No. 810,249. PATENTED JAN. 16, 1906.

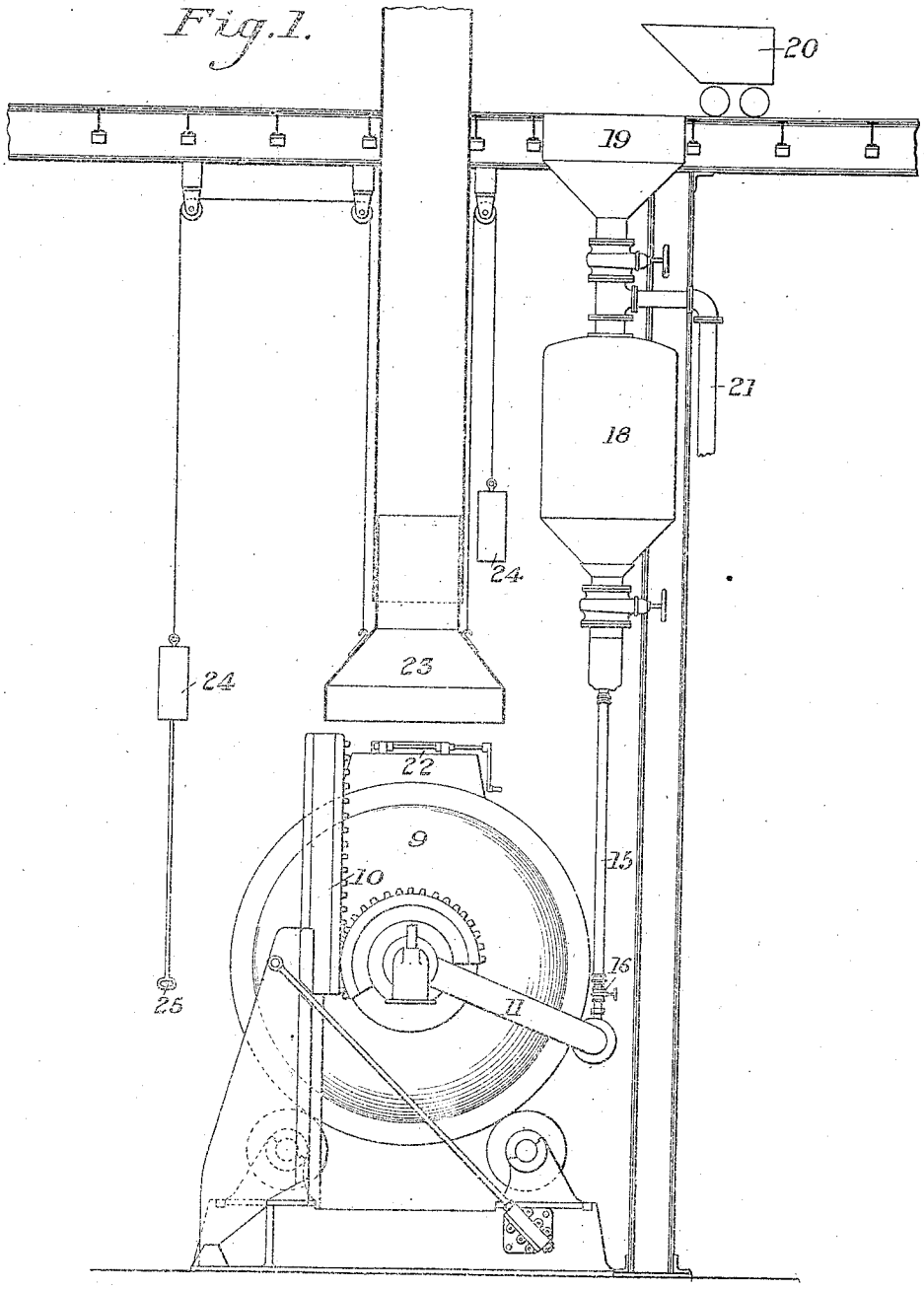
R. BAGGALEY, C. M. ALLEN & E. W. LINDQUIST.

METHOD OF REFINING COPPER.

APPLICATION FILED JUNE 5, 1905.

4 SHEETS—SHEET 1.

Fig. 1.



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4 SHEETS—SHEET 3.

Fig. 2.

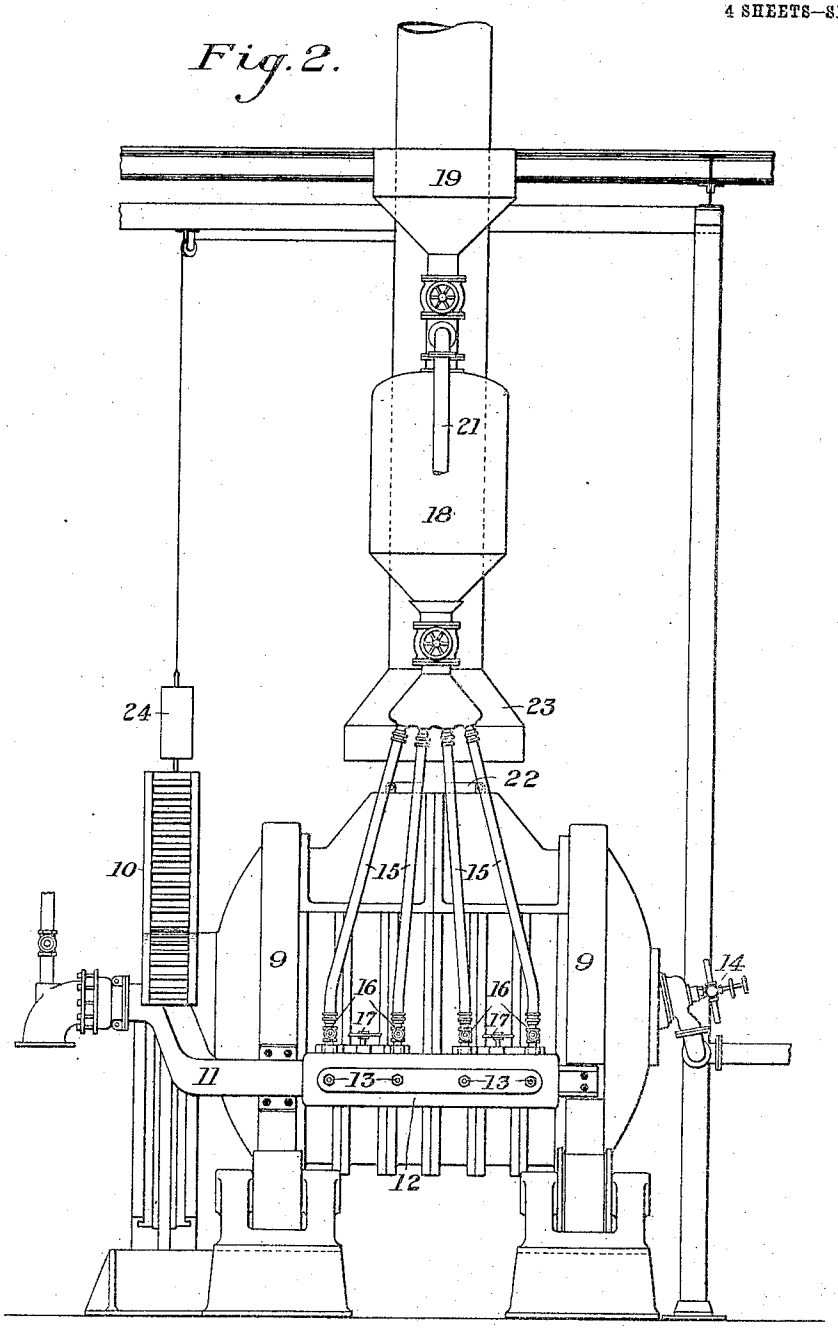

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Fig. 7.

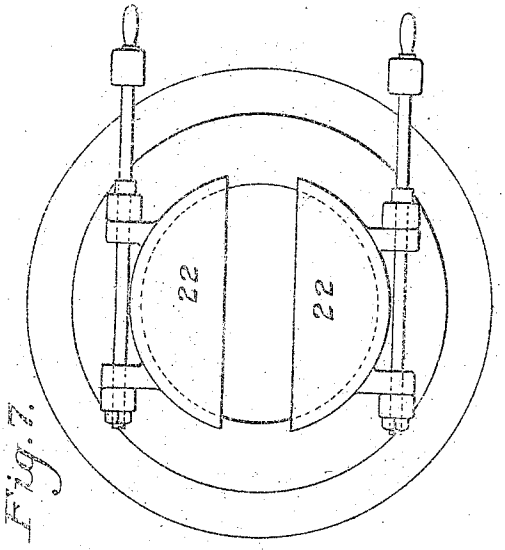


Fig. 8.

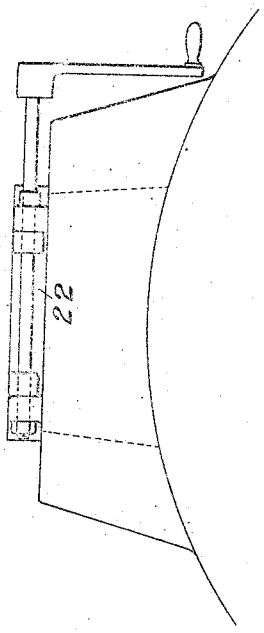


Fig. 4.

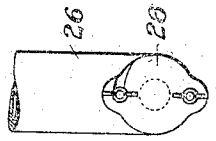
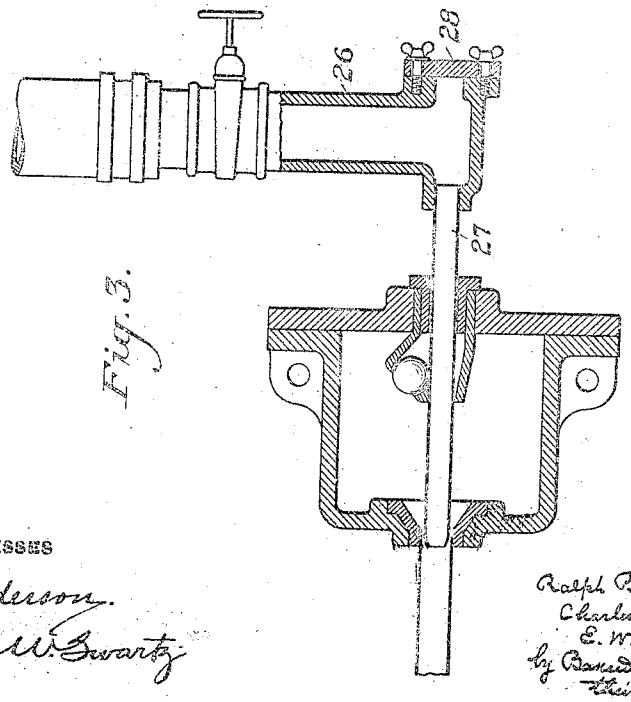


Fig. 3.



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4 SHEETS—SHEET 4.

Fig. 6.

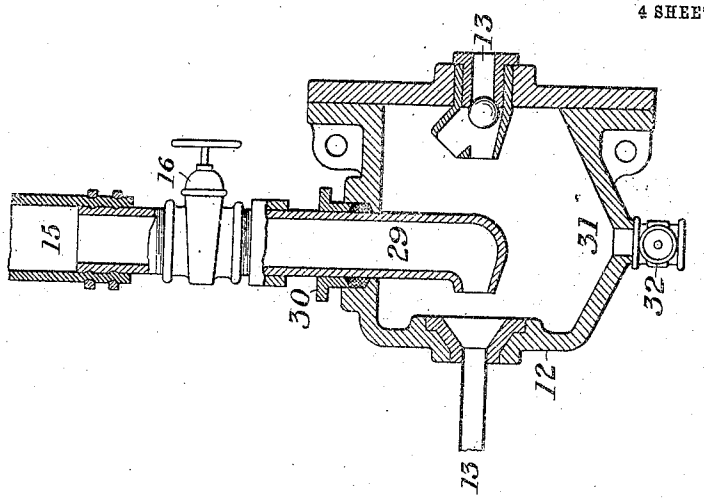
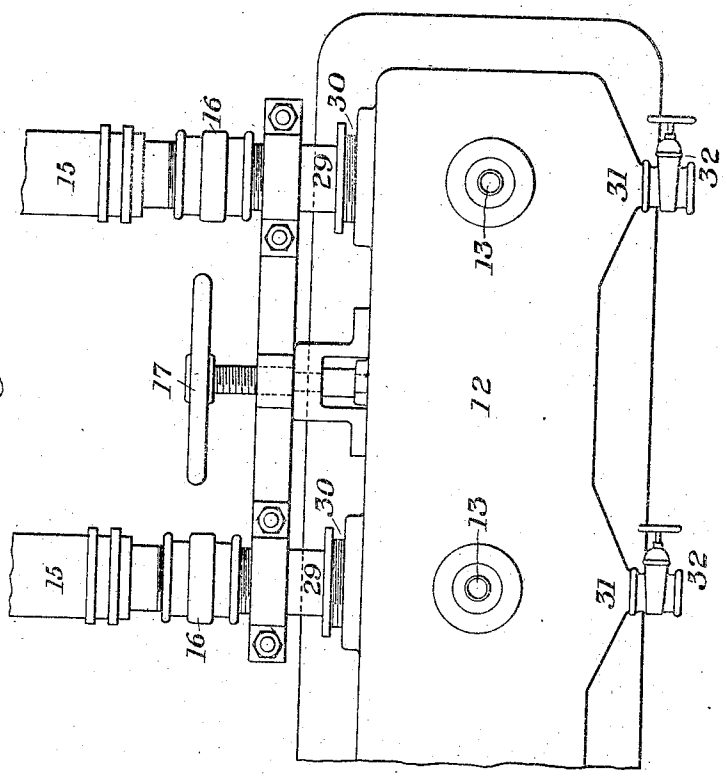


Fig. 5.



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UNITED STATES PATENT OFFICE.

RALPH BAGGALEY, OF PITTSBURG, PENNSYLVANIA, CHARLES M. ALLEN, OF LOLO, MONTANA, AND EDWARD W. LINDQUIST, OF CHICAGO, ILLINOIS; SAID ALLEN AND LINDQUIST ASSIGNORS TO SAID BAGGALEY.

METHOD OF REFINING COPPER.

No. 810,249. Specification of Letters Patent. Patented Jan. 16, 1906.

Application filed June 5, 1905. Serial No. 263,693.

To all whom it may concern:

Be it known that we, RALPH BAGGALEY, of Pittsburg, Allegheny county, Pennsylvania, CHARLES M. ALLEN, of Lolo, Missoula county, Montana, and EDWARD W. LINDQUIST, of Chicago, Cook county, Illinois, have invented a new and useful Method of Refining Copper, of which the following is a description, reference being had to the accompanying drawings, forming part of this specification, in which—

Figure 1 shows an end elevation of apparatus suitable for the practice of our invention. Fig. 2 shows a side elevation of the apparatus. Fig. 3 shows in cross-section a detail of an alternative apparatus for practicing our invention. Fig. 4 shows the front cap on the apparatus illustrated in Fig. 3. Fig. 5 shows, on a much larger scale, a portion of the wind-box, also two twyers illustrated in Fig. 2 Fig. 6 shows in cross-section the wind-box one twyer and our preferred form of apparatus for practicing our invention. Fig. 7 shows a plan view of dampers and one form of actuating mechanism for the same to control the escape of hot gases, as shown at the top of the apparatus in Figs. 1 and 2. Fig. 8 shows a side view of Fig. 7.

The object of our invention is to cheapen, simplify, expedite, and reduce to an exact and accurate science the refining of blister-copper. Its object is also to make it possible to refine copper in small batches or in comparatively small batches—such, for instance, as may be recevied from a single bessemerizing converter charge from time to time as work in a smelting plant progresses.

To this end our invention consists in forcing sawdust, by means of gas-pressure or air-pressure, underneath a bath of molten blister-copper, using either hydrocarbon gas under pressure or compressed air as the propelling medium for the sawdust. The gas-producing constituents of the sawdust are thus instantly and automatically converted into hydrocarbon or reducing gas through the medium of the heat of the molten bath.

In present practice the refining of copper is a most intricate, a most uncertain, and expensive process. The refining-gases are produced in the molten copper itself and by its own heat solely through laborious and expensive hand-poling. A supply of green hard wood poles must be procured continuously for the purpose, and these must be utilized before the moisture dries out of them. The work cannot be done successfully with a bath of less than from eight to ten tons. Present practice tends steadily in the direction of larger baths than that stated. Fifty, one hundred, and even one hundred and fifty tons of blister-copper are being treated in the refining-furnace at one time. It has been found that with a large bath the heat can be better retained than in small ones, for the reason that the proportion of chilling exterior is much less in the former than in the latter. Inasmuch as blister-copper is extremely sensitive to its surrounding conditions and because it always shows a great tendency to chill, the increased heat that thus becomes possible through handling a very large bath at one time is of great importance. It will be apparent that such a large bath necessarily represents a large accumulation of product. Assuming that the ordinary product of a converter charge is four tons, a bath of one hundred tons in the refining-furnace will represent twenty-five such charges from a converter. Even a small bath in the refining-furnace—say of twelve tons—will represent three converter-charges. The net result of these things is that in present practice it is impossible to transfer blister-copper in the molten form direct from the converter into the refining-furnace for treatment. In lieu of this desired practice it is necessary to store the converter product of many charges, to remelt these in a large refining-furnace with carbonaceous fuel at a heavy expense, and to thereafter hold this great molten bath over a period of many hours and sometimes for days while the tedious and expensive hand-poling process is practiced upon it as a means of subjecting the molten bath to the reducing influences of the hydrocarbon gases. This requires the services of several gangs of expert workmen, who command high wages and who work in shifts of eight hours each. Furnacemen are necessary for maintaining the fires. Copper refiners, who command very high wages, are necessary in applying the green hard-wood poles to the bath. Other workmen are required who are engaged in tapping and in casting the molten copper into plates, slabs, bars, or cathodes. Dur-

ing all of this time the great molten bath constantly absorbs oxygen on its surface from the atmosphere, and during this time the sides and the bottom of this large furnace are absorbing by saturation vast quantities of copper, gold, and silver. A single furnace may thus absorb through saturation from fifteen to thirty thousand dollars worth of metal. A new furnace when started may thus absorb practically all of the metal contained in successive charges for a week or for even a longer period. Even if this vast sum be partially recovered when work is permanently stopped in a furnace it will be apparent that in the meantime the capital is not available for use in conducting the business.

Ideal practice would be to receive the bath in small volume and in molten form directly from the converter immediately after each charge has been oxidized to the requisite extent, because in this way each separate converter charge of blister-copper can then be received directly into the refining-furnace and without the expense and delay of remelting it can be immediately refined and at once thereafter cast into cathodes, plates, or bars, as may be desired, for shipment. It is also possible to perform this refining operation in the finishing converter itself without transferring it to a special refining-furnace, as hereinafter explained, such as that described in Serial No. 258,152, filed May 1, 1905, and which furnace is supplied with the heat of an oil or gas flame to increase or to regulate the temperature of the molten bath. Where a smelter plant is not provided with such a special refining-furnace, we much prefer to do this work within the finishing converter, as stated, as there is not enough heat left in the molten copper at this stage of the operation to enable one to transfer it without producing a very heavy skull of congealed copper that must later be remelted in order to recover its contained values.

The object of our invention is to make this ideal practice possible and, in short, to admit of the refining of copper in small batches in a smelter plant as quickly as made, continuously, and without interruption, the same as the bessemerizing or the oxidation of mattes are now carried on in converters. It will be apparent that if this method of refining be practiced through the use of our invention it will necessarily be radically different from anything that at present exists in the trade.

Among the advantages that we claim for this invention may briefly be enumerated the following:

First. The ability to receive a single charge of molten copper directly from a bessemerizing converter, to hold this charge indefinitely at any desired heat, to increase this heat at will, and in this manner to make it possible to refine a small bath.

Second. To accomplish thorough, complete, and exact refining in a fraction of the time at present required.

Third. To admit of carrying on the refining of copper in small baths and as a practically continuous process exactly as the converting of copper mattes is now done.

Fourth. To materially reduce the present costs of refining.

Fifth. To accomplish the work practically throughout by means of machinery, thus eliminating the present high-priced skilled labor, that is sometimes paid as much as seven dollars per day of eight hours for each workman.

Sixth. To make it possible to subject a bath of molten blister-copper to the reducing influences of hydrocarbon gases up to a perfect pitch, or, in other words, to the exact desired point of refinement, then to instantly stop the reducing action, and thereafter to immediately pour the copper before it can have an opportunity of changing its pitch through the absorption of oxygen from the atmosphere, as is the case in all present practice.

Seventh. To eliminate the present enormous metal losses from saturation in the end and in the side walls and in the bottoms of refining-furnaces.

Eighth. To make it possible to refine copper automatically by the use of gas created by the combustion of sawdust in lieu of the present practice of hand-poling. Where copper is refined by means of our present invention, the propelling medium being a precreated ligneous gas, it may be produced from any kind of cheap waste ligneous material, such as sawdust, slabs, and the waste refuse of the forest. These materials may thus be entirely consumed in effective work, and the reducing effects on the copper of this precreated gas are by our present invention supplemented and enormously increased by the delivery of sawdust or similar materials underneath the molten bath. Where the refining of copper is produced by hand-poling, only carefully-selected hard-wood poles can be used. Only a small portion of each pole can be actually consumed in performing effective work. These poles must be provided fresh from the forest at frequent intervals, and they must be used while yet filled with natural moisture; otherwise they become useless for the purpose.

Ninth. To change what is now an extremely erratic, uncertain, hazardous, and expensive art into a simple, cheap, certain, and exact science.

Tenth. To make it possible to retain the copper in a thoroughly hot liquid condition until poured.

Eleventh. To make it possible to pour and to cast the copper into any desired form by machinery with a single workman in lieu of several gangs of skilled workmen, as de-

manded in all present practice and as hereinbefore described.

Twelfth. To eliminate the troubles incident to all present practice from the congealing of copper at or near the tap-hole of the furnace, where it often solidifies to a thickness of eight or twelve inches, thus often necessitating the use of air-drills or hand-bars and sledges to punch the tap-hole and to maintain a flow of the molten metal. In the apparatus shown in the drawings the temperature of the molten bath may be maintained as long as desired and throughout the act of pouring to a point where the congealing of the bath is impossible. The pouring-lip in this apparatus is always open, free, and hot. Consequently the bath cannot solidify upon it, as is the case where tap-holes are resorted to. During the act of pouring the vessel is tilted by machinery to any desired degree and until after the refined copper has been discharged from the vessel to the last drop. For this reason solidification and losses are impossible.

Thirteenth. A saving in expense over present practice through providing and continuously maintaining a heavy charcoal covering on the molten bath. Our present invention, through the delivery of the sawdust underneath the molten metal, automatically provides and maintains its own carbon covering.

Fourteenth. An increased capacity in a given time.

Fifteenth. The ability to refine copper as a continuous operation in a small inexpensive apparatus, while utilizing waste materials exclusively to produce the desired result in lieu of present practice, which involves an enormous investment for a large furnace, a heavy current expense for various gangs of workmen and for fresh green poles, with enormous losses of capital due to saturation, as described.

Many other advantages may be mentioned that need not here be enumerated.

Referring now to the drawings, 9 in Figs. 1 and 2 shows the body of the vessel, 10 the actuating mechanism, and 11 the means for introducing the propelling medium for the sawdust or similar material.

12 in Fig. 2 illustrates the wind-box, 13 the twyers through which the sawdust is propelled, and 14 the oil or gas jets for preheating the vessel and thereafter maintaining the heat of the bath at will and at any desired temperature.

15 illustrates flexible tubes for the delivery of the sawdust into the wind-box. Hinges or other metallic tubes may be utilized for this purpose, if preferred, without departing from the spirit of our invention.

16 shows valves to regulate the flow of the sawdust into each twyer-orifice.

17 illustrates means for temporarily or permanently removing the sawdust-delivery tubes to the wind-box, if desired for any purpose.

18 illustrates a receptacle into which the sawdust or similar material may be delivered from above by gravity from the hopper 19 by means of the car 20 or otherwise.

21 illustrates the pipe through which the pressure of the ligneous gas or other propelling medium is maintained on top of the supply of sawdust in order to facilitate its delivery into the apparatus.

22 in Figs. 1, 2, 7, and 8 illustrate the heavy-metal dampers that partially cover the top of the refining-furnace, so as to enable the operator to control at will the escape of the hot internal gases poduced by the process or supplied by the auxiliary heat-jet 14. The dampers 22 are purposely arranged so that there will always be ample space between them for pouring the molten copper after it has been refined. We prefer to make these dampers for economy of metal, preferably cast-iron or cast-steel, without lining of any description. We have found that if these be made sufficiently heavy they will successfully withstand the internal heat practically without injury.

23 illustrates the telescopic cover for the apparatus so arranged that it may be lowered, if desired, while refining is in progress, or it may be raised when it is desired to tilt the vessel. Counterweights 24 are intended to balance the weight of the telescopic portion of this hood, so that it may be readily raised or lowered by a single operator by means of the handle 25.

The receptacle 18 may be made of any desired form or size without departing from the spirit of our invention. As shown in the drawings, its capacity is sufficient to hold sawdust to refine two converter charges of four tons each of blister-copper.

26 in Fig. 3 illustrates an alternative method of delivering sawdust into the refining-furnace by inserting the tube 27 through the wind-box, as shown. Should this tube become obstructed, it may be punched, and thereby reopened, the same as a twyer through the plate illustrated in Figs. 3 and 4 at 28.

Fig. 5 is intended to illustrate, on a larger scale than that given in Fig. 2, a method of quickly raising or lowering the sawdust-jets 29 (illustrated in cross-section in Fig. 6) by means of the hand-wheel and screw 17 illustrated in Fig. 5.

Fig. 6 illustrates our preferred form of delivering sawdust into the vessel. The tube 29 is preferably made of seamless brass, and it is provided with a stuffing-box 30 to prevent leakage of the propelling medium. The globe-valve 16 admits of an exact regulation of the flow of sawdust into each separate twyer. The elastic or hinged pipe delivery

medium for sawdust into this jet, as shown at 15, is intended to remain permanently in position. This entire sawdust-delivery apparatus may be removed at will, so that thereafter the refining of copper may be conducted by means of ligneous gas alone.

The wind-box, as illustrated in Figs. 5 and 6, is preferably provided with a belly or with a receptacle with sloping sides below each sawdust-jet, as shown at 31. The object is to compel any sawdust that fails to enter the twyer 13 to drop into this receptacle at its lowest point and thereafter to be removed by simply opening the globe-valve 32.

Should any of the twyers become plugged with chilled accretions, the sawdust jet 29 may be instantly raised out of line with the twyer by means of the hand-wheel 17, and thereafter the twyer may be punched through the orifice 13 in the usual manner.

The foregoing description relates to the practice of our present invention in connection with the method disclosed in United States Patent No. 746,246, issued December 8, 1903, and in application Serial No. 258,152, filed May 1, 1905, by Ralph Baggaley, for a copper-refining furnace, in each of which a precreated hydrocarbon gas is utilized as the propelling force to drive the sawdust into the molten bath. To this end such precreated gas may be compressed to whatever extent may be found necessary to produce the desired result. When used in connection with the inventions aforesaid, the propelling medium will act in harmony with the sawdust to produce a reducing action alone. Each will therefore supplement and assist the other. We wish, however, to state distinctly that our present invention is not limited to the use of precreated hydrocarbon gas as the propelling medium. Air may be used for this purpose, if properly handled, with great success and with great economy. Where air is utilized for the purpose, it may be done in connection with any ordinary copper-bessemerizing converter by providing suitable connections to the wind-box and by providing apparatus like or similar to that shown in the drawings for the delivery of the requisite supply of sawdust or similar material. Where our present invention, however, is used in connection with an oxidizing or bessemerizing converter in the manner stated and with air under pressure as the propelling medium for the sawdust, we much prefer to practice this art in a small finishing converter, such as that described in application Serial No. 255,869, filed April 17, 1905, and to do this at the end of the converting operation in the same vessel without pouring or transfer. When ores and mattes contain important percentages of arsenic, antimony, selenium, tellurium, and even a minute percentage of bismuth, the molten copper must be "overblown," as it is called in the trade—*i. e.*, it must be submitted to overoxidation as a means of eliminating the last vestige of such impurities. Arsenic and bismuth (particularly the latter) cling with great tenacity to the copper, and for this reason to thoroughly expel it demands that the bath be overoxidized, as stated. This has the effect of charging the copper with heavy percentages of suboxid, the effect of which is to impair or to destroy the ductility and the conductivity of the metal. If arsenic, and particularly bismuth, be allowed to remain, these also produce the same effect, and they reduce the market value of the metal to an important extent. It is therefore desirable in bessemerizing copper that all objectionable impurities be thoroughly expelled through the medium of overoxidation and that the metal thereafter be restored to its proper pitch or temper by the removal of suboxid. The latter may also be absorbed from the atmosphere as well as from the air-blast during the treatment of the bath in the furnace. It never floats upon the surface, as many impurities do, in the form of a slag or dross. It becomes an integral part of the metal itself, and the bath that contains it may be perfectly bright and clean, yet such copper must be restored to its proper pitch as a means of restoring its ductility and conductivity and as a means of yielding its full market value when sold.

The presence of any of the objectionable impurities or the suboxid so impairs the ductility of the metal that it will split into slivers or strips. In this form it is practically useless in the arts, excepting possibly in the form of ingots for melting in the manufacture of castings. Even then its market value is considerably reduced, and it is not by any means as desirable for this or for any purpose as copper from which these impurities and this suboxid have been thoroughly eliminated.

When used in connection with an oxidizing-converter and with an air-blast under pressure as the propelling medium, the delivery of the sawdust should be commenced some time before the oxidation of the bath has been completely accomplished. This will result in a simultaneous oxidation and reducing action similar to that which exists in all blast-furnace work as at present conducted.

It will be noted that in delivering the material in the granulated or comminuted form each separate particle of this material will be accompanied by the oxygen in the blast, which will facilitate the combustion. Attention is also called to the fact that the combustion of each separate particle of this material will produce carbon the same as in a blast-furnace during the combustion of coke. The effect of this carbon will be to materially augment the reducing action. The entrance

of the air-blast into the molten bath will produce the desired violent agitation, which is important in quickly producing the refinement of the bath. We use sawdust for this purpose for the following reasons:

First. It is cheap.

Second. It is rich in hydrocarbon-producing materials, and this is particularly true of firs, pines, coniferæ of all kinds, beech, maple, &c., which are the usual forest growths at or near copper-smelting plants.

Third. It may be readily and cheaply dried before using, if preferred; but we prefer to use green sawdust as a means of increasing the agitation by ebullition.

Fourth. Sawdust is capable of being delivered through the twyers without material injury to the same, and any such wear may be absorbed by lining each twyer with a seamless brass tube which may be quickly and cheaply replaced. Any material of an abrasive nature—such, for instance, as coal-dust—is highly objectionable for use in practicing this art, because its action while passing through the twyers is equivalent to a sand-blast. Hence the delivery of a single charge of such material through the twyers may destroy them.

Fifth. The delivery of sawdust or similar material in a granulated or comminuted form is particularly favorable for an even distribution of the hydrocarbon gases quickly and thoroughly throughout the entire volume of the molten bath. Where hard-wood poles are used in refining copper, it will be apparent that the refining action is confined to the immediate contiguous neighborhood in the bath of the pole, whereas in our present invention the hydrocarbon-gas-producing material is delivered and distributed evenly and thoroughly throughout the entire body of the molten bath. The action of the entering blast and sawdust also has the effect of continuously revolving the molten bath within the vessel, and in this way the granulated or comminuted material is evenly and continuously distributed through it, as stated, the net result of this process being the accomplishment of the desired result in a fraction of the time that it is possible to accomplish the same work by hand-poling.

Enough sawdust or other similar material should be fed into the molten bath where an air-blast is used so that the reducing gas produced will greatly exceed and will thus conquer the oxidizing effects of the propelling medium. The sawdust when delivered underneath the molten bath accompanied with ample oxygen to facilitate its combustion will be forced to rise through the entire body of the bath, and its combustion will have a distinctly heating as well as a refining effect on the copper. This is of great importance to success, and it may obviate the necessity of using the auxiliary heat of a flame. It is well known that after copper has reached the grade of blister, and even before that point, the effect of an air-blast alone is chilling, because the oxidizable or heat-producing elements and compounds are practically exhausted. It is common practice during the final stages of the converting process to throw blocks of wood onto the surface of the bath as a means of maintaining its heat until the refining process can be carried to completion. The delivery thus of sawdust in large quantities underneath the molten bath, particularly when accompanied with the requisite volume of oxygen to facilitate its combustion, will be distinctly heating, and this will have the effect of holding the bath under treatment at a high temperature and in a thoroughly liquid condition until after the reducing gases have performed their mission and until the refined copper can be poured. This method of refining copper will automatically supply a carbon covering for the bath during treatment, which will have the effect of preventing it from absorbing oxygen, and thus forming a suboxid from the atmosphere until poured, as hereinbefore described.

The materials utilized in practicing this art may be sawdust or other ligneous material in granulated or comminuted form derived either from hard woods or from the coniferæ. The hydroscopic moisture may be first extracted or not, as preferred. The immediate effect of the presence of hydroscopic moisture will be chilling, because it is well known in the arts that to eliminate such hydroscopic moisture demands the consumption of a proportionate amount of heat. Nevertheless there are arguments in favor of permitting such hydroscopic moisture to remain in the sawdust, assuming that the heat units contained within the molten bath and produced through the combustion of the sawdust are ample for the purpose. The presence of the hydroscopic moisture will produce steam in the bath and will facilitate the agitation and the distribution throughout it of the gases the same as results from the use of green hard-wood poles in the present hand-poling process. It is well known that the art of hand-poling cannot be successfully practiced with dry-wood poles. Green poles, and preferably green hard-wood poles, are essential to success. The steam generated by the heat of the molten bath produces the desired agitation of the molten copper, and it aids in distributing the gases. If desired, we may add to the sawdust which is injected into the bath wax, oils, grease, or like material, provided the same is not added in such quantities as to clog in the twyers or produce explosive effects in the furnace.

We are aware that in British Patent No. 6,399 of 1892 a process is described in which paraffin-wax and various volatile oils are utilized as a means of refining copper; but

such processes cannot be practiced for many reasons. Among others may be mentioned the immediate clogging and closing of the twyers and the wind-box through the chilling effect of the blast if paraffin or any of the heavy oils be used. The lighter volatile oils cannot be used successfully without the risk of serious and continuous explosions.

In our judgment it is esesential to success that the hydrocarbon-gas-producing materials be in granulated or in comminuted form. It is also necessary that their physical condition should be such that they will not destroy the twyers while being driven under pressure into the molten bath. We do not know of any cheaper or better material that is capable of accomplishing this result than ordinary sawdust, which is easily obtained about all mines and smelter plants, where the manufacture of lumber is a necessary accompaniment of mining work. This material is to-day a waste product, and as a rule it costs money to dispose of it. Green hard-wood poles are purchased often at a heavy expense. They accomplish the result slowly, expensively, and imperfectly, and a continuous supply must be provided in order to have them ready for use in the green state.

The desired result through the use of our invention is produced thoroughly, and the work is simplified, cheapened, and rendered exact through the use of a waste product. It is non-explosive, it is rich in hydrocarbon gases, and after combustion it furnishes automatically sufficient carbon to constitute the oxygen-excluding cover to the molten bath. After combustion this carbon product will approximate nine per cent. of the amount of sawdust charged. By reason of its physical condition and its specific gravity it will naturally rise in the form of charcoal to the surface, and thus float on the molten bath, in which condition it automatically provides an ideal carbon covering to exclude oxygen during the treatment of the bath. Sawdust has sufficient weight and volume to admit of its being successfully propelled by means of the air-blast into the body of the heavy molten copper, which would be impossible were paraffin or any of the heavy or lighter volatile oils used. If preferred, the hydrocarbon-gas-producing power of the sawdust or other suitable material may be greatly increased before use by soaking it in oils, paraffin, greases, or the lighter volatile oils without departing from the spirit of our invention. The fundamental feature that we claim to be broadly new is the introduction of such material of a non-abrasive character in a solid though comminuted form which admits of its successful delivery underneath the molten bath. Attention is again called to the important point that only such hydrocarbon-gas-producing materials should be used for this purpose which by their nature or their physical condition will not obstruct the twyers and that will not destroy them by abrasion. Wax, paraffin, heavy oils, and greases could not be used successfully. They are inflammable and liable to cause explosions when brought into contact with the molten bath. Wax, paraffin, and the heavy oils would soon clog the twyers, the wind-box, and the air-passages. On the other hand, if coal-dust or other gas-producing material of an abrasive or of a partially-abrasive nature be used the tendency would be to act like a sand-blast; and this would soon result in the destruction of the apparatus. Such has been the effect, for example, of efforts to inject silica into converters through the twyers.

Doubtless many modifications will suggest themselves to those skilled in the art in practicing this invention without departing from its spirit, since—

What we claim is—

1. The method of refining copper which consists in injecting into a bath of molten copper, granulated or comminuted hydrocarbon-gas-producing material, non-abrasive and of such nature that it will not melt and clog in the twyers at the temperature there present; substantially as described.

2. The method of refining copper which consists in injecting sawdust into a bath of molten copper; substantially as described.

3. The method of refining copper which consists in injecting sawdust into a bath of molten copper in a Bessemer converter after oxidation; substantially as described.

4. The method of refining copper which consists in injecting sawdust into a bath of molten copper in a Bessemer converter before oxidation is completed and utilizing air under pressure as the propelling medium substantially as described.

5. The method of refining copper which consists in injecting with air-pressure into the molten copper before suboxid has been formed, hydrocarbon-gas-producing material of a non-abrasive kind in a granulated or comminuted form; substantially as described.

6. The method of refining copper which consists in injecting hydrocarbon-gas-producing material of a non-abrasive kind, in a granulated or comminuted form, into a molten bath of black or blister copper by means of an air-blast under pressure before the stage of oxidation has been reached where appreciable amounts of suboxid have been formed in the bath; substantially as described.

7. The method of refining copper, which consists in injecting sawdust into a molten bath of copper by means of an air-blast, before the completion of the converting operation and in the same vessel in which the converting action has brought the bath of mol-

ten copper to a point ready for refining; substantially as described.

8. The method of refining copper, which consists in injecting into a bath of molten copper, sawdust whose hydrocarbon-gas-producing power has been augmented with fusible hydrocarbon; substantially as described.

In testimony whereof we have hereunto set our hands.

RALPH BAGGALEY.
CHARLES M. ALLEN.
EDWARD W. LINDQUIST.

Witnesses:
AZELLE E. HOBART,
WILLIAM M. KIRKPATRICK.