

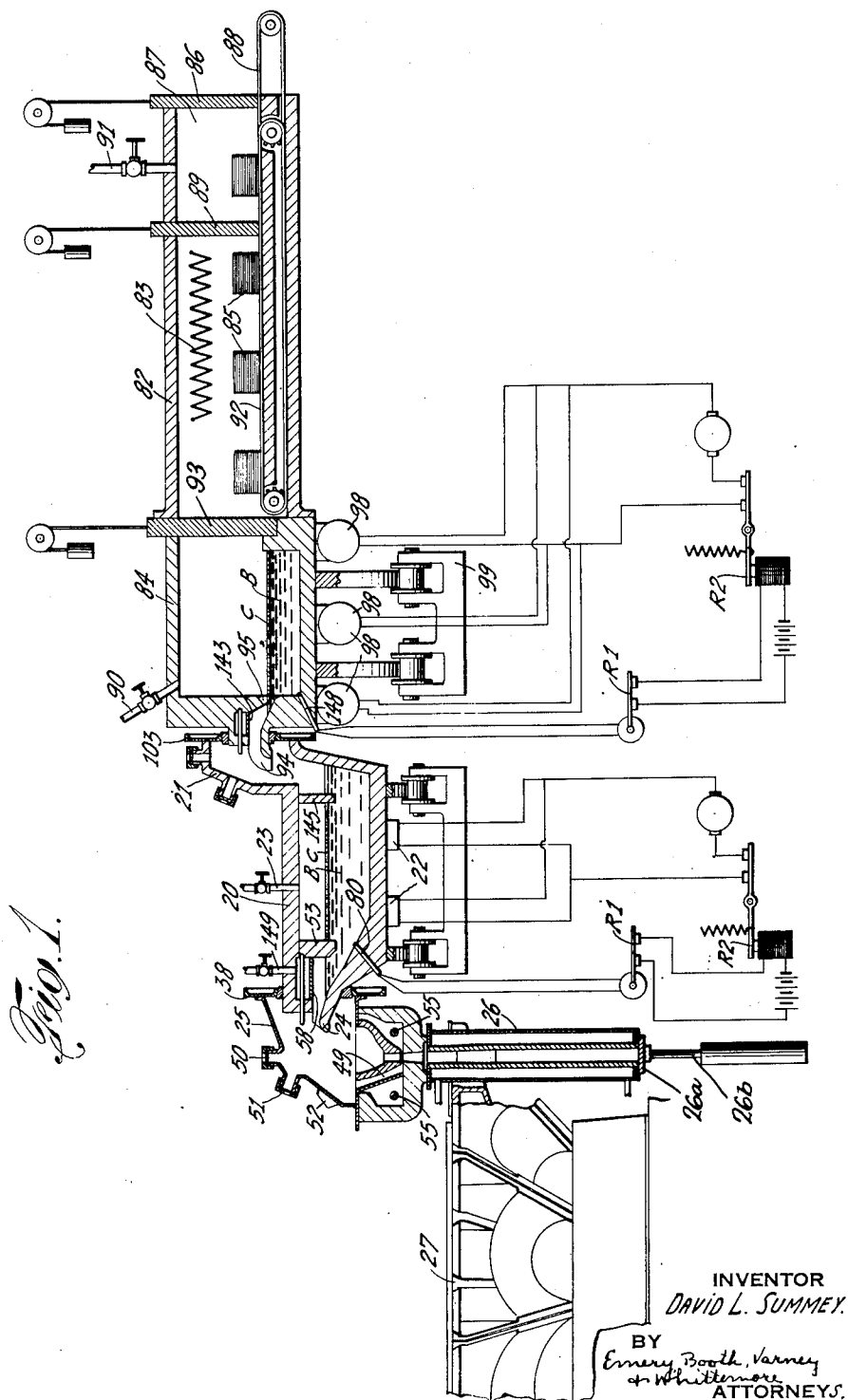
Nov. 10, 1936.

D. L. SUMMEY

2,060,134

APPARATUS FOR REFINING METALS

Original Filed June 27, 1932 8 Sheets-Sheet 1



Nov. 10, 1936.

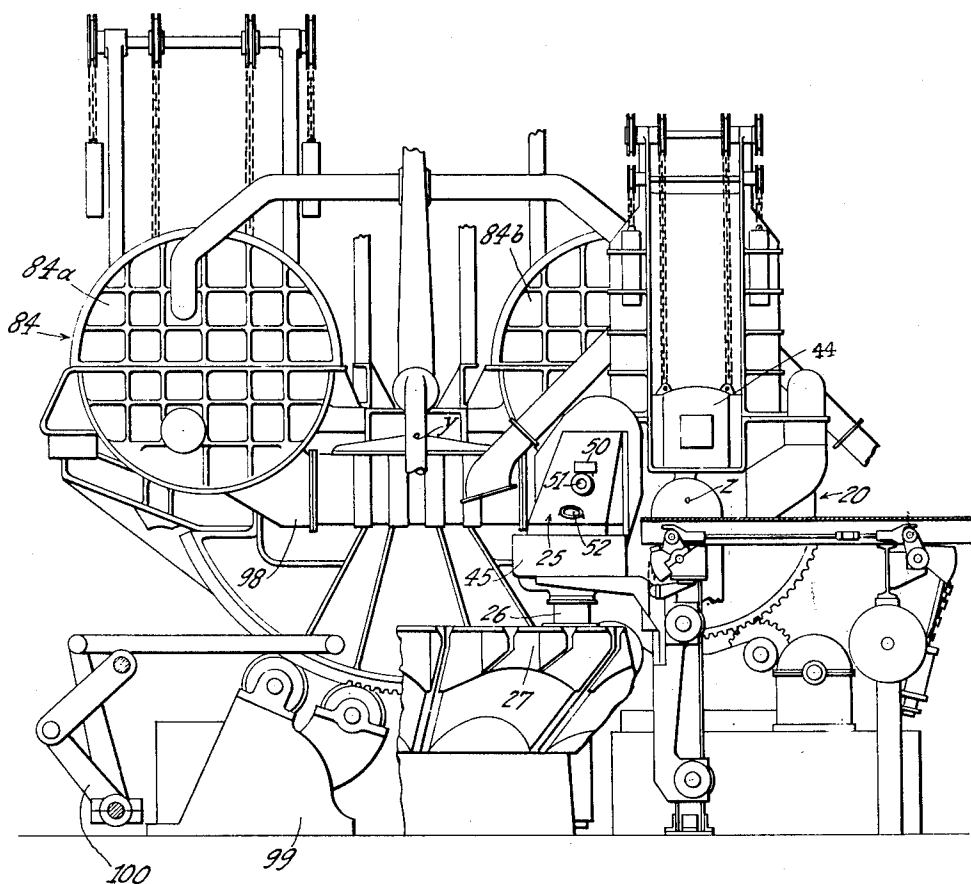
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APPARATUS FOR REFINING METALS

Original Filed June 27, 1932 8 Sheets-Sheet 2

Fig. 2.



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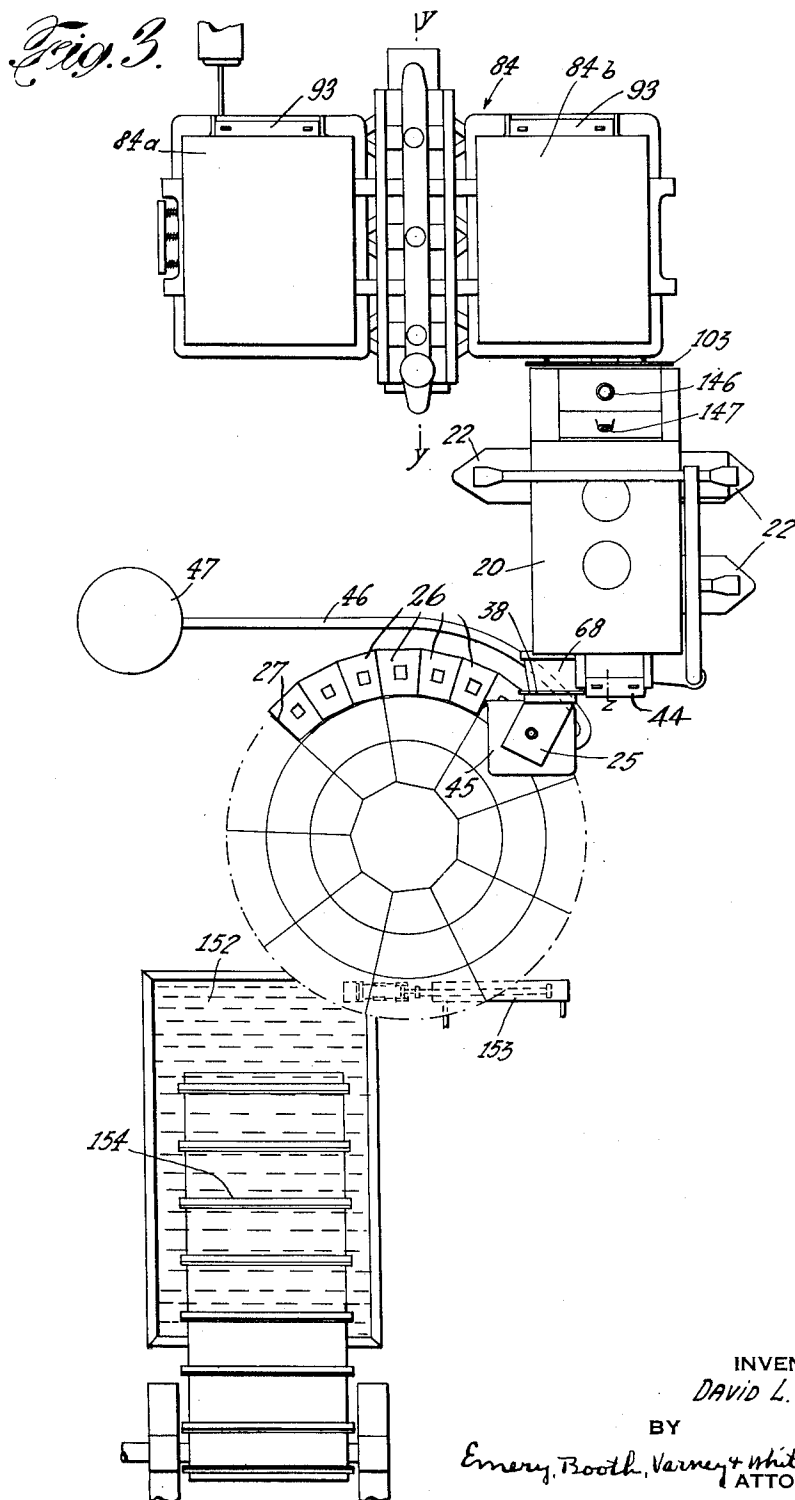
Nov. 10, 1936.

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Original Filed June 27, 1932 8 Sheets-Sheet 3



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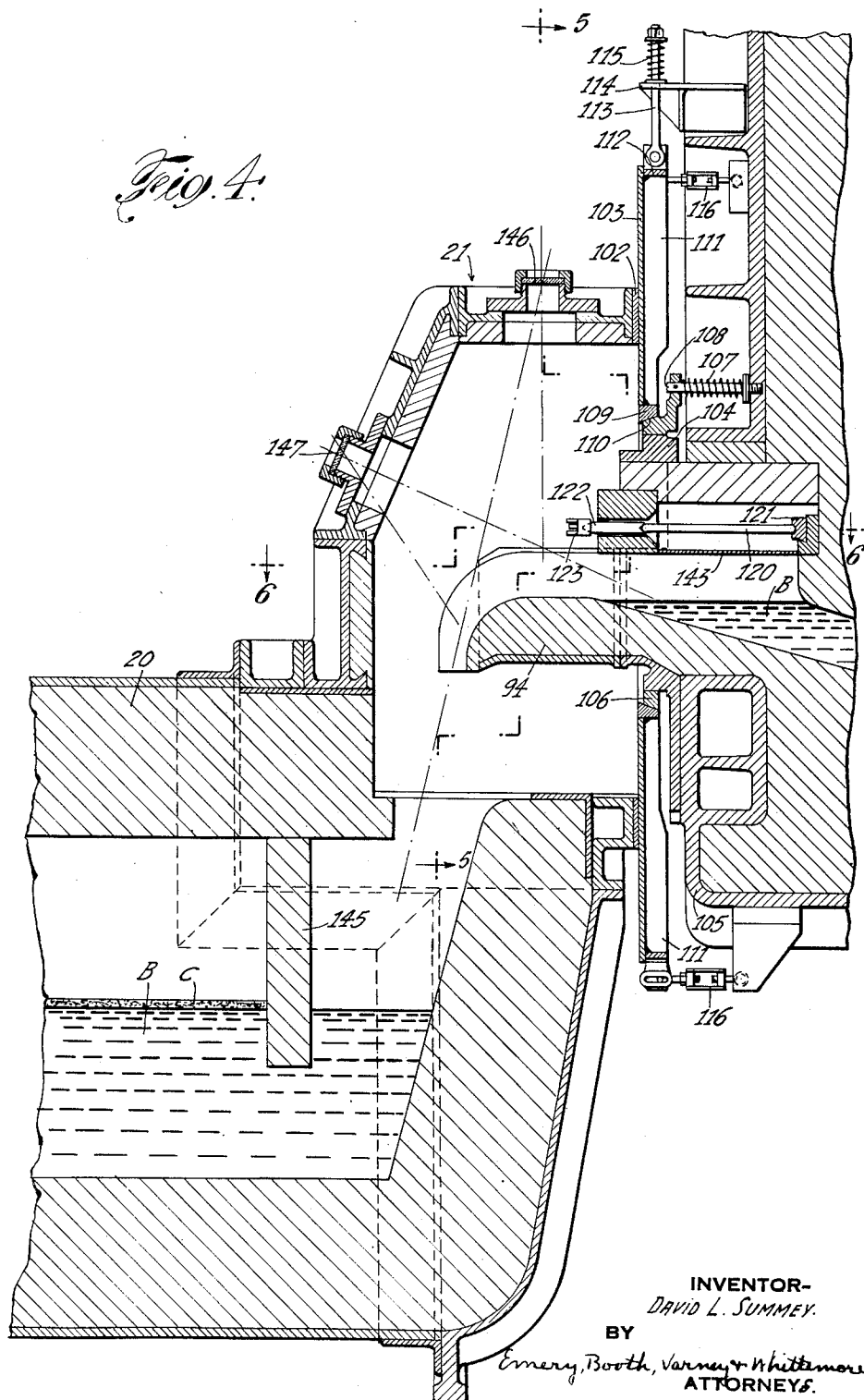
Nov. 10, 1936.

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2,060,134

APPARATUS FOR REFINING METALS

Original Filed June 27, 1932 8 Sheets-Sheet 4



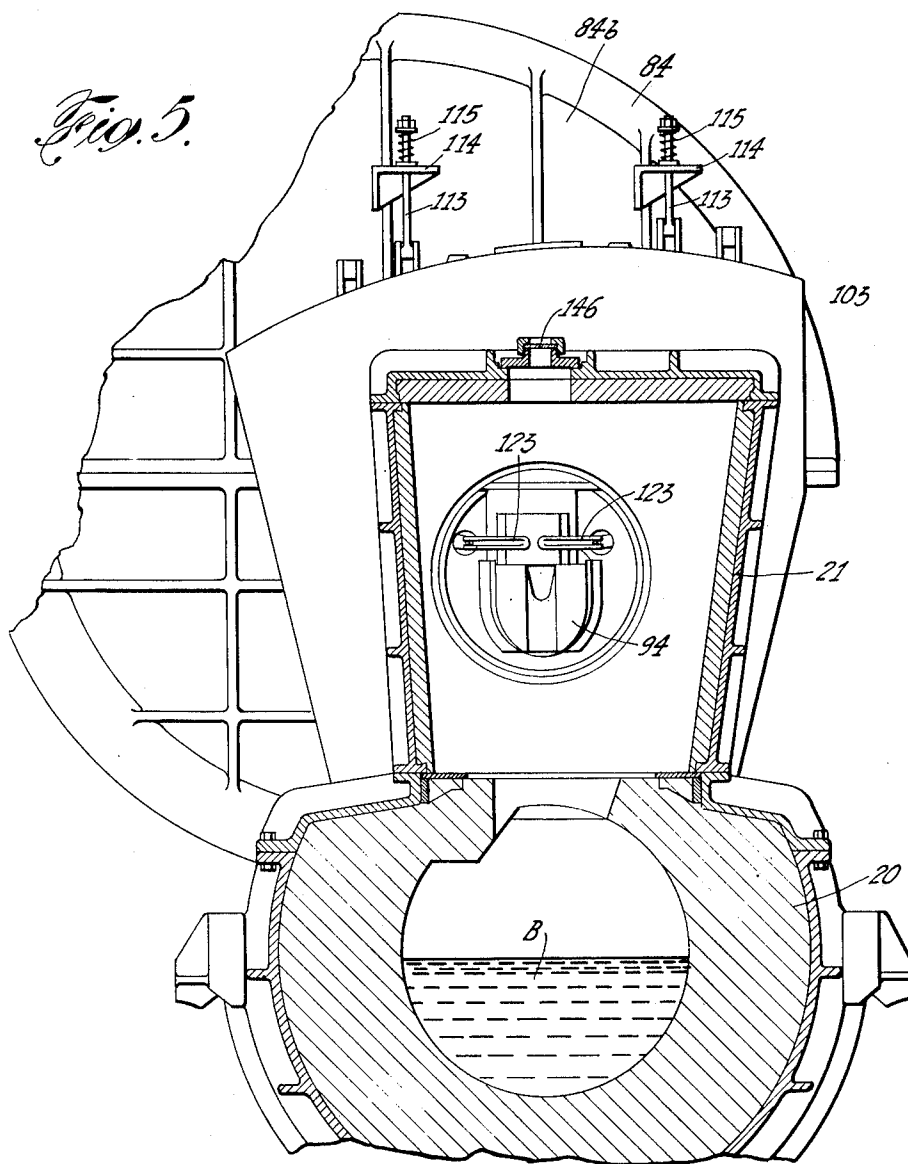
Nov. 10, 1936.

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Original Filed June 27, 1932 8 Sheets-Sheet 5



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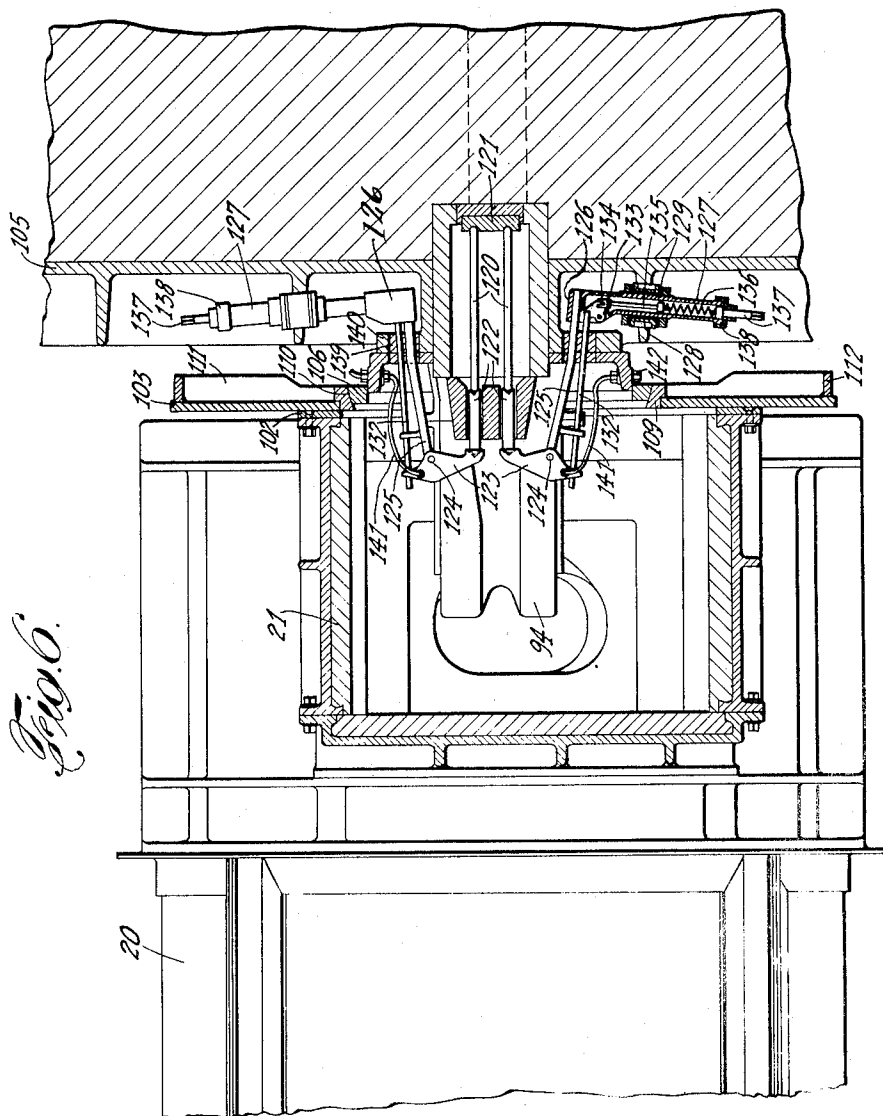
Nov. 10, 1936.

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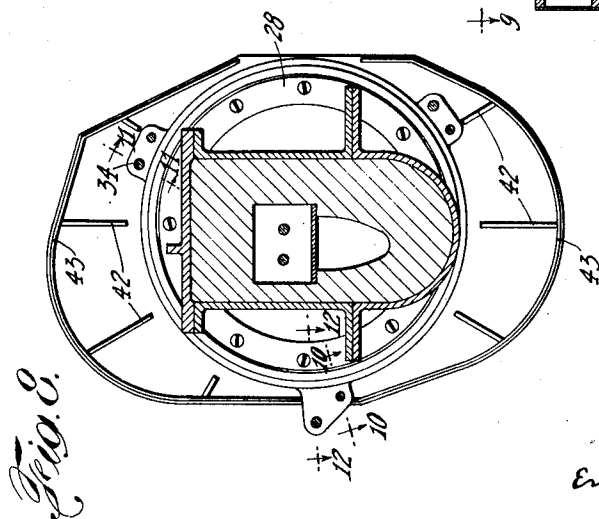
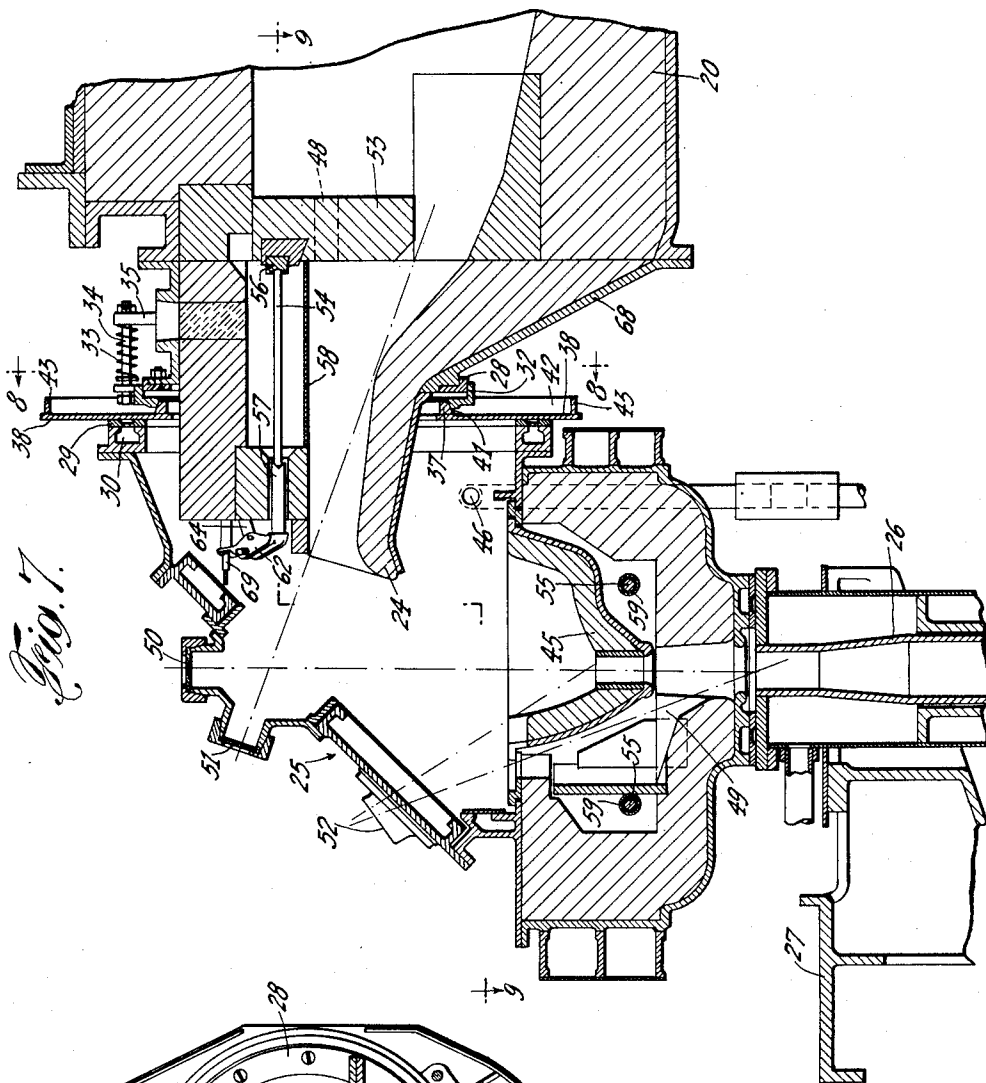
Nov. 10, 1936.

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Original Filed June 27, 1932 8 Sheets-Sheet 7



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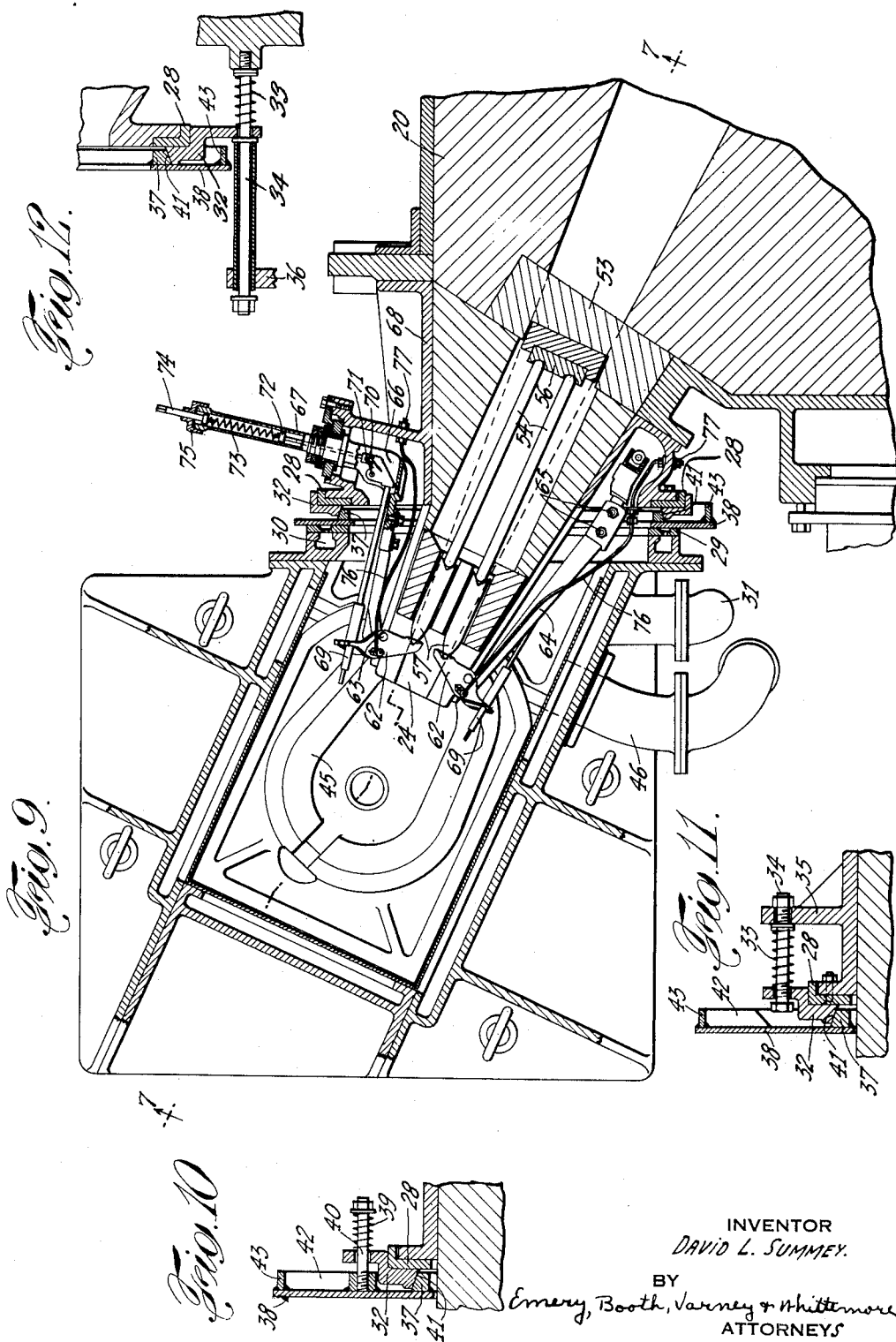
Nov. 10, 1936.

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2,060,134

APPARATUS FOR REFINING METALS

Original Filed June 27, 1932 8 Sheets-Sheet 8



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2,060,134

APPARATUS FOR REFINING METALS

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Application June 27, 1932, Serial No. 619,474
Renewed June 29, 1935

45 Claims. (Cl. 22—64)

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

Among the objects of the invention is 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 apparatus for effecting 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 of the metal to the air.

Further objects of the invention are to provide apparatus for 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 a 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.

This application is for the most part a continuation of my co-pending application, Serial Number 535,829, filed on May 8, 1931.

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

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 will be no porosity; and that if less than a critical amount is present there will be excessive porosity. According to present practices which do not keep the 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. The batch process is the only one which has been found commercially practicable, no successful continuous process being available, so far as known, prior to the present invention.

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 gained wide acceptance 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 will contract on freezing and the ingots produced will have a sunken surface. But during poling the oxygen content of the metal falls, and the hydrogen content of the metal increases, and since the hydrogen reacts with the oxygen during solidification to generate steam, which causes porosity, the cast ingots from poled metal will be less sound. The surface depression will become less noticeable, until a point will be reached at about 0.35 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 will cause a rapid increase in the hydrogen content of the metal. It is estimated that the quantity of hydrogen present will be doubled by lowering the oxygen content by 0.02%. From this it appears that a very slight further poling beyond a critical point will cause a noticeable increase in the porosity of the ingot.

This theory, and most others as a matter of fact, assumes 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 phosphorous, 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 the incomplete mass action, moreover, some of the products of the reaction, which usually are undesirable, remain in the metal.

Slags such as calcium chloride and barium 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 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 the use of 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. If the oxygen is not present at the beginning, it can be kept out by the same agents or even by certain inert substances which produce no harmful results upon the metal. This treatment may be accomplished by the apparatus disclosed herein.

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 has there been any commercial apparatus devised which would be applicable to the continuous production of cast metal free from oxygen and solid deoxidizing agents. By "cast" metal in this application is meant all metal which is produced by a pyrometallurgical process whether the metal be cooled in molds or be cooled while it is being worked.

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 hundreds of tons of the desired grade of copper in this manner and will now describe the apparatus and procedure by which it was produced so as to enable others to duplicate my results.

The process may be practiced with various forms of apparatus but for the purpose of illustration I have shown selected forms which I at

present prefer. In the accompanying drawings thereof,

Fig. 1 is a diagrammatic sectional elevation of apparatus embodying the present invention;

Fig. 2 is a left end elevation of the apparatus shown in Fig. 1, parts being broken away;

Fig. 3 is a top plan view with the preheating unit omitted;

Fig. 4 is a vertical section through a pouring conduit or hood between the melting and the pouring furnaces;

Fig. 5 is a vertical section thereof taken on the line 5—5 of Fig. 4;

Fig. 6 is a horizontal section taken on the line 6—6 of Fig. 4;

Fig. 7 is a vertical section through a pouring conduit or hood between the pouring furnace and the mold;

Fig. 8 is a transverse vertical section taken on the line 8—8 of Fig. 7;

Fig. 9 is a horizontal section taken on the line 9—9 of Fig. 7;

Figs. 10, 11, and 12 are sectional views of details taken respectively on the lines 10—10, 11—11 and 12—12 of Fig. 8.

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 electro-deposited copper, which generally will be used, 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; but must be remelted and cast to render it workable. The process and apparatus which I use are adapted to keep the metal pure; and in case the metal is contaminated with certain impurities, are also adapted to remove them quickly and efficiently. As mentioned above, there is no great difficulty in producing oxygen-free copper in the molten condition; the heretofore unsolved problem has been to produce oxygen-free and otherwise acceptable copper in the solid condition.

Considering first the apparatus shown in Fig. 1 and assuming that the pouring furnace 20 is used alone to supply all of the heat to the metal or that molten metal is supplied to the furnace 20 from an outside source, and furthermore assuming that the hooded connection 21 for charging from another furnace is modified for charging from other appropriate means, the metal either solid or molten is charged into the furnace, after which the charging opening is tightly closed. When the pouring furnace is used for melting the metal as well as for holding the metal in molten condition, it is made of greater capacity than when it is used only for holding the metal if the same amount of cast metal is to be produced. This avoids heavy fluctuations in the temperature of the metal at the pouring end by reason of the charging of cold metal at the other end of the furnace.

A carbon covering such as charcoal C is maintained on the bath B of metal to remove the oxygen therefrom. The carbon may be introduced as desired through a charging door 44. 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. If the metal is not oxygen-free when charged it will be necessary to provide an effective contact between the same and the carbon covering. The

contact may be produced by movement of the metal.

Any heating means may be used provided it does not introduce harmful impurities such as sulphur and oxygen. For this reason heating means such as open flames which give off harmful combustion gases are to be avoided. I prefer to heat the metal by electrical induction heaters 22, for these not only entirely avoid contamination but may be used in such manner as also to effect a thorough circulation of the metal to bring it in contact with the covering material for purification. The heaters 22 of furnace 20 are so arranged as to secure these effects. 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. Indeed, a carbon covering may be maintained upon a bath of molten metal for a great length of time without deoxidizing it if no adequate circulation is 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. This may be supplied from outside sources or be generated by the action of the carbon placed on the bath of metal. A door 44 is provided in the end of the furnace (Fig. 2) for charging and skimming. 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 where it has been melted and partially refined. The metal may contain oxides since the present process is adapted to remove oxides. One way of providing the gaseous agent is to generate carbon monoxide outside and introduce it into the furnace as by the pipe 23. 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.

If the deoxidizing or inert gases are constantly supplied and permitted to escape 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 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. The furnace 20 and its operation as a separate unit are covered in my co-pending application, Serial No. 605,147, filed April 14th, 1932.

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 forms 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 except on the surface 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 enclosure preferably is articulated to accommodate the tilting movements of the furnace during pouring. Herein the pouring spout 24 is arranged at one side of the central vertical plane of the cylindrical furnace 20 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 20 and the stream-protecting hood 25 respectively. The plates are held together by any suitable and preferably resilient means.

This connecting structure is shown in Figs. 7 to 12. The sealing plate construction will be designed to suit the requirements of the devices with which the furnace is to be connected. In the present instance the hood 25 cooperates with one of a series of molds 26 which, as shown in Figs. 1, 2, and 3, are mounted upon a rotatable carrier 27. If the tops of the molds and the bottom of the hood are not so arranged by accuracy of machining or operation as to fit so closely together that only a small amount of gas may escape at the joint between them, the construction and operation may be as shown in the illustrated embodiment, which is as follows: The molds move horizontally in a circle but do not have any vertical movement. The hood moves up and down vertically to seat upon the top of the mold. The sealing plate construction is, therefore, designed to accommodate this vertical movement of the hood and the oscillatory movement of the spout 24 of the furnace. As shown, a seal ring seat 28 is rigidly secured to the furnace around the spout. A face plate 29 is rigidly secured to the hood. It has sufficient clearance interiorly to accommodate all required movements of the hood or the furnace. In some instances it may be desirable to dispose of gases which tend to escape at this joint so the plate 29 is provided with spaced holes which open into an annular chamber 30 of the hood member to which it is secured and a vacuum may be maintained in this chamber by a pipe 31 (Fig. 9). The pipe 31 is connected with the chamber 30 by channels which do not appear in the drawings. The pipe has a flexible connection such as a sliding joint to permit vertical movement of the hood. A seal ring 32 surrounds the seal seat 28 and has permis-

sible axial movement thereon while still maintaining a seal therewith. It is urged away from the seat by springs 33 (Figs. 11, 12) which are mounted on bolts 34. Most of the bolts are retained by nuts acting against the seal ring 32 and fixed brackets 35 secured to the furnace. One of the bolts (Fig. 12) is threaded into the end wall of the furnace and is supported at the outer end by a bracket 36 secured to the furnace. The seal ring 32 cooperates with a mating seal ring 37 which is rigidly secured as by welding to the back of a face plate 38. The rings 32 and 37 are urged together by springs 39 (Fig. 10) which are placed on studs 40 secured to the plate 38. The assembly including the parts 32, 37, and 38 is pressed against the face plate 29 of the hood by the springs 33 mentioned above. The surface 41 between the seal rings 32 and 37 is spherical so as to permit tilting of the face plate 38 as required to maintain contact with the face plate 29. The face plate 38 may be reinforced by radial ribs 42 and circumferential ribs 43. The seal between the plates 38 and 29 may be further insured by introducing a thick viscous substance such as tar between them. This should be heat resistant and preferably should have some lubricating properties.

It may be desirable, especially when pouring into molds with small openings, to provide means for directing the metal. As shown herein, a strainer 45 is inclosed within and is mounted with the hood. The hood and strainer are described and claimed as to details in my copending application Serial Number 608,177, filed April 29, 1932. Herein the general features which concern the plant as a whole will be considered. Means are provided for introducing a suitable gas under pressure into the hood, such means herein comprising (Fig. 3) a pipe 46 which receives gas from a gas producer 47. If desired a by-pass passage 48 may be provided for passing gas from the hood into the furnace or from the furnace into the hood. If not used this opening may be left plugged up. Carbon monoxide or a mixed inert or deoxidizing gas such as described above for use in furnace 20 is suitable. The pipe 46 is provided with a flexible connection or a slide joint to permit vertical movement of the hood. A by-pass 49 around the strainer is provided to permit the gas to flow through and purge the mold before metal is poured therein and to come into contact with the metal as it is poured. A bottom closure 26a may be provided for each of the molds 26. This is left open when the mold is first halted beneath the hood for purging but is closed before metal is poured therein. It may be closed by a power closure operating device 26b located in proper position relative to the path of the mold. The closure operating device and associated casting apparatus are covered in my Patent No. 2,030,482, granted February 11th, 1936.

Sight openings 50, 51, 52 are provided in the hood giving a view into the top of the mold, into the pouring spout and into the strainer and mold respectively as indicated by dot and dash lines. These sight holes are quite important since they enable the operator to control the pouring properly. The dual sighting at 52 is particularly important as it enables the operator to observe the metal in the strainer, and the stream of metal from the strainer into the mold simultaneously. It also enables him to tell when the mold is full.

A skimmer or baffle 53 is provided in the furnace at the spout for holding back the covering material when metal is poured.

Electrical heaters 54 and 55 or other heating means which cause no contamination of the metal may be employed in the spout and around the strainer respectively for keeping the metal molten at these points where otherwise it would tend to solidify between pours. Incrustations of frozen metal are to be avoided because it is difficult to obtain access to the enclosure for removing them. The heating units shown are of the resistance type comprising rods of silicon carbide or similar material disposed between fixed electrodes 56 and movable electrodes 57. The resistors are protected against splashing metal which might injure them by thin refractory coverings. The spout resistors are protected by thin refractory plates 58 and the strainer resistors are protected by thin refractory sleeves 59.

The electrical connections for the strainer resistors have been described and claimed in the prior application on the strainer. The connections for the spout resistors are shown in Fig. 9. The fixed electrode 56 is set into the refractory lining of the furnace and is provided with sockets for two resistors. The movable electrodes are mounted on devices which are designed to meet several requirements. They are movable with the spout. They are protected as far as possible from the heat of the metal issuing from the spout. They are sealed against the escape of gas from the hood. They furnish resilient pressure to the electrodes. And they are sturdy and strong so as to keep the electrodes in proper position at all times. The electrode terminals 62 are pivoted intermediate their length upon pins 63 mounted in brackets 64. The brackets 64 are removably secured as by bolts 65 to the elbow 66 of a tubular post 67 which is rigidly and removably secured to the casing 68 of the spout. The post 67 is electrically insulated from the casing by mica bushings and washers or the like. The terminals are inclined upwardly from the electrodes to avoid splashing molten metal as much as possible. One of the posts 67 is disposed horizontally and the other vertically on account of structural characteristics of the spout and furnace casings. Otherwise the mountings for both electrodes are the same. The terminal 62 is pressed by a push rod 69 which extends through an aperture in the outer end of the terminal. The push rod is pressed by a short lever 70 which is pivoted upon the elbow 66 by a pin 71. The outer end of the lever is pressed by a plunger 72 which is slidably mounted in the post 67. The plunger is engaged by a spring 73 which is adjusted by an adjusting screw 74 threaded through a sealing cap 75. Electrical current is supplied to the terminal 62 by a flexible conductor 76 which is attached to a terminal post 77 which passes through and is insulated from the spout casing. If the conductor is insulated, a heat proof material such as asbestos is used.

Before the metal is poured into them the molds are thoroughly cleaned on the inside and coated with a suitable material to procure 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 cooled molds are used to cause the gases to be forced upward without being entrapped in the metal to cause unsoundness.

It is important to maintain a uniform pouring temperature and for this purpose the current switch to the heating elements 22 is controlled by a pyrometer 80 and suitable relays R1, R2, etc. in the well known manner of controlling power switches from pyrometers. The sensitive element of the pyrometer must be encased in a refractory tube, for example, one of silica alumina, which is closed at the inner end to protect the sensitive element from the molten metal. In the case of molten oxygen-bearing copper no refractory material is known which will not break down in a very short time; but I am enabled to use the pyrometer for controlling the heat applied to copper 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 to be used indefinitely without deterioration. Without some automatic temperature control such as this it is practically impossible to maintain satisfactory pouring conditions, for even with the most constant supervision the metal will first be too hot and then too cold and the castings cannot be poured under ideal conditions. The pyrometer is placed near the outlet end of the furnace where the metal is ready to pour and where it is more apt to be completely free from oxygen.

After pouring and before the protecting gas has escaped, for example, after the hood has been raised a short distance above the mold and before the latter has been removed, the billets are covered to prevent oxidation. A covering such as finely divided charcoal, barium chloride, calcium chloride, or a heavy gas is used, the charcoal being preferred.

The covering is allowed to remain until the metal cools below the point at which it will absorb gases from the atmosphere.

The solidified billets are dropped out of the molds when they are positioned over the corner of a bosh or cooling tank 152 (Fig. 3). The billets descend upon an elevator against the action of a pneumatic cylinder 153 and drop over upon the conveyor 154 which elevates them from the water in the tank 152 to a point of discharge. The sudden plunging of the billets into a cooling fluid avoids surface oxidation in case the billets are still hot enough to be oxidized. This is especially beneficial in metal which has been made substantially oxygen free by the above described process because it is desirable to avoid even superficial contamination of the surface.

While the induction furnace as used herein is best for producing clean heating and advantageous for producing thorough circulation of the metal it may not be the most economical when used as the whole 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 20. If the impurities of the metal are high it may be desirable to melt and partly refine the metal before it is introduced into the furnace 20. For these purposes I have provided a preheater 82 employing electrical heating means such as the resistance heaters 83 or other heating means which will not contaminate the metal. In some cases there may also be provided a melting furnace 84 which is heated inductively. Such a furnace is included in the plant assembly shown in Fig. 1. The furnace 84 is provided with a charging door 93 (Fig. 3).

The preheater, besides supplying heat economically, may be employed for removing sulphur when that is present. For example, after a

charge of crude metal 85 has been passed through the outer door 86 into the lock chamber 87 by the conveyor 88 the inner door 89 is raised and a gas such as hydrogen (for copper) may be injected at the inlet 90 to reduce the sulphur when the metal becomes heated sufficiently. The hydrogen may also remove some of the oxygen from the metal. 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 91. While being heated the charges are moved by the conveyor 92, upon which they are deposited from the conveyor 88, and finally are discharged into the melting furnace 84, when that is used.

When hydrogen is used, the bath in furnace 84 is left uncovered and there the action continues due to the circulation of the metal. The process carried out in furnace 20 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.

The furnace 84 is provided with a spout 94 for passing the metal to the furnace 20. The spout is equipped with a baffle 95 for retaining the covering material in the furnace 84, when such covering material is used. The articulated hood 21 provides an enclosure for excluding air from the stream of metal flowing from the furnace 84 to the furnace 20. If desired the hood may be filled with deoxidizing or inert gases which are supplied from either of the furnaces or from an outside source directly into the hood. In any case the pressure within the hood will be greater than the pressure of the surrounding air and any leakage through the hood will be outward.

The hood structure will be designed to suit the movements of the two furnaces which it connects. As heretofore noted the pouring furnace 20 is cylindrical and oscillates about a horizontal axis Z (Figs. 2 and 3). The hood is above this axis of oscillation. The furnace 84 which is used (Figs. 2 and 3) is of the type having the spaced hearths 84a, 84b connected by the induction heated channel units 98. The furnace is mounted to oscillate about a horizontal axis Y (Figs. 2 and 3). The furnace is mounted upon rollers on the base cradle 99 and is oscillated both for rocking to circulate the metal and for tilting to pour the metal by the oscillating mechanism 100. This furnace in its details is disclosed and claimed in my co-pending application, Serial Number 596,980, filed March 5, 1932. The oscillating mechanism may be of the type shown in that application or of the type shown in the co-pending application of another. The latter is the type herein illustrated.

The articulated hood connection which is shown herein according to Figs. 4, 5, and 6 comprises mutually slidable face plates 102 and 103 which are mounted upon and movable with the furnaces 20 and 84 respectively. The plate 102 is rigidly attached upon the end of the hood 21 which is mounted on the furnace 20 while the plate 103 is resiliently mounted upon the furnace 84 about the spout 94 thereof so as to tilt slightly if necessary to maintain a tight seal. If desired the engaging surfaces of the plates may be coated from time to time by a heavy viscous heat resistant material such as asphalt tar to further insure a good seal.

The mounting of the face plate 103 comprises a seal ring seat 104 secured to the shell 105 of

the furnace 84 about the spout 94. A seal ring 106 is slidably mounted on this seat. It is pressed toward the back of the face plate 103 by springs 107 on studs 108 which are threaded into the shell 105. A mating seal ring 109 is rigidly secured as by welding to the back of the face plate 103. The seal rings have a spherical joint 110 between them to permit tilting movement while maintaining the seal. The plate 103 is strengthened by radial ribs 111 and peripheral ribs 112. The plate is supported by rods 113 from brackets 114 fast on the shell 105, springs 115 being interposed to take up movement. Adjustable turn-buckles 116 are connected between the plate 103 and the furnace shell 105 to keep the plate from moving too far out.

Means are provided for keeping the metal molten in the hood 21. Such means, like that for the hood 25, is of the type which will not contaminate the metal and preferably comprises (Figs. 4, 5, and 6) resistors 120 held between fixed electrodes 121 and movable electrodes 122. The movable electrodes are pressed by terminal levers 123 mounted upon pivot pins 124 secured in the outer ends of brackets 125. The brackets are secured to elbows 126 which are mounted upon tubular posts 127. The posts are secured to and electrically insulated from the shell 105 of the furnace 84. Mica bushings 128 and washers 129 may be employed for insulation.

The levers 123 are pressed by rods 132 which engage apertures in the ends of the levers. The other ends of the rods are actuated by levers 133 pivoted at 134. The levers are pressed by rods 135 and springs 136 which are mounted within the bores of the tubular posts 127. The springs are adjusted by screws 137 which are threaded through caps 138 which are secured on the ends of the tubular posts. The hole 139 in the flange 140 of the shell 105 through which the bracket 125 and the rod 132 pass may be closed by suitable sleeves or by refractory material packed thereabout. Current may be supplied to the terminals 123 by flexible conductors 141 attached to terminal posts 142 which pass through and are insulated from the seal ring seat 104.

The heating elements are protected against splashing metal by a refractory plate 143.

A baffle 145 in the pouring furnace 20 may be provided for keeping the gases from passing therefrom into the hood and into the furnace 84.

Sight openings 146, 147 may be provided in the hood giving a view into the pouring spout, into the furnace 20 and to the stream of molten metal, as indicated in dot and dash lines in Fig. 4.

Instead of using hydrogen to remove sulphur, air may be used if the bath of metal in furnace 84 is protected by a suitable covering such as carbon. When air is used the inner door 89 is left open permanently and after a charge has been introduced the outer door 86 is left open a slight amount to admit the small quantity of air required. Exhaust fumes may escape by way of the opening 90 or by some other vent which may be provided near the furnace end of the preheating chamber. For this operation the vent 91 is closed off. The air, of course, will form additional oxides in the metal but these will be reduced when the metal is melted beneath the carbon covering in the bath of the furnace 84 and if any remain they will be completely removed in the furnace 20.

It may be desirable to cover the bath in furnace 84 with carbon even when hydrogen gas is used in the preheater for removing sulphur and oxy-

gen. 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 84 into the molds. When this is done the protection during and after pouring will be provided as described for pouring metal from the furnace 20.

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 required both to bring all of 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 induction heating or by mechanical movement of the vessel or both.

The temperature of the metal in the furnace 84 may be automatically controlled by a pyrometer 148 immersed in the molten metal near the pouring spout 94 together with suitable electrical connections like those provided for the furnace 20.

By similar instruments the temperature in the hoods 25, 21 and about the strainer 45 may be automatically controlled by controlling the flow of current to the resistors 54, 55, and 120. The pyrometers in this case need not be immersed in the metal but may merely be placed within the hoods near the metal.

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 produced. Such gases as remain and any fine holes which they form, because of their clean surfaces may readily be closed by hot working the metal in the solid state.

Where in the claims it is specified that the vessels and hoods fully enclose or fully protect the metal from the air, it is to be understood that if the vessels and hoods are filled with a protecting gas certain openings may be tolerated in the structure if they are not too large to be filled by outflowing gas rather than by inflowing air. The permissible size of openings will, of course depend upon the volume and pressure of the protecting gas.

While specific embodiments of apparatus 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.

I claim:

1. Apparatus for producing refined metal, comprising in combination, a preheater for heating solid metal, electrical resistors for heating the metal in said preheater, an induction electric furnace for melting the metal after it issues from said preheater, a pouring spout on said furnace, a vessel for receiving the molten metal, a hood enclosing the stream of metal from said spout to

the receiving vessel, said hood being sufficiently gas tight to maintain a protecting body of gas therein under sufficient pressure to completely exclude atmospheric air from the metal therein.

2. Apparatus for producing refined metal, comprising in combination, a preheater for heating solid metal, electrical resistors for heating the metal in said preheater, an induction electric furnace for melting the metal after it issues from said preheater, a mold for receiving and solidifying the metal from said furnace, a hood for protecting the metal while being poured from the furnace into the mold, and an electric heating element for maintaining metal in a molten condition within said hood.

3. Apparatus for producing refined metal, comprising in combination, a preheating furnace for heating solid metal which completely excludes atmospheric air, an electrical heater therein, means to admit a gas to purify the heated metal in said preheater, and means to melt and pour the metal after it issues from said preheater out of contact with air.

4. Apparatus for producing refined metal, comprising in combination, a metal pouring vessel, which is fully enclosed from the air, a pouring spout therefor, a receiving vessel into which the metal is poured which is fully enclosed from the air, said pouring vessel and receiving vessel being mounted for movement relative to each other, a hood completely protecting the metal from the air as it is poured from said spout to said receiving vessel, and a joint for said hood providing relative movement between the pouring vessel and the receiving vessel for pouring.

5. Apparatus for producing refined metal, comprising in combination, a furnace for maintaining molten metal which is fully enclosed from the air, a pouring spout therefor, a vessel into which the metal is poured which is fully enclosed from the air, said furnace and vessel being mounted for movement relative to each other, a hood completely protecting the metal from the air as it is poured from said spout to said vessel, a joint for said hood providing relative movement between the furnace and the vessel for pouring, and a strainer for directing the metal into the vessel.

6. Apparatus for producing refined metal, comprising in combination, a furnace for maintaining molten metal which is fully enclosed from the air, a pouring spout therefor, a vessel into which the metal is poured which is fully enclosed from the air, said furnace and vessel being mounted for movement relative to each other, a hood completely protecting the metal from the air as it is poured from said spout to said vessel, a joint for said hood providing relative movement between the furnace and the vessel for pouring, a strainer for directing metal into the vessel, and means for by-passing a protecting gas past said strainer.

7. Apparatus for producing refined metal, comprising in combination, a furnace for maintaining molten metal which is fully enclosed from the air, a pouring spout therefor, a vessel into which the metal is poured which is fully enclosed from the air, said furnace and said vessel having movement relative to each other, a hood completely protecting the metal from the air as it is poured from said spout to said vessel, a joint for said hood providing relative movement between the furnace and the vessel for pouring, a strainer for directing metal into the vessel, and heating means creating no sulphur or oxidizing effect within

said hood for keeping metal molten in said strainer.

8. Apparatus for pouring molten metal, comprising in combination, a vessel containing molten metal, a series of molds, a pouring spout on said vessel, an enclosed hood connected with said vessel, said hood being formed at its unattached end to fit a mold, a joint in said hood permitting movement of the vessel after the hood has been contacted with the mold, and means to first bring said hood and mold together and subsequently to pour metal from said spout into the mold.

9. Apparatus for pouring molten metal, comprising in combination, a vessel holding molten metal, means to present molds one after the other to said vessel, and an enclosed hood seating on a mold when in position and having a joint with said vessel which permits movement of the vessel during pouring while maintaining a tight seal with both the vessel and the mold.

10. Apparatus for refining molten metal, comprising in combination, a vessel containing molten metal and excluding atmospheric air from the metal, a metal receiving vessel, one of said vessels having movement relative to the other for pouring the metal, an articulated hood entirely enclosing the pouring passage between said vessels to compensate for the relative movement, and means for maintaining a protecting gas above atmospheric pressure in said receiving vessel and hood.

11. Apparatus as set forth in claim 10 which further includes in combination, means for heating the metal within said hood.

12. Apparatus for refining metal, comprising in combination, a furnace for molten metal, a vessel into which metal is poured from the furnace, a hood sealing the space between said furnace and said vessel, said hood and furnace being provided with face plates meeting in a plane for sliding movement to permit relative movement between the parts on each side of the plates, and means for forcing said plates together in all positions of the parts.

13. Apparatus for refining metal, comprising in combination, a furnace for molten metal, a vessel for receiving molten metal from said furnace, a hood sealing the space between said furnace and said vessel, said hood and furnace being provided with face plates meeting in a plane for sliding movement to permit relative movement between the parts on each side of the plates, and mounting means for one of said plates permitting it to tilt relative to its adjacent part to maintain face to face engagement with the other plate in all positions of the parts.

14. Apparatus as set forth in claim 13 in which said mounting means comprises seal rings having mating spherical surfaces movable over each other, and means for keeping said seal rings and said plates in contact.

15. Apparatus for refining metal, comprising in combination, a metal melting furnace including two spaced hearths and connecting channels, means for heating the metal in said channels electrically, said furnace being oscillatable about a horizontal axis between the hearths, means for oscillating said furnace, a pouring furnace of generally cylindrical shape mounted at the end of one of said hearths and oscillatable about a horizontal axis, means for oscillating said pouring furnace, means for heating the metal in said pouring furnace electrically, a mold disposed at the end of said pouring furnace and at one side of the axis thereof, a strainer for directing metal

from said pouring furnace into said mold, and hoods between the several units which completely exclude air and fully protect the streams of metal, said units and hoods being flexibly connected so as to permit free movements of all units while maintaining a tight seal.

16. Apparatus as set forth in claim 15 which includes in further combination, means for providing a gas envelope or covering about the metal at all points from the place where it is melted to the place where it is solidified.

17. Apparatus as set forth in claim 15 in which a carbon covering is maintained upon the bath of metal in said melting furnace and in which said oscillating means is operated to pass metal successively back and forth through said connecting channels, and in which a carbon covering is maintained upon the bath of metal in said pouring furnace, and the electrical heating means of the pouring furnace comprises induction units which cause circulation of metal into contact with the carbon covering.

18. Apparatus for refining metal comprising in combination, a furnace for molten metal mounted for tilting movement about a horizontal axis, a spout at the end of said furnace at one side of the axis of movement, a hood mounted to be raised and lowered relative to said spout and a sealing joint between said hood and furnace about the spout having sliding movement in a vertical plane.

19. Apparatus for refining metal comprising in combination, a melting furnace tiltable about a horizontal axis, a spout at the end of the furnace at one side of the axis, a pour hearth mounted to tilt about a horizontal axis, a metal receiving opening in said pour hearth at one end above the axis of movement, and a hood sealing the space between the melting furnace and the pour hearth, said hood having a joint with mating parts slidable along a vertical plane.

20. Apparatus as set forth in claim 19 in which said hood is mounted substantially entirely upon the pour hearth about said receiving opening.

21. Apparatus as set forth in claim 19 in which the joint comprises mating sliding sealing plates one mounted to move with the pour hearth and one mounted to move with the melting furnace.

22. Apparatus as set forth in claim 19 in which the joint comprises mating sliding sealing plates one mounted to move with the pour hearth and one mounted to move with the melting furnace, and resilient means for supporting the plate on the melting furnace.

23. Apparatus as set forth in claim 19 in which the joint comprises mating sliding sealing plates one mounted to move with the pour hearth and one mounted to move with the melting furnace, resilient means for supporting the plate on the melting furnace, and resilient means pressing said plates together.

24. Apparatus for refining metal comprising in combination, a furnace for pouring molten metal, a hood for protecting the stream of metal from said furnace, a resistor heating element in said hood, a movable electrode for said element and means for resiliently pressing said electrode against said element, said means comprising a lever, a bracket pivotally supporting said lever, a tubular post supporting said bracket, a rod in said post, adjustable and resilient means in said post for actuating the rod, and means for transmitting movement from said rod to said lever.

25. Apparatus as set forth in claim 24 in which said post supports all of the resistor pressing de-

vices, said post being secured to and electrically insulated from the metal casing of said apparatus.

26. Apparatus for refining metal comprising in combination, an enclosed melting furnace, an enclosed preheating furnace for supplying metal to the melting furnace, electrical resistors for heating metal in said preheating furnace, a seal chamber at the entrance to said preheating furnace, doors for said chamber, a conveyor to pass metal through the outer door into the seal chamber, and a conveyor for moving the metal through the preheater and dropping it into the melting furnace.

27. Apparatus for refining metal which is easily oxidized, comprising in combination, an enclosed preheater, electrical resistor heating means for said preheater, means to pass hydrogen into said preheater to desulphurize the metal, a melting furnace including spaced cylindrical hearths and connecting channels, said furnace being mounted to tilt about a horizontal axis located between the hearths, electrical induction heating means for said furnace, said furnace having a carbon covering on the bath of metal therein, means to rock the furnace to circulate metal through the channels and into contact with the carbon on the bath, said preheater and furnace having a close sliding fit to keep out air, a pour hearth mounted to tilt about a horizontal axis and having a carbonaceous covering on the bath of metal therein, electrical induction heating means for heating the bath of metal in the pour hearth and stirring it into contact with the carbonaceous covering, a hood having sliding movement to seal the stream of metal between the melting furnace and the pour hearth, a mold wheel carrying a plurality of molds and presenting them successively to the pour hearth, a hood and strainer assembly movable vertically to seat upon molds as they arrive in position, said hood having a sealing sliding fit with said pour hearth, means to supply a protecting gas to said hood, a by-pass to permit the gas to flow past the strainer into the mold to purge it and protect the molten metal, and a cooling tank and conveyor for taking the billets from said molds.

28. Apparatus for producing refined metal, comprising in combination, a metal melting furnace entirely enclosed from the air and providing a body of metal substantially free from metallic oxides, hydrogen and water vapor at the point of pouring, a pouring spout therefor, a mold, a strainer for maintaining a shallow pool of the metal to promote gas release and for directing the stream of metal from the spout into the mold so that the metal will have a vertical fall, and a hood free from oxidizing gases entirely enclosing the space between the furnace and the mold and embracing said strainer and completely excluding air therefrom.

29. Apparatus of the through-passage continuous-operation type adapted for the production of refined metal comprising in combination, a pouring vessel provided with spatially separated charging and pouring positions at which fresh charges of metal are received and at which substantially deoxidized molten metal is delivered respectively, the vessel being constructed and operated in such manner as to protect the metal from oxidation, to substantially deoxidize the metal if it is received in an oxidized condition and to deliver it in deoxidized condition at the pouring position, a receiving vessel which excludes atmospheric air and oxidizing agents from

the metal received therein until it has solidified to the point where it is substantially unaffected by oxygen, and means for positively and completely excluding the admission of oxidizing agents to the metal throughout its passage from the pouring vessel to the receiving vessel, said means at all points where the metal flows in a free stream or cascade comprising a substantially complete structural enclosure around the stream for excluding contaminating gases, and means for maintaining within the structural enclosure about the stream a protecting gas under sufficient pressure and in sufficient volume to completely inhibit the inflow to the metal stream of contaminating gases.

30. Apparatus as set forth in claim 29 in which said receiving vessel is removably connectible with a stream enclosure whereby it may be removed and replaced by other vessels of like kind.

31. Apparatus as set forth in claim 29 in which said pouring vessel and said receiving vessel are directly connected by a structural enclosure, said pouring vessel being movable for pouring metal and said receiving vessel being removably connectible with the enclosure whereby it may be removed and replaced by other vessels of like kind, said enclosure and vessels being articulated to provide the required movements of said vessels while maintaining sealed connections.

32. Apparatus for refining molten metal, comprising in combination, a metal pouring vessel, a metal receiving vessel provided with a movable closure at a point distant from said pouring vessel to permit the passage of gas there-through to scavenge it, said vessels having relative movement for positioning for pouring and for pouring, a hood forming with said vessels an air excluding enclosure at the time of pouring but permitting the required movements for positioning and pouring, and means for filling said receiving vessel and said enclosure and scavenging said receiving vessel with a metal-protecting gas before pouring.

33. Apparatus for pouring molten metal, comprising in combination, a movable metal-pouring vessel, a metal-receiving vessel, a hood fitting between said vessels, said hood being constructed to permit the required movements of said metal-pouring vessel for pouring metal while forming with the vessels at the time of pouring an air excluding enclosure, and means for supplying heat to the metal within said enclosure.

34. Apparatus for pouring molten metal, comprising in combination, a metal-pouring vessel, a metal receiving vessel, a hood fitting between said vessels, said hood being constructed to permit the required movement between said vessels for pouring metal while forming with them at the time of pouring an air excluding enclosure, means within the enclosure for holding a pool of metal and directing a stream of metal into the receiving vessel, and means for supplying heat to the metal within said enclosure.

35. Apparatus for pouring metal comprising in combination, a device providing molten metal, a device for receiving molten metal, a conduit or hood for entirely enclosing the stream of metal between said devices, said hood being adjustably sealed to said pouring device in all positions of the device and hood and being seated upon the upper end of a receiving device when the latter is positioned therebeneath, and means for vertically reciprocating said hood to seat it upon a receiving device or to raise it therefrom.

36. Apparatus for pouring metal comprising in combination, a tiltable hearth for pouring metal, a vertically fixed mold for receiving the metal, a vertically movable hood, means securely sealing the hood with said hearth which permits independent movement of either the hood or the hearth, said hood being sealed with the mold when it is lowered to seat thereon, a pipe for supplying gas to said hood and a vertically adjustable connection in the pipe for accommodating the movements of said hood.

37. Apparatus of the character described, comprising in combination, a device for pouring molten metal, a device for receiving the molten metal, a structural enclosure for the metal moving between the pouring device and the receiving device, said enclosure having a permanent tight seal with said pouring device and having a close fit with the receiving device when the latter is in pouring position, and means for maintaining within the enclosure a protecting non-oxidizing gas under sufficient pressure and in sufficient volume to completely inhibit the entrance of air at atmospheric pressure therein and to replenish the gas lost through such small openings as there may be in the enclosure, whereby the inflow and admixture of air with the protecting gas is prevented and the metal moving between the devices is positively protected from the atmospheric air and other contaminating influences.

38. Apparatus of the character described, comprising in combination, a device for pouring molten metal, a device for receiving the molten metal, a structural enclosure for the metal moving between the pouring device and the receiving device, such enclosure being sufficiently tight to exclude air at atmospheric pressure, and a strainer within said structural enclosure for halting the metal in a relatively shallow pool and redirecting it to said receiving device for the purposes set forth.

39. Apparatus as set forth in claim 38 which further includes in combination, means for supplying heat to the metal within said enclosure to keep it molten.

40. Apparatus of the character described, comprising in combination, a device for pouring metal, a device for receiving metal, a structural enclosure for the metal moving between the pouring device and the receiving device, said enclosure including parts cooperating with said pouring device to establish a tight seal therewith while permitting relative movement between the pouring device and the enclosure, and parts cooperating with said receiving device to establish a tight seal therewith which may be readily broken for separating the enclosure from the receiving device.

41. In an electric furnace in combination, a hearth, a pouring spout for said hearth, a baffle for said pouring spout, and means to heat metal outside the baffle, said means comprising electrical heating elements located above and out of contact with the metal.

42. A furnace as set forth in claim 41 which further includes a thin refractory sheet between the metal and said heating elements.

43. Apparatus for refining copper comprising a melting furnace provided with spatially separated charging and pouring openings, said furnace being provided with agencies for completely excluding air from the molten metal and delivering it to the pouring opening entirely free from copper oxide, a refractory covered pyrometer immersed in the bath near the pouring opening, and

control means regulated by the pyrometer for governing the temperature of the bath.

44. Apparatus for controlling the temperature of a molten bath of deoxidized metal comprising in combination an induction heating furnace for containing said bath, means for excluding air from the metal and maintaining it at a point of delivery entirely free from metallic oxides, and means for automatically controlling the rate of application of heat to the bath, said means including a pyrometer encased in a refractory cover which is in contact with the molten metal and control means actuated thereby for regulating the

current supplied to the induction heating furnace.

45. Apparatus of the character described, comprising in combination, a melting furnace, a deoxidizing furnace free from fuel combustion containing carbon for removing oxygen from a copper bath therein, a mold for receiving the deoxidized metal, a conduit for supplying a harmless carbonaceous reducing gas into the mold and around the pouring stream to protect the metal from the atmosphere, and a shield between the deoxidizing furnace and the mold for confining the protecting gas and excluding the atmosphere.

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