. Attempts have heretofore been made to simplify the process, but except for improvements of a mechanical nature for lightening the hand work involved, these attempts have been unsuccessful and the metallurgy of the process has remained unchanged.

In addition to being difficult to control properly, the refining process is subject to other disadvantages which heretofore have not been overcome. One of these disadvantages is that the process is inherently a batch operation. Each furnace charge must be heated and melted, oxidized and poled before casting can commence, and so the casting operation, during which time the furnace is actually producing a marketable product, is limited to a small fraction of the time required for each cycle of operation. In the case of the usual twenty-four hour cycle, for example, casting proceeds for only about five hours. Attempts heretofore made to make the melting and casting operation continuous have been unsuccessful.

A further disadvantage of the refining process is that it imposes severe treatment on the furnace employed. The alternate heating and cooling of the furnace refractories due to the repeated emptying of molten metal, charging with cold metal, and again melting, results in extensive heat losses and causes the furnace refractories to crack and spall. The average life of a furnace used in the refining process is only about five to six months.

In recent years, certain processes for the production of oxygen-free copper of high electrical conductivity have been developed. Such oxygen-free copper possesses certain desirable properties for a number of uses, and in view of the success that has been attained in its production, it might appear that the production of tough-pitch copper is doomed to obsolescence. Actually, however, this is not the case, for tough-pitch copper possesses some advantages over even oxygen-free copper. Moreover, the production of oxygen-free copper by the processes now available is expensive, and the demand for the consequently relatively expensive oxygen-free product is limited. By far the greater amount of copper now being sold is the less expensive tough-pitch copper, and it is likely that it will continue to be the most common form of copper sold for many years to come.

The present invention provides an improved method for producing tough-pitch or flat-set cast copper shapes in a manner that overcomes the disadvantages of the heretofore customary refining process. In accordance with the invention, substantially oxygen-free copper (e. g. cathode copper) to be melted is introduced into the melting chamber of a fuel-fired muffle furnace and therein is heated and melted largely by radiant heat. In this manner the copper during melting is kept out of contact with combustion gases, and so is not contaminated thereby during melting. A gaseous non-oxidizing (and preferably reducing) atmosphere is maintained in the melting chamber during melting to prevent oxidation of the metal. Substantially oxygen-free molten copper is withdrawn from the melting chamber and is exposed to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling. The resulting oxygen-bearing molten copper is then cast into suitable shapes.

An especially satisfactory and economical furnace for melting copper in accordance with the invention is a muffle furnace having a lower muffle or melting chamber and an upper combustion chamber separated by an arch of good heat conductivity. A bath of substantially oxygen-free molten copper is established and maintained in the melting chamber under conditions permitting unhindered transfer of radiant heat to the surface thereof. In other words, no medium of relatively poor heat conductivity, such as slag, charcoal and the like covers the surface of the molten metal. The copper to be melted is introduced into the melting chamber under conditions substantially inhibiting the introduction of air into the chamber, and fuel is introduced and burned in the combustion chamber above the arch in a manner to heat the arch and establish and maintain at its under surface a temperature at least equal to the melting point of copper, and preferably several hundred degrees thereabove. The copper in the melting chamber is melted largely by heat radiated thereto from the arch, while maintaining the aforesaid slag-free bath of substantially oxygen-free molten copper.

It has been found that the surface of the copper in the melting chamber should be maintained substantially free of reactive fused slag. The presence of such slag interferes with the transfer of radiant heat to the metal charge, and may attack the refractory lining of the melting chamber unless expensive refractories resistant to such attack are employed. It may be advantageous, however, to maintain on the surface of the copper in the melting chamber a layer of finely divided refractory material having a relatively high emissivity and of good heat conductivity, such as finely divided or granular silicon carbide. Such a layer may improve the transfer of radiant heat to the furnace charge.

The copper to be melted advantageously is charged continuously into the furnace and molten copper is withdrawn continuously therefrom for casting. The copper may be withdrawn through an open launder, with a layer of charcoal being maintained over, but not completely covering, the surface of the copper flowing through the launder. The amount of charcoal so employed is controlled so as to control the area of copper exposed to the air in a manner to permit incorporation in the copper of a proper amount of oxygen to produce a flat-set upon casting and cooling.

The oxygen-bearing product flowing from the launder is cast in any desired manner into suitable shapes.

The invention will be better understood from the following description, considered in connection with the accompanying drawings, in which

Fig. 1 is a longitudinal cross section through a furnace suitable for use in carrying out the invention; and

Fig. 2 is a horizontal cross section taken substantially along the line 2—2, of Fig. 1.

The furnace shown in the drawings comprises side walls **10** and **11** and end walls **12** and **13** of refractory brickwork. The furnace is provided with a refractory floor **14** adapted to support a body of molten copper, and an arched masonry roof **15** of refractory brick. The furnace is braced by vertical buckstays **16** and **17** connected by horizontal tie-rods **18** and **19** above and below the furnace. To conserve heat and enable development of adequately high temperatures (which the brickwork must be sufficiently refractory to withstand), the roof of the furnace is covered with a layer of insulation material **20** and the walls are insulated by layers of insulating brick **21** and **22**.

The interior of the furnace is divided into a muffle or melting chamber **23** and a combustion chamber **24** by means of a melting chamber arch **25** sprung between the side walls of the furnace. The arch **25** is relatively thin and of highly refractory material possessing good heat-conducting properties. The most satisfactory refractory material for the arch is silicon carbide (e. g. that known commercially as "Carborundum"), which is mechanically strong, highly refractory, and possessed of fairly good properties as a heat conductor. The arch should be as thin as it is practical to make it in order that there will be a maximum heat transfer therethrough. Silicon carbide is sufficiently strong mechanically to enable construction of a thin arch, of the order of a few inches in thickness, about six feet or so wide.

The arch 25 is sprung between refractory blocks 26 extending the length of the furnace. Advantageously these refractory blocks also are of silicon carbide.

Oil burners 27 extend into the interior of the combustion chamber 24 through one end wall 12 of the furnace. A flue 28 at the opposite end of the furnace is provided for the withdrawal of combustion gases from the combustion chamber.

One or more charge openings 29 are provided in the side walls of the furnace for introducing copper to be melted into the melting chamber 23. The charge opening 29 slopes downwardly toward the melting chamber. Copper cathodes are passed to the charge opening through a charging lock 30 closed by two doors 31 hinged at their upper ends. The floor of the charging lock 30 slopes in conformity with the charge opening so that cathodes may be slid easily into the melting chamber. The charging lock 30 substantially inhibits the introduction of air into the melting chamber and thus aids in maintaining the contemplated non-oxidizing atmosphere in the melting chamber. A vent stack 32 may be provided at the outer end of the charging lock for the withdrawal of gases leaking from the furnace through the lock.

Gas inlet conduits 33 extending through the side walls of the furnace are provided for introducing gas into the melting chamber 23 for the purpose of maintaining therein an atmosphere of the desired composition.

A tap hole 34 is provided in the end wall 12 of the furnace for withdrawing molten copper therefrom. The tap hole may be partially or wholly plugged with clay, and the clay may be gradually broken down for intermittent tapping, or the tap hole may be left open for the continuous run-out of metal in continuous operations. The tap hole opens into a launder 35 for conducting molten copper to a tilting pouring ladle or furnace or other suitable casting equipment (not shown).

A curtain wall 36 may be provided in the furnace adjacent the tap hole 34. A single opening 37 through the curtain wall is disposed adjacent the bottom thereof below the normal level of molten copper in the furnace. A normal depth of molten copper in the furnace forms a liquid seal of the opening through the curtain wall, without preventing out-flow of the copper. In combination with the curtain wall, this liquid seal effectively excludes air entering through the tap hole from passing into the melting chamber behind the curtain wall. The small body of copper in the furnace between the tap hole and the curtain wall may be covered with charcoal, if necessary, to protect it from the air.

In practicing the invention, copper to be melted is introduced through the charging lock 30 and the charge opening 29 into the melting chamber underneath the melting chamber arch 25. Fuel oil is admitted through the burner 27 and burned in the combustion chamber 24 above the arch 25 in a manner to heat the arch and establish and maintain at its under surface a temperature at least equal to the melting point of copper. The melting chamber is heated largely by radiant heat from the arch 25, and to a lesser extent by heat conducted through the side and end walls of the furnace. Pure copper melts at a temperature of about 1980° F. and accordingly the temperature maintained at the under surface of the arch must at least equal this value in order to melt copper largely by radiation of heat to it from the arch. For practical purposes, however, it is desirable to heat the molten copper to a temperature of about 2050° F. in order to secure satisfactory casting results, and in order to achieve an adequate melting rate in the furnace for economic commercial operations, it is desirable to maintain a temperature considerably higher even than this figure at the under surface of the arch. Accordingly a temperature of about 2500° F. preferably is maintained at the under surface of the arch.

Since the copper in the melting chamber 23 is melted largely by heat radiated to it from the under surface of the arch, it is important to establish and maintain conditions favoring the transfer of radiant heat to the copper. One such condition is the emissivity of the material at the surface of the charge. In a sense this emissivity is a measure of the ability of the charge to absorb the heat radiated to it. The emissivity of molten copper is adequately high to enable melting to proceed at a reasonable rate when the temperature at the under surface of the arch is maintained sufficiently high (at about 2500° F.).

Fused slags generally possess higher emissivities than molten copper, but they are poor conductors of heat. If present on the surface of the molten copper, they impede rather than aid in the transfer of heat to the copper. Since reactive fused slags are not required in the melting chamber to remove impurities from the copper, their presence is undesirable, and in the preferred practice of the invention care is exercised to maintain the surface of the molten copper substantially free of such slags.

Reactive fused slags also have been found objectionable for the reason that they are apt to attack the refractory lining of the side walls of the melting chamber. Molten copper which is substantially free of oxygen or oxides exerts practically no effect upon common and inexpensive silica refractories, so that such refractories may be employed in constructing the melting chamber side walls. Many fused reactive slags, however, quickly attack silica refractories, so that the presence of slag in the melting chamber, while accomplishing no useful purpose, necessitates the use of expensive refractories resistant to such attack, or results in serious damage to the furnace linings.

It has heretofore been proposed to deoxidize molten copper by maintaining a layer of charcoal on the surface thereof. Such a layer of charcoal would perform no useful purpose in the practice of the present invention, and would moreover be objectionable since its relatively poor heat conductivity would impede the transfer of radiant heat to the molten copper. The presence of charcoal on the surface of the molten copper is apt to be attended by the further disadvantage of coating the under-side of the arch 25 with a film of finely divided charcoal which may objectionably decrease the heat conductivity of the arch.

While the surface of the molten copper in the melting chamber is free of slag and of any other medium impeding the transfer of radiant heat thereto, floating patches of unfused or partially fused refractory material may gather on the surface of the molten copper. Where the melting chamber is lined with silica brick, these floating patches consist mainly of silica and appear to be due to mechanical erosion of the lining by the molten copper. This has been observed to occur to a small extent in a newly-lined furnace when it is first put in operation. So long as these floating patches cover in the aggregate only a small part of the surface of the molten copper, they are of no practical significance. However, they should be raked or pulled off the surface of the molten copper from time to time, in order to insure efficient transfer of radiant heat to the surface of the molten copper as well as effective direct exposure of the surface of the molten copper to the gaseous reducing atmosphere.

The copper in the melting chamber is kept out of contact with the combustion gases of the fuel by means of the melting chamber arch **25**, and so is not contaminated from this source. A bath of substantially oxygen-free molten copper is established and maintained in the melting chamber, and a non-oxidizing, and preferably reducing, atmosphere is maintained above the surface of the molten copper. A satisfactory reducing atmosphere is one of charcoal producer gas consisting predominantly of carbon monoxide and nitrogen, say about 25% carbon monoxide and about 75% nitrogen. Under favorable operating conditions, nitrogen alone may be employed, but it is relatively expensive, and the reducing quality of carbon monoxide is usually advantageous, and may be necessary, to establish and maintain the desired bath of substantially oxygen-free molten copper.

The non-oxidizing (or reducing) atmosphere above the molten copper should be free of any constituent capable under the operating conditions prevailing within the melting chamber of deleteriously affecting the oxygen-free molten copper. The presence of hydrogen should be avoided, since hydrogen is readily absorbed by molten copper, and adversely affects the set of copper upon casting. Even the presence of a small amount (of the order of a few per cent) of water vapor in the gases admitted to the melting chamber is objectionable, for at the temperature prevailing in the chamber, water vapor decomposes into hydrogen and oxygen (particularly in the presence of carbon monoxide) and the resulting hydrogen may affect the set of the copper during casting.

The melting chamber atmosphere should be reasonably free of carbon dioxide, since carbon dioxide reacts with molten copper to yield carbon monoxide and cuprous oxide. A small amount of carbon dioxide in the presence of a large amount of carbon monoxide may not be detrimental, since in the presence of the carbon monoxide the formation of cuprous oxide is for most practical purposes sufficiently retarded.

The presence of decomposable hydrocarbons in the melting chamber atmosphere is undesirable, since such hydrocarbons are cracked at the prevailing temperature and carbon is deposited on the surface of the metal or on the under surface of the arch or on both. Such deposits of carbon, whether on the surface of the metal or on the undersurface of the arch, materially lower the melting rate of the furnace. The illuminants present in coal gas or in enriched producer gas or water gas such as is available in most cities are examples of decomposable hydrocarbons which behave in this fashion.

It is also desirable to avoid the presence of sulphur in the melting chamber atmosphere. Some sulphur (usually in the form of copper sulphate or sulphuric acid occluded in the cathode) is unavoidably introduced into the melting chamber with the charge. The small amount of sulphur so introduced is not objectionable, for it cooperates with the oxygen incorporated in the copper as it is withdrawn from the melting chamber to produce the desired set of tough-pitch copper. The copper charged to the melting chamber usually contains as much sulphur as it is desirable to have, however, and so it is best to avoid the presence of sulphur or sulphur compounds in the melting chamber atmosphere.

The gas providing the non-oxidizing or reducing atmosphere in the melting chamber is admitted thereto through the inlet conduits **33**, and preferably is maintained in the melting chamber under a slight positive pressure of the order of 1/100 of an inch of water to prevent air or combustion gases from leaking into the melting chamber.

Since the copper melted in the melting chamber is not allowed to come in contact with contaminants, it is substantially as pure as the metal charged. The process is particularly adapted for melting electrolytic copper cathodes, and when this material is used as the charge, the molten copper in the melting chamber is substantially oxygen-free. This substantially oxygen-free copper is withdrawn through the furnace tap hole **34** and the launder **35** to the casting equipment.

The copper flowing through the launder is covered with a layer of charcoal to prevent it from becoming oxidized to an undesirable extent, but the coverage of the copper by the charcoal is incomplete, so as to permit the copper to be exposed to the air sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling. A number of variable factors, such as the temperature of the metal flowing through the launder, the rate of flow of metal therethrough, and the presence of air currents in the vicinity of the launder influence the amount of oxygen absorbed by the copper as it flows through the launder. Other variable factors, such as the amount of sulphur present in the copper, affect the amount of oxygen required to produce a flat-set upon casting and cooling. Accordingly, it is not possible to formulate precisely what proportion of the surface of the copper flowing through the launder should be exposed to the air. This can be determined, however, by the usual procedure of casting small test blocks and observing the set thereof upon solidifying. If the set indicates that too much oxygen is present in the copper, additional charcoal may be added to the launder, or if the set indicates a deficiency of oxygen, some of the charcoal may be raked from the surface of the copper in the launder. It has been found that in general about 0.01% to 0.05% oxygen by weight of the copper should be incorporated in the copper to obtain the desired flat-set.

Although the test here employed is the same as that used in the heretofore common refining process, the amount of oxygen incorporated in the molten copper is very much easier to control in the new process than is the poling operation of the refining process.

The copper flowing from the launder **35** may be introduced into any suitable casting equipment for casting into molds. Ordinarily a small reservoir in the nature of a tilting furnace or ladle is interposed between the launder and the mold. Almost any of the pieces of equipment commonly in use for this purpose may be employed. For example, the copper from the launder may be introduced into a tilting electric furnace from which it may be poured into the molds, or it may be introduced into a pouring ladle suitably heated, for example, by an oil flame. It has been found that contact of the copper with combustion gases in an oil heated ladle is not objectionable, apparently because the copper remains in the ladle for so short a period of time that it does not become contaminated thereby.

Although the method of the invention may be operated intermittently as a batch process, it is suited to continuous operation and is most economically practiced when carried out continuously. The copper cathodes to be melted may be charged continuously into the furnace, and melted copper may be continuously withdrawn therefrom at substantially the same rate as the cathodes are charged.

The hooks of the initial starting sheets of copper cathodes are preferably cut off before charging the cathodes into the melting chamber. Undesirable amounts of oxidized copper, copper sulphate, etc., are frequently associated with these hooks and it is hence better not to attempt to melt them in practicing the present invention. Whatever slight amount of oxidized copper that may be introduced into the bath of molten copper during charging and melting of cathodes and the like is readily reduced by the gaseous reducing atmosphere, so that the bath of molten copper in the melting chamber is for all practical purposes substantially oxygen-free. In addition to copper cathodes, other forms of equally pure substantially oxygen-free copper may constitute all or part of the copper charged into the melting chamber. Where insufficient sulphur is naturally present in the copper to be melted, a controlled amount of sulphur may be incorporated in the molten copper in the melting chamber, as for example, by the controlled introduction of sulphur dioxide gas or by the addition of elemental sulphur along with the copper as charged into the melting chamber.

Aside from the usually minute amount of oxidized copper present on the surface of copper cathodes, the method of the invention removes no impurities from the copper. But the method of the invention does effectively reduce whatever amount of oxidized copper is ordinarily associated with the copper cathode. The surface of the molten copper is exposed to the direct influence of the gaseous reducing atmosphere and any cuprous oxide in the molten copper is thereby reduced. Such cuprous oxide tends naturally to migrate to the surface of the molten copper, and this tendency is promoted by the agitation of the molten copper as the cathodes drop into it. When conducted as a continuous operation, the method of the invention permits of marked fuel economy, higher output of cast copper shapes and greatly increased furnace life than in the heretofore customary melting and refining process. The invention eliminates the former operations of oxidizing and poling the molten copper and their attendant difficulties, particularly in controlling the quality of the copper produced. The only variable control that need be exercised in practicing the invention is the incorporation of oxygen in the molten copper withdrawn from the melting chamber, and this control is not difficult to maintain.

The method of the invention imposes no severe treatment on the furnace refractories. The substantially oxygen-free molten copper does not affect the refractory lining of the melting chamber, and no slag is present to attack the lining. The furnace is not repeatedly heated and cooled, as heretofore customary in melting copper cathodes, and the furnace refractories are hence not subject to thermal shock, and the extensive heat losses inherent in the prior art intermittent operation are eliminated. The life of furnaces used in carrying out the invention is therefore measured in years instead of months, as in the case of furnaces used in the heretofore customary refining process.

This application is a continuation-in-part of our pending and allowed application Serial No. 304,674, filed November 16, 1939.

We claim:

1. The method of producing substantially flat-set cast copper shapes which comprises introducing substantially oxygen-free copper into the melting chamber of a fuel-fired muffle furnace, heating and melting the copper therein largely by means of radiant heat while maintaining a non-oxidizing atmosphere within the melting chamber, withdrawing substantially oxygen-free molten copper from the melting chamber and exposing it to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

2. The method of producing substantially flat-set cast copper shapes which comprises heating the melting chamber of a fuel-fired muffle furnace to a temperature above the melting point of copper, maintaining a bath of substantially oxygen-free molten copper in said melting chamber, the surface of said bath of molten copper being free of slag, maintaining in the melting chamber above the molten copper therein a gaseous reducing atmosphere, introducing the substantially oxygen-free copper to be melted into the melting chamber under conditions substantially inhibiting the introduction of air into the chamber and melting the copper so introduced while maintaining the aforesaid slag-free bath of substantially oxygen-free molten copper, withdrawing substantially oxygen-free molten copper from the melting chamber and exposing it to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

3. The method of producing substantially flat-set cast copper shapes which comprises introducing copper cathodes into the melting chamber of a fuel-fired muffle furnace, heating and melting the copper therein largely by means of heat radiated to the exposed surface of the copper, maintaining the surface of the copper in the melting chamber substantially free of reactive fused slag, maintaining a non-oxidizing atmosphere within the melting chamber, withdrawing substantially oxygen-free molten copper from the melting chamber and exposing it to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

4. The method of producing substantially flat-set cast copper shapes which comprises introducing substantially oxygen-free copper into the

melting chamber of a fuel-fired muffle furnace, heating and melting the copper therein largely by means of heat radiated to the exposed surface of the copper, maintaining a layer of finely divided refractory material having a relatively high emissivity and good heat conductivity over the surface of the molten copper in the melting chamber while at the same time maintaining the surface of the molten copper free of any medium impeding the transfer of radiant heat thereto, maintaining a non-oxidizing atmosphere within the melting chamber, withdrawing substantially oxygen-free molten copper from the melting chamber and exposing it to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

5. The method of continuously producing substantially flat-set cast copper shapes which comprises continuously introducing substantially oxygen-free copper into the melting chamber of a fuel-fired muffle furnace, heating and melting the copper therein largely by means of radiant heat while maintaining a non-oxidizing atmosphere within the melting chamber, continuously withdrawing substantially oxygen-free molten copper from the melting chamber and exposing it to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling, and continuously casting the resulting oxygen-bearing molten copper into a suitable shape.

6. The method of producing substantially flat-set cast copper shapes which comprises introducing substantially oxygen-free copper into the melting chamber of a fuel-fired muffle furnace, heating and melting the copper therein largely by means of radiant heat while maintaining a non-oxidizing atmosphere within the melting chamber, withdrawing substantially oxygen-free molten copper from the melting chamber through an open launder, maintaining the surface of the copper in the launder partially but incompletely covered with charcoal, controlling the area of copper in the launder exposed to the air in a manner to permit incorporation in the copper of a proper amount of oxygen to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

7. The method of producing substantially flat-set cast copper shapes which comprises introducing substantially oxygen-free copper into a melting chamber of a furnace below a melting chamber arch, introducing and burning fuel in a combustion chamber above said arch in a manner to heat the arch and establish and maintain at its under surface a temperature of about 2500° F., whereby copper in the melting chamber is melted largely by heat radiated thereto from the arch, withdrawing substantially oxygen-free molten copper from the melting chamber and exposing it to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

8. The method of producing substantially flat-set cast copper shapes which comprises introducing substantially oxygen-free copper into the melting chamber of a furnace below a melting chamber arch, maintaining a non-oxidizing atmosphere substantially free of hydrogen and decomposable hydrocarbons in the melting chamber, introducing and burning fuel in a combustion chamber above the arch in a manner to heat the arch and establish and maintain at its under surface a temperature at least equal to the melting point of copper whereby copper in the melting chamber is melted largely by heat radiated thereto from the arch, withdrawing substantially oxygen-free molten copper from the melting chamber and exposing it to an oxidizing atmosphere sufficiently to incorporate therein a proper amount of oxygen to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

9. The method of continuously producing substantially flat-set cast copper shapes which comprises continuously introducing substantially oxygen-free copper into a melting chamber of a furnace below a melting chamber arch, continuously introducing and burning fuel in a combustion chamber above said arch in a manner to heat the arch and to establish and maintain at its under surface a temperature substantially above the melting point of copper, whereby copper in the melting chamber is heated and melted largely by heat radiated thereto from the arch, maintaining a non-oxidizing atmosphere substantially free of hydrogen and decomposable hydrocarbons and consisting predominantly of carbon monoxide and nitrogen in the melting chamber, maintaining the surface of the copper in the melting chamber substantially free of reactive fused slag, continuously withdrawing substantially oxygen-free molten copper from the furnace through an open launder, maintaining the surface of the copper in the launder partially but incompletely covered with charcoal, controlling the area of copper in the launder exposed to the air in a manner to permit incorporation in the copper of an amount of oxygen from 0.01% to 0.05% sufficient to produce a flat-set upon casting and cooling, and casting the resulting oxygen-bearing molten copper into a suitable shape.

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