

- [54] CONTINUOUS PROCESS FOR REFINING SULFIDE ORES

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[30] Foreign Application Priority Data

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- [51] **Int. Cl.**..... **C22b 9/10**

- [58] **Field of Search** 266/9, 11, 24, 34 R, 35;
75/72-74, 75

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[57] **ABSTRACT**

A continuous process for refining metal sulfide ores which is carried out by arranging a smelting furnace and a blister furnace, each maintaining discreteness in the reaction zones, wherein a separator is provided subsequent to the smelting furnace so as to limit the function of the smelting furnace to the melting of the raw material and absorption of the copper content in a slag formed in and returned from the subsequent process furnace into a matte layer thus achieving the smelting process at a higher furnace rate. The reaction products in the smelting furnace are all tapped out simultaneously without being separated each other, and transferred to this separator where they are separated and tapped out therefrom individually.

9 Claims, 5 Drawing Figures

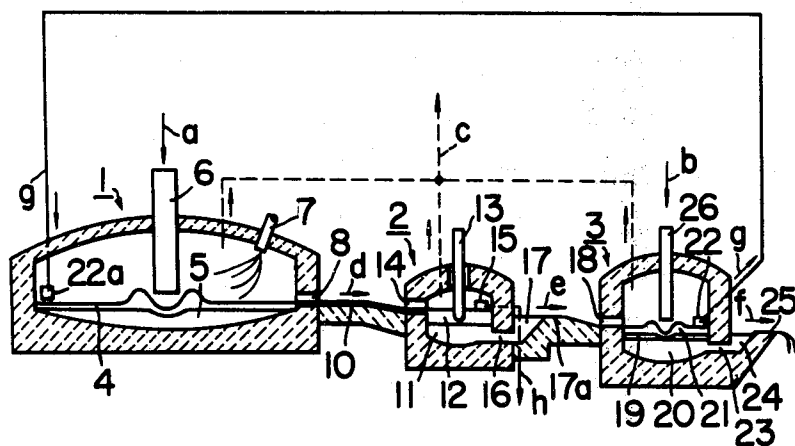


FIG. 1

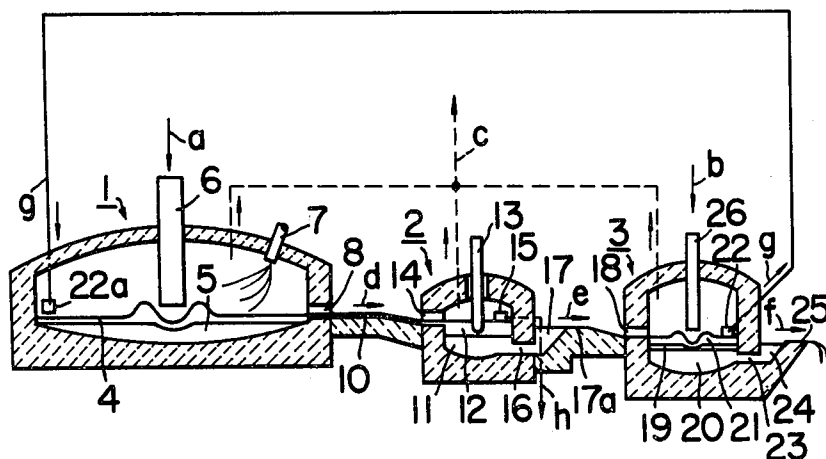


FIG. 2

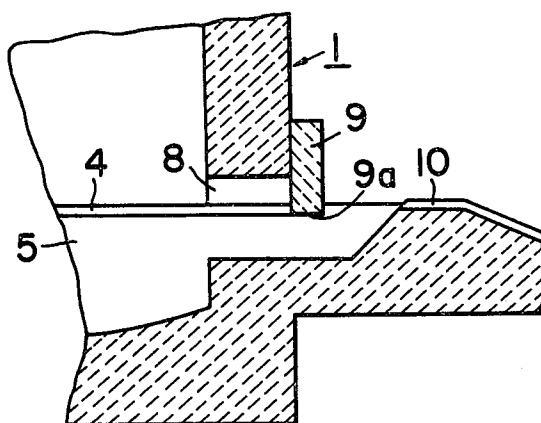


FIG. 3

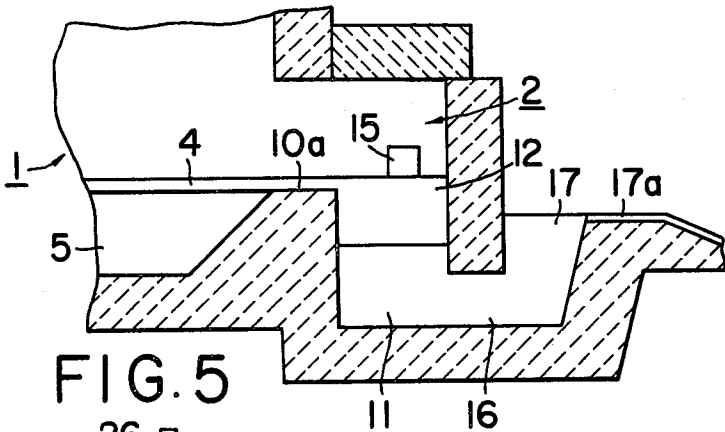


FIG. 5

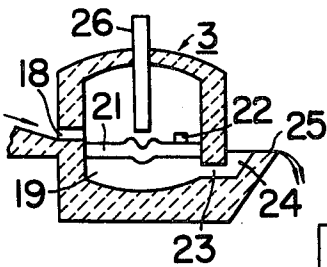
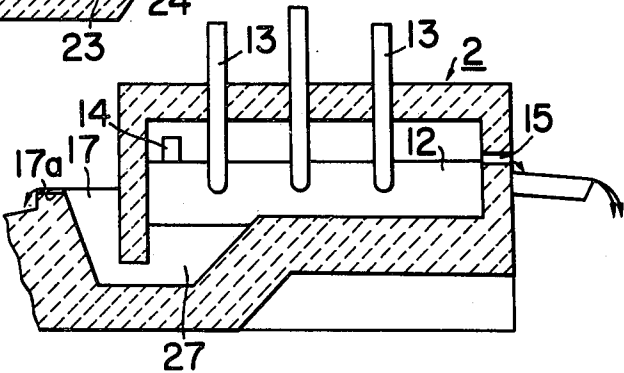


FIG. 4



CONTINUOUS PROCESS FOR REFINING SULFIDE ORES

This is a division of application Ser. No. 356,172, filed May 1, 1973.

The present invention relates to a continuous process for refining sulfide ores and an apparatus therefor. More particularly, the present invention is directed to a continuous method for refining a sulfide ore of metal such as copper, nickel, and cobalt and an apparatus therefor, wherein the sulfide ore is treated in a continuous and consistent manner by means of a series of furnaces to obtain the intended metal in a large quantity and in a most economical manner.

This invention is an improvement in the invention disclosed in U.S. patent application Ser. No. 881,226, now U.S. Pat. No. 3,725,044.

It is a primary object of the present invention to provide an improved method and an apparatus therefor, wherein each of the process steps essential for the metal refining is connected each other so as not to cause any difficulty in operations as well as in sequence of the operations as a whole, while the structure of the furnaces in charge of the respective refining process steps and the devices to connect these furnaces with each other are made simple and durable, thereby to facilitate the construction, operations, and maintenance thereof, and to carry out the furnace operations in a consistent and continuous manner over a long period of time, thereby to obtain a high thermal efficiency within the furnaces and a high yield of the objective metal.

The foregoing object as well as the operations of the method and apparatus according to the present invention will become more apparent from the following detailed description of the invention when read in conjunction with the accompanying drawing.

In the drawing:

FIG. 1 is a longitudinal cross-section showing the basic arrangement and connection of the furnaces according to the present invention;

FIG. 2 is an enlarged view showing an overflowing part of the melt in the smelting furnace to be used in the first process step;

FIG. 3 is an enlarged view of a longitudinal cross-section showing an example wherein the smelting furnace and the separator are integrally constructed;

FIG. 4 is a longitudinal cross-section showing another example of the separator; and

FIG. 5 is a longitudinal cross-section showing an example wherein a white matte is produced in the blister furnace 3 shown in FIG. 1.

The method according to the present invention may be applied for treating copper ore as well as other metal ores such as nickel and cobalt that may be refined by the same or similar reaction as copper. Hereinbelow, however, the present invention will be described with reference to copper as an example.

The process disclosed in the prior U.S. patent application Ser. No. 881,226 now U.S. Pat. No. 3,725,044, which is essential in the ordinary refining method of copper, comprises three process steps: the first process step for smelting copper ore (formation of matte and slag) and simultaneous recovery of copper content in a slag produced in the second process step; the second process step wherein the iron content in the matte produced in the first process step is oxidized and removed

(formation of white metal and slag); and the third process step wherein the sulfur content in white metal produced in the second process step is oxidized and removed. These three process steps are carried out by use of three furnaces corresponding to the abovementioned, respective process steps, i.e., a smelting furnace, slagging furnace, and a blister furnace, all these furnace being connected with each other to enable continuous transfer of a melt to be realized therebetween, and each of the furnaces being so arranged that the compositions, temperatures, and residence quantities of matte, slag, white metal, and blister copper residing in the furnace may be controlled independently of the other two furnaces, whereby a blister copper can be produced in a continuous manner as a whole. In this process wherein each process step for copper refining is carried out in a furnace corresponding thereto, it is possible to control the reaction conditions, mainly the slag composition, independently of the other two steps. Consequently, in each individual furnace, the furnace efficiency in each process step can be increased without disturbing the discreteness in the furnace operation in each step, which might arise in a furnace having a plurality of reaction zones, by convection and agitation of the melt formed therein due to supply of the raw material and air, so that the operational efficiency of the entire system can also be improved.

In this method, however, for the reaction products to be tapped out of the furnace in the state of their being separated each other, the matte and the slag should exist separately in at least a part of each furnace with the result that when the furnace efficiency is to be increased to a considerable extent, there would appear restriction from this point. Particularly, as the slag produced in the first process step is an ultimate tailing, reduction in the copper content in this slag to the minimum possible degree constitutes an important factor affecting the economy of the copper refining process per se.

Therefore, it is the ordinary practice to provide a settling furnace to recover a part of the copper content residing in the slag as a matte, the copper content existing mainly in the form of matte dispersed in the slag. In this case, as the matte to be recovered is small in quantity, it is practically troublesome and not desirable in the actual operation to recycle the matte into the refining process in a continuous manner.

According to the present invention, on the other hand, a separation step is provided subsequent to the first process step, whereby the function of the smelting furnace for the first process step is limited to the smelting of the raw material and absorption of the copper content in a slag formed in the second process step into a matte layer therein, and the reaction products are all tapped out simultaneously without being separated each other, and transferred to the subsequent separation step, where these reaction products are separated and tapped out therefrom individually, thereby further improving the furnace efficiency of the smelting furnace, and ensuring the separation of the matte and the slag more satisfactorily. By thus providing the separation process, the present invention has successfully achieved reduction in the copper loss as well as orderly arrangement of the flow path of a melt to facilitate the maintenance and control of the entire system.

More particularly, the present invention may be carried out by properly arranging a furnace for smelting

sulfide ore in the main (smelting furnace), a furnace for chiefly separating products formed in the smelting furnace into matte and slag (separator), and another furnace for principally oxidizing iron and sulfur contained in the matte to produce white metal or blister copper (blister furnace), each of which is so designed that the composition, temperature, surface level, and interfacial level of a melt therewithin may be controlled and maintained constant independently of the remaining furnaces, and is further connected each other by means of mutual transfer of the melt therebetween, whereby the entire refining system may be operated in a continuous manner as a whole. The essentials of the operations in each furnace and between them will be set forth hereinbelow.

FIRST PROCESS STEP (SMELTING PROCESS)

In this process step, a raw material to be smelted which consists principally of a sulfide ore and a flux (hereinafter referred to simply as "raw material") is mixed with fuel and air at an appropriate mixing ratio in accordance with predetermined reaction conditions such as grade of matte to be produced, composition of slag, a furnace temperature, and so forth, and the raw material is then fed directly and continuously into a melt bath which is the reaction products formed in the first process step at a prescribed feed rate per unit time (hereinafter referred to as "a raw material feeding rate") and is caused to melt without delay, thereby forming matte and slag. On the other hand, a slag formed in the aforementioned blister furnace (blister furnace slag) is transferred back to the smelting furnace in a substantially continuous manner, and the major portion of the objective metal contained in the blister furnace slag is caused to be absorbed into the smelting furnace matte, while the products formed in the smelting furnace are being discharged simultaneously out of the furnace in a substantially continuous manner, and then transferred to the separator for the second process step. The term "substantially continuous manner" referred to hereinabove designates a transfer system, in which, even if the transfer of the melt is batchwise from the micro-analytical standpoint, the transfer quantity thereof at every one time is so small in comparison with the residence quantity of the melt within the smelting furnace that variations in the reaction conditions therewithin for such batch system becomes negligible from the metallurgical standpoint. Furthermore, transfer of the melt from the smelting furnace to the separator is carried out by the gravity of its own utilizing difference in the surface level between the two furnaces.

SECOND PROCESS STEP (SEPARATING PROCESS)

In this process step, all kinds of the reaction products formed in the first process step is continuously charged into the separator and caused to stand therewithin for a certain period of time, thereby separating matte from slag and tapping each of these melts continuously out of the separating furnace.

THIRD PROCESS STEP (BLISTERING PROCESS)

In this process step, the matte separated in and tapped out of the separator (second process step) is charged into the blister furnace in a substantially continuous manner, while air, flux, and coolant are mixed

at an appropriate ratio to be determined in accordance with the raw material feeding rate in the foregoing first process step, the admixture of which is charged directly and continuously into a melt within the blister furnace consisting of reaction products formed in the third process step so as to produce and separate crude metal and slag (blister furnace slag) without delay, and tap each of these melts out of the blister furnace. The crude metal is then forwarded to a refining process of known type, and the blister furnace slag is recycled to the smelting furnace in a substantially continuous manner so as to be subjected to the treatment as stated in the foregoing. In this case, transfer of one of the crude metal and the blister furnace slag between the blister furnace and the smelting furnace or refining process is carried out by the gravity of the melt utilizing difference in the surface level between the furnaces concerned (automatic transfer), and the other by physical force being applied from outside (forced transfer).

Furthermore, by maintaining constant the residence quantity of each melt of matte, slag, and crude metal in the respective process steps, the rate of production of each melt and the rate of transfer thereof between the respective furnaces are so regulated as to be equilibrated to the rate of feeding of the raw material in the first process step as well as to the rate of feeding of the coolant in the third process step, and, at the same time, the composition, temperature, surface level, and interfacial level of the melts in each furnace are controlled independently and maintained constant, thereby producing the intended metal from the corresponding ore in a continuous and highly economical manner.

More detailed explanation of the operations of the furnaces according to the present invention will be made hereinbelow with reference to the accompanying drawings.

In FIG. 1, a smelting furnace 1 accommodating therein slag 4 and matte 5 is provided with a lance 6, a burner 7, a melt discharging port 8, a melt overflow weir 10, and a revert slag charging port 22a; a separating vessel (or a separator) 2 accommodating therein matte 11 and slag 12 is provided with a device 13 for keeping the separator at a required temperature, a charging port 14 for the melts formed in the smelting furnace, a discharging port 15 for a separated slag 12, a matte tapping port 16, and a matte siphon 17; and a blister furnace 3, in which layers of white metal 19, blister copper 20, and slag 21 are held, is provided with a matte charging port 18, a blister furnace slag discharging port 22, a blister copper tapping port 23, a blister copper siphon 24, a blister copper overflow weir 25, and a lance 26.

In the smelting furnace 1, a raw material which is principally composed of sulfide ore and a flux such as a silicic ore is mixed with fuel and air at an appropriate ratio being suitable for the predetermined reaction conditions, the mixture of which is charged directly and continuously, at a predetermined feed rate, into a melt consisting of the matte 5 and the slag 4 which are the reaction products in the smelting furnace. While any practical method may be employed for feeding the mixture material, the raw material may better be crushed into a powder or granular form and then blown into the melt carried on a gas current through the lance provided in the furnace, whereby a large quantity of the raw material can be smelted quickly and, also, generation of dust can be prevented. In this case, the pressure

of the gas supplied is determined automatically by the inner diameter of the lance as well as the position of the tip end thereof at a value which is sufficiently high to feed the gas current and the raw material directly into the melt. As the result of this, the melt is agitated satisfactorily, and the reaction within the furnace proceeds rapidly, whereby the furnace efficiency can be improved. The matte grade may be controlled at any desired level by adjusting the air ratio to the raw material. Here the air ratio signifies the ratio between the net quantity of air for reaction which is the balance after subtraction of the quantity of air necessary for combustion of the fuel from the total air quantity injected into the furnace. More particularly, when the grade of the matte to be produced is raised, there is resulted such an advantage that the heat generated from oxidation-reaction of the iron and sulfur contents in the raw material ore can be utilized effectively for smelting the raw material, etc., whereas the copper loss in the slag inevitably increases. In this case, addition of a reducing agent such as pyrite into the separator, in a manner as will be stated later on, will prevent the copper loss from increasing to a certain extent.

Any kind of fuel having fluidity, including solid fuel in a powder form, may be used for the present invention, and, furthermore, the consumption of the fuel to be used for the smelting may be reduced by substituting the whole or a part of air for equivalent amount of oxygen. Fuel may not be necessarily fed to the same place in the furnace as that of the raw material, but it had better be blown directly into the melt bath in the same manner as the raw material for the significantly increased heat transfer efficiency. In this consequence, the temperature of the furnace atmosphere and the exhaust gas therefrom can be lowered to a level almost equal to that of the melt with the result that capture and treatment of the exhaust gas is facilitated and the life of the furnace walls can be extended remarkably.

Fuel may be burnt by a burner 7. In this case, the fuel consumption may be reduced by preheating and/or oxygen-enriching the air for the combustion.

All kinds of the products formed in the smelting furnace are tapped out of the furnace through the melt discharging port 8. Explaining this with reference to FIG. 2 which shows an enlarged partial view of the melt discharging port, the melt formed in the smelting furnace is tapped out of the furnace through the melt discharging port 8, wherein a sealing damper 9 fitted on the outside of the melt discharging port 8 prevents the furnace gas from puffing out, or the atmospheric air from infiltrating into the furnace, and the slag layer 4 retained within the furnace can be controlled and kept at a required constant thickness by fixing the bottom end 9a of the sealing damper 9 at a certain constant difference in the level which is lower than the melt overflow weir. The sealing damper 9 should be wide enough for closing the melt discharging port 8 and be made movable up and down. The durability of the sealing damper 9 may be further increased by means of a water cooling jacket provided thereon. In the case that the matte and the slag are tapped out separately through a siphon and a slag discharging port 22 directly provided on the furnace as in the case of the blister furnace 3 shown in FIG. 1, it may be difficult to reduce the thickness of the slag layer to one thinner than a certain critical value (about 100 mm) for the purpose of effecting the separation of the matte and the slag to a satisfactory

degree, and preventing the matte from mixing into the slag. It is, however, possible to form a slag layer having a desired thickness of even thinner than 50 mm by means of the aforementioned sealing damper 9, whereby the rate of reaction between the melt and the air supplied thereto through the lance is improved significantly.

By maintaining the melt overflow weir 10 and the bottom end 9a of the sealing damper 9 at required constant levels so as to cause the residence quantities of the matte and the slag to be maintained constant within the furnace, the feeding quantity of the melt into the separator can be equilibrated with the rate of feeding of the raw material into the smelting furnace, whereby a constant feed rate thereof may be maintained. As the result, the melt is continuously charged into the separator 2 by way of a launder and through the melt charging port 14, where it is caused to stand for a certain period of time until it is separated into the matte 11 and the slag 12. The slag 12 is then tapped out of the separator through the slag discharging port 15, and dumped as indicated by the arrow (h) either as it is or after it has been caused to stand within a settling furnace to settle the matte particles contained therein. On the other hand, the matte 11 is taken out of the separator through the matte tapping port 16, and then the matte siphon 17, after which it is allowed to overflow from the matte overflow weir 17a and fed into the blister furnace 3 in a continuous manner.

The separator 2 may be kept at a required temperature by means of a burner (not shown) or an electric heating device 13. Also, as shown in FIG. 3, the separator 2 may be integrated with the smelting furnace 1, thereby simplifying the installation. In this case, by maintaining the level 10a of the melt discharging port 8 of the smelting furnace lower than the level of the slag discharging 15 of the separator, the liquid surface in both smelting furnace and separator is made common, and the residence quantities of the matte and the slag within the smelting furnace are maintained constant. As shown in FIG. 4, the separator 2 may be formed in a shape longitudinally extended in the flow direction of the melt (e.g. oval, rectangular, etc.) with a matte sump 27, a matte siphon 17, and a melt charging port 14 being provided at one end thereof, and a slag discharging port 15 provided at the other end thereof, whereby the matte particles in the slag can be sedimented more perfectly. In this case, the rate of recovery of the copper content in the slag may be increased further by addition of a reducing agent such as pyrite, coke, and so on. The matte separated in the separator and a matte newly produced as the result of extraction of the copper content from the slag by addition of pyrite are tapped out of the furnace in combination through the matte tapping port 16 and then the matte siphon 17, the entire matte as combined being then fed into the blister furnace 3. In either case, thickness of each of the matte layer and the slag layer retained in the separator can be kept at a fixed value by maintaining constant the slag discharging port and the matte overflow weir at fixed heights, respectively. In this consequence, the flow rates of the slag and the matte are brought to an equilibrium with the feed rate of the melt transferred from the smelting furnace.

The matte from the separator 2 is continuously charged into a melt bath in the blister furnace 3 consisting of blister furnace slag 21, white metal 19, and blis-

ter copper 20, all of which are the reaction products in the third process step, while air and a flux are simultaneously fed directly and continuously thereto. A coolant (or cold dope) containing the objective metal such as the raw material or scrap to be charged into the melt bath can be fused by the excessive heat generated in this third process step, thereby preventing the furnace temperature from exceeding the ordinary operating temperature, and simultaneously allowing the entire treating capacity of the ore to increase further. The way, in which these materials are fed into the blister furnace, is carried out through the lance 26 provided therein in the same manner as in the smelting furnace. The total quantity of the air to be introduced into the blister furnace should be in such quantity that is sufficient to convert the total quantities of the matte and the coolant to be charged into the blister furnace slag and a blister copper, and thickness of a white metal layer residing in the furnace is maintained constant. The blister copper is tapped out of the furnace through the blister copper tapping port 23 and then the blister copper siphon 24, after which it is caused to continuously overflow from the blister copper overflow weir 25, and is forwarded to the refining process of known type. On the other hand, the blister furnace slag is continuously discharged out of the furnace through the blister furnace slag discharging port 22, the melt transfer passage (g), and then recycled to the revert slag charging port 22a provided in the smelting furnace in a substantially continuous manner by a forced transfer. Any practical means such as a bubble pump (air-lift), a bucket conveyor operated in a continuous motion, an electromagnetic transfer, and so on may be employed for the forced transfer.

Transfer of the blister furnace slag to the smelting furnace may preferably be achieved in the molten state taking advantage of its own temperature. However, it is also possible to transfer the blister furnace slag in the solidified or granulated form to facilitate handling. In case the grade of matte is high and the formation of blister furnace slag is small, increase in the fuel consumption required for remelting the blister furnace slag is not so large in comparison with what will be required in the event that the matte grade is low and the quantity of the blister furnace slag is large.

In the above-described example, the level of the melt bath in the separator is made to be lower than that in the smelting furnace, while the melt bath level in the blister furnace is made to be far lower than that in the separator, whereby the transfer of the matte is carried out by the gravity of the melt in taking advantage of the difference in head among these three furnaces. On the other hand, when the surface level of the melt in the blister furnace is made higher than that in the smelting furnace, the transfer of the blister furnace slag is carried out by the gravity thereof, whereas the transfer of the matte from the separator to the blister furnace may be accomplished by a forced transfer.

White metal 19 is an intermediate product of the blister making step, which is not tapped out but is maintained in a constant residence quantity by adjusting the reaction conditions.

The thickness and residence quantity of each of the melt layers in the blister furnace can be maintained constant by setting the slag discharging port and the blister copper overflow weir 25 at constant levels in the same manner as in the separator. In this consequence,

the rates of production of the slag and the blister copper in the blister furnace are controlled by the rate of feeding of the matte thereto (which is governed by the reaction conditions and the rate of feeding of the raw material in the smelting furnace) and the rate of feeding of the coolant into the blister furnace (which is governed by the grade of the matte to be fed into the blister furnace and the reaction conditions therewithin), whereby the entire reaction system can be controlled under certain constant reaction conditions.

The reaction in the blister furnace may also be carried out under co-existence of the two phases of slag and blister copper only, without presence of a white metal in the furnace, by charging thereto more quantity of air than required to oxidize principally the entire quantities of iron and sulfur contained in the matte and the coolant. In this case, the sulfur content in the blister copper can be reduced below the saturated concentration thereof by increasing the ratio of air to be supplied to a desired extent. That is, as the ratio of air increases, the copper content in the slag is also increased, whereas the sulfur content in the blister copper is decreased. Here, the air ratio signifies the ratio of air to the total quantities of the matte and coolant. When a white metal layer exists in the blister furnace, the copper content in the slag ranges from 2 to 6%, whereas the copper content may be increased to a range of from 40 to 50% when no white matte is present in the furnace. However, the matte grade and the reaction conditions in the blister furnace should be set within such a range where the copper content in the slag formed in the blister furnace does not exceed the copper content in the materials fed thereto, and, further, the flux (particularly lime) fed into the blister furnace does not exceed the amount which is needed in the entire system. In the ordinary converter process, silica sand is used as a flux, whereas, in the blister furnace according to the present invention, the fluidity of the slag formed therewithin can be increased by use of lime or a mixture of lime and silica sand.

Exhaust gas discharged from each furnace in the above-stated process steps is collected and let out through a flue duct (c), and the total quantity thereof is cooled and utilized as a raw material for production of sulfuric acid.

According to another embodiment of the present invention, the third process step may be further divided into two stages to conduct the entire furnace operations in four process steps. In this case, the third process step carries out production of white metal and blister furnace slag in the blister furnace 3. More particularly, as shown in FIG. 5, while the matte is being continuously fed into the blister furnace through the matte charging port 18, air and a flux are charged through the lance 26 into the melt which is composed of the blister furnace slag 21 and the white metal 19 formed by the reaction within the furnace. The excess heat generated at this time is utilized for melting the coolant in the same manner as in the previous example. Air should be charged at such a feed rate as required to oxidize principally the entire part of iron and a part of sulfur contained in the matte and the coolant fed into the furnace, respectively, and to produce a white metal and a slag. The flux used in this case may be silica sand as in the case of the ordinary slag-forming process by a converter.

The slag 21 is then caused to flow continuously out of the furnace through the slag discharging port 22, and, as in the previous example, is transferred and recycled into the smelting furnace. It has been confirmed that the copper content in the slag exists principally in the form of white metal particles and metallic copper particles. Instead of returning the slag into the smelting furnace in a molten state, it may be crushed and treated by floatation, thereby to concentrate the copper content therein, after which the concentrate may be recycled to the smelting furnace.

On the other hand, the white metal 19 is tapped out of the furnace through the tapping port 23 and then the siphon 24, thereafter caused to flow over the overflow weir 25. The white metal which is principally composed of a single or a plurality of the objective metal sulfides may in some cases be regarded as the final product in this treating process. When the objective metal is nickel, for instance, the white metal is forwarded as it is to an electrolytic process, or transferred to a reducing process after it has been crushed and roasted. Furthermore, when white metal produced from a raw material contains therein two or more kinds of metals such as copper, nickel, and cobalt in such quantities that none of these metals can be neglected from the economical or technical standpoint, the white metal is sent to a process to separate the objective metals from each other by such means as, for example, a floatation treatment after it has been cooled slowly. When a white metal is principally composed of sulfides of copper, the white metal is transferred in its molten state to another blister furnace, wherein the fourth process step is carried out. The blister furnace used in this fourth process step may be an ordinary converter, but should preferably be another unit of blister furnace according to the present invention, whereby the white metal can be treated in a continuous manner. The operational process of the fourth process step is exactly same as that of the third process step in the foregoing first embodiment, except that the material charged thereto is the white metal and the quantity of a slag produced therein is extremely small. The quantity of the slag to be produced from the white metal is less than 10 percent by weight of the white metal, normally in a range of from 2 to 6%, with the result that transfer of the slag in its molten state back to the smelting furnace becomes somewhat difficult. In this consequence, the slag tapped out of the furnace is once solidified and then charged together with the other raw materials into the smelting furnace.

In order to restrain the slag formation in the fourth process step, a coolant which is not contributive to the slag formation such as a scrap of the objective metal may be fed into the blister furnace for the fourth process step.

The treatment of exhaust gas discharged from this blister furnace can be done in the same manner as in the afore-mentioned first example.

The above-described process according to the present invention has not only the generally known advantages associated with a continuous process such as a lower cost for construction and operations thereof than the batch system, and facilitating introduction of an automatic control system thereto, but also the following additional features owing to the unique process steps and reaction system thereof.

In the process according to the present invention, the smelting furnace is caused to function only for reaction (i.e., smelting) of the raw material charged thereto, while the separation of slag and matte produced in this smelting furnace is carried out in the separator, whereby the agitation of the melt in the smelting furnace can be performed without any restriction and the charges such as the raw material can be fed into the furnace covering the largest possible area of the furnace bed with the result that the furnace efficiency (i.e., smelting rate) is remarkably improved. Furthermore, the thickness of the slag layer formed in the smelting furnace can be decreased and, at the same time, the agitation of the melt can be strengthened, whereby the contact between the matte and the slag becomes satisfactory, and the copper content in the revert slag (blister furnace slag) is absorbed quickly and completely into the matte phase until the equilibrium therebetween is reached.

It has been confirmed by a microscopic observation on a quenched sample that, under the reaction conditions according to the present invention, most part of the copper content in the slag exists in the form of matte granules, each having a diameter of from about 0.5 to about 3 mm. The copper granules was found to have settled rapidly as to be readily calculated from the Stoke's equation and to have been able to be separated from the slag easily in the separation furnace, whereby a satisfactory result could be obtained without installing a settling furnace along with the separator.

As to the slag layer, the thickness thereof in the smelting furnace according to the present invention could be reduced to as thin as from one tenth to one twentieth of that formed in an ordinary reverberatory furnace. As the result of this, a sufficiently high rate of reaction in the furnace could be achieved, even if the pressure of air to be blown into the melt was considerably low, without immersing the tip end of the lance into the melt, whereby economical effects such as a saving of the power consumption and an extended life of the lance can be resulted. In other words, as the air reacts with the matte in the main, and as there is only an extremely thin layer of the slag in the melt bath, which prevents the air from contacting the matte, the contact between the air and the matte is improved and the reaction rate therebetween in the furnace increases significantly.

Also, a reducing agent such as pyrite may be added into the separator to further improve the rate of recovery of copper. In this case, the recovered matte is merged into the smelting furnace matte separated within the separator and continuously transferred in its entirety into the blister furnace through the one and same flow path, so that the melt flow path can be simplified and the furnace control is facilitated. (It is a well known fact that, when a flowing quantity of the melt in the launder is small, there is accompanied great difficulty in the transfer operation thereof.)

Furthermore, in the process according to the present invention, corrosion of the bricks constituting the furnace can be suppressed. Slag is the principal cause of corrosion of the bricks. In the present process, the slag layer is maintained extremely thin, hence the area of contact between the slag and the furnace walls is small, whereby economical burden to be derived from use of a refractory material or a jacket having particularly excellent durability (these being most expensive, of

course) to cover such contact area can be reduced significantly.

In order to reduce the present invention into practice, the following preferred examples are presented. It should, however, be noted that these examples are just illustrative, and do not intend to limit the scope of the present invention as set forth in the appended claims.

EXAMPLE 1

6,000 kg per hour of a copper concentrate consisting of 24.0% of copper, 34.2% of iron, 34.2% of sulfur, and 3.7% of SiO_2 , 1,500 kg per hour of silica sand containing 90.0% of SiO_2 , and 500 kg per hour of lime stone containing 53.4% of CaO were directly charged into a melt bath which was the reaction product in the smelting furnace together with 1,500 Nm^3 per hour of air having a gauge pressure of 2 kg per square centimeter through a lance provided in the furnace. By use of another lance, 3,500 Nm^3 per hour of air having a gauge pressure of 0.8 kg per square centimeter and 500 Nm^3 per hour of oxygen for industrial use were mixed, and the mixed gas was directly charged into the melt bath in the same manner as was done with the above raw material. The raw material had all been previously classified into granules, each having a diameter of less than 10 mm, and dried until the water content thereof ranged from 1 to 2%.

On the other hand, 250 liters per hour of fuel oil was burnt with aid of 2,500 Nm^3 per hour of air having a gauge pressure of 0.2 kg per square centimeter and preheated to 300°C by use of a burner provided on top of the furnace. A blister furnace slag was fed into the furnace through a blister furnace slag charging port provided therein. Thickness of the slag layer within the furnace was maintained at about 20 mm. The products consisting principally of matte and slag were caused to continuously flow out of the furnace through a melt discharging port provided in the furnace and further caused to flow into a separator by the dead weight thereof. The SO_2 content in the exhaust gas discharged from the smelting furnace was from 8 to 10%. The temperature within the furnace was kept in a range of from 1,220° to 1,260°C by adjusting the fuel supply thereinto.

The separator employed herein was of the type shown in FIG. 4, and its capacity to hold the melt was about 10 tons. 150 kg per hour of pyrite containing 45% of sulfur and 50 kg per hour of coke breeze were charged into the separator. The thickness of the slag layer and the residence quantities of slag and matte within the separator were kept constant by maintaining a matte overflow weir at a level 120 mm lower than a slag overflow weir also provided in the separator. The slag was caused to flow out of the separator through a slag discharging port provided in the separator and then granulated with water jet. The slag quantity thus produced was 5,600 kg per hour and the composition thereof was controlled to be from 0.4 to 0.6% of copper, from 33 to 35% of SiO_2 , and from 5 to 6% of CaO. The matte was continuously tapped out of the furnace through a siphon provided therein and fed into a blister furnace. The grade of the matte thus produced was controlled to have from 59 to 62% of copper.

Into the blister furnace, there were charged 200 kg per hour of the above-mentioned silica sand, 100 kg per hour of lime stone, and 100 kg per hour of precipitate containing 60% copper, together with 2,400 Nm^3

per hour of air at a gauge pressure of 2 kg per square centimeter. The charges were supplied directly into the melt bath formed by reaction therewithin through a lance provided in the furnace. The copper content in the slag formed in the furnace was controlled to be from 20 to 25% with the result that no white metal was formed in the furnace and the melt bath formed therewithin was found to have been composed of two layers of slag and blister copper respectively. The slag thus formed was composed of from 8 to 13% of SiO_2 , from 4 to 6% of CaO, and from 38 to 45% of iron. Most part of iron was found to have been composed of Fe_3O_4 . The slag was then caused to continuously flow out of the furnace through a slag discharging port provided in the furnace, and transferred to the aforementioned smelting furnace by a bucket conveyor being operated in continuous motion. The blister copper, on the other hand, was caused to flow out of the furnace through a siphon provided contiguous to the blister copper tapping port. The rate of production of the blister copper was 1,550 kg per hour, and its composition was from 98 to 99% of copper and from 0.2 to 0.3 of sulfur.

When adjustment was so made as to cause a white matte layer to exist in the blister furnace by changing the rate of feeding of the afore-mentioned silica sand and lime stone into the smelting furnace to 1,700 kg and 350 kg per hour, respectively, and by changing the kind of the flux to be fed into the blister furnace to lime stone at a rate of feeding of 250 kg, and by reducing the rate of feeding of air into the blister furnace by approximately 2% less than the afore-described example, the slag produced therein was found to have been composed of from 6 to 8% of copper, from 12 to 16% of CaO, and from 55 to 65% Fe_3O_4 , and the quantity of copper recycled to the smelting furnace was reduced, whereas the sulfur content in the blister copper increased to 1% and above. Furthermore, it was observed that the fluidity of the slag tended to lower, when the content of calcium oxide (CaO) in the slag was reduced to 5 to 7%.

The rate of production of the blister furnace slag was approximately 1,000 to 1,500 kg per hour. In such case of low rate of production of the slag, a portion of the slag solidified in the course of its transfer to the smelting furnace, but this did in no way adversely affect the operation of the smelting furnace. Sulfur dioxide (SO_2) contained in the exhaust gas discharged from the blister furnace was from 14 to 16%, and the temperature within the furnace was from 1,200° to 1,270°C.

The exhaust gas from each furnace was all collected and cooled, after which it was delivered to a sulfuric acid production plant. The flue dust contained in the exhaust gas collected in the dust chamber was found from 1 to 2% with respect to the total quantity of the raw material used.

EXAMPLE 2

Into the smelting furnace, there were charged 5,000 kg per hour of copper concentrate consisting of 18.9% of copper, 33.8% of iron, 36.5% of sulfur, and 1.5% of silicic acid, 1,400 kg per hour of silica sand containing therein 89% of SiO_2 , 570 kg per hour of lime stone containing therein 53.4% of CaO together with 200 Nm^3 per hour of air at a gauge pressure of 2 kg per square centimeter. The charges were supplied directly into the melt bath composed of reaction products within the furnace through a lance provided therein together with

3,000 Nm³ per hour of air at a gauge pressure of 0.8 kg per square centimeter and 510 Nm³ per hour of oxygen gas for industrial use. At the same time, 160 liters per hour of fuel oil was blown into the furnace together with 1,700 Nm³ per hour of air at a gauge pressure of 0.8 kg per square centimeter through a separate lance, and was burnt therewithin. In the meantime, blister furnace slag was continuously charged into the melting furnace through the blister furnace slag charging port provided therein. The matte and slag thus produced were introduced into a separator which had been integrally formed with the smelting furnace as shown in FIG. 3 thereby to separate matte and slag each other. The slag layer within the smelting furnace was maintained in a thickness of 20 mm. Also, the rate of feeding of fuel was so adjusted as to maintaining the temperature within the furnace in a range of from 1,220° to 1,270°C. The exhaust gas discharge from the smelting furnace was found to have contained from 13 to 16% of SO₂.

In the separator, the matte overflow weir provided therein was set at a certain level which was lower by 70 mm than the level of the slag outlet port also provided therein, whereby the slag layer within the furnace was maintained in a thickness of about 300 mm. The slag thus formed was caused to continuously flow out of the furnace through the slag discharging port, and then water-granulated. The composition of the slag was controlled to have from 32 to 34% of SiO₂ and from 5 to 6% of CaO. The slag contained from 0.30 to 0.45% of copper and the rate of production thereof was 5,900 kg per hour. The matte thus produced, on the other hand, was caused to flow continuously out of the furnace through a siphon provided contiguous to the matte tapping port, and then charged into the blister furnace. The matte was controlled to contain from 39 to 42% of copper.

Into the blister furnace, there were charged 1,000 kg per hour of the aforementioned raw material ore and 500 kg per hour of silica sand together with 3,040 Nm³ per hour of air at a gauge pressure of 2 kg per square centimeter. The charges were fed directly into a melt bath consisting of the reaction products formed by reaction within the furnace. The reaction products were composed of white matte and slag, and the slag layer within the furnace was kept in about 100 mm thick. The slag thus produced was caused to continuously flow out of the furnace through a slag discharging port provided therein, and then recycled to the smelting furnace by means of a bubble pump. The slag contained from 22 to 24% of SiO₂ and from 2 to 6% of copper, and the rate of production thereof was about 2,300 kg per hour according to calculation. The white matte thus produced, on the other hand, was caused to continuously flow out of the furnace through a siphon provided contiguous to the white matte tapping port and then forwarded to a copper refining process of known type. The matte was controlled to contain from 77 to 79% of copper. The sulfur content therein was from 19 to 20%, and the temperature within the furnace was from 1,250° to 1,300°C. The exhaust gas discharged from the furnace contained from 13.5% to 15.0% of SO₂. The exhaust gas from each furnace was treated in the same manner as stated in Example 1.

It is of course possible that various modification in the refining process may be made by employing the existing copper refining facilities without changing the

basic principles of the present invention. For example, in the first process step, a heretofore-known reverberatory furnace or an electric furnace may be employed in place of the above-mentioned smelting furnace according to the present invention. In this case, a revert slag charging port is provided therein, as the case may be, through which the blister furnace slag is charged into the furnace. Further, in order to control the grade of the matte produced, a lance may be provided in these substitute furnaces in the same manner as in the foregoing smelting furnace according to the present invention to supply air therethrough into a melt bath within the furnace, or whole or a part of the ore charged thereinto may be rotated beforehand.

In the first process step, a heretofore-known flush-smelting furnace or blast furnace may be employed singly or in combination with the smelting furnace according to the present invention. In the latter case, the products formed in these two furnaces are all charged into a separator provided subsequent to the first furnace, whereas the blister furnace slag is charged into the smelting furnace only according to the present invention, whereby treatment of the slag can be done efficiently.

What we claim is:

1. A system for continuous processing of metal sulfide ores to produce crude metal therefrom, which consists of:

- a. a smelting furnace 1 for smelting the raw material metal sulfide ores, which is provided with a lance 6, a burner 7, a melt discharging port 8, a sealing damper 9 fitted on the outside of the melt discharging port 8 in a manner to be sufficiently wide to close the discharging port and movable up and down to control a slag layer in the furnace at a required constant thickness, a melt overflow weir 10, and a revert slag charging port 22a;
- b. a separator 2 for separating matte and slag in the melts transferred from the smelting furnace, which is provided with heating means 13 to maintain the same at a required temperature, a melt charging port 14 being communicated with the melt overflow weir 10 of the smelting furnace, a slag discharging port 15, a matte tapping port 16, a matte siphon 17, and a matte overflow weir 17a; and
- c. a blister furnace 3 for making white metal, crude metal and blister furnace slag from the matte transferred from the separator, which is provided with a lance 26, a matte charging port 18, a blister furnace slag discharging port 22, a crude metal tapping port 23, a crude metal siphon 24, and a crude metal overflow weir 25,

said smelting furnace, separator, and blister furnace being arranged in such a manner that the reaction conditions such as temperature, composition, surface level, and interfacial level of a melt residing in each furnace may be controlled independently of the other; the feeding quantity of the melt into the separator being equilibrated with the rate of feeding of the raw material into the smelting furnace by maintaining the melt overflow weir 10 and the bottom end of the sealing damper at their respective required constant levels to set the residence quantities of the matte and slag in the smelting furnace; and the feeding quantity of the matte into the blister furnace being equilibrated with the feeding rate of the melt into the separator by maintaining

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the slag charging port 15 and the matte overflow weir 17a at their respective constant levels to set the residence quantities of the matte and slag in the separator.

2. The system according to claim 1, wherein the separator is elongated in the direction of the flow of the melt and wherein the separator contains at one end thereof, a matte sump, a matte siphon and a charging port for the melt and at the other end thereof, a slag discharging port.

3. The system according to claim 1, in which the bottom end of the sealing damper is adjusted to be at a position lower than the level of the melt overflow weir to maintain constant thickness of the slag layer within the smelting furnace.

4. The system according to claim 1, wherein the matte overflow weir and the slag discharging port 15 are positioned at constant levels having a definite difference in height therebetween to maintain a constant thickness of the slag in the separator as well as the residence quantities of the slag and matte.

5. The system according to claim 1, wherein the crude metal overflow weir and the slag discharging port 22 are positioned at constant levels having a definite difference in height therebetween to maintain a constant thickness of the slag in the blister furnace as well as the residence quantities of the slag and crude metal.

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6. The system according to claim 1, wherein the crude metal overflow weir and the slag discharging port 22 are positioned at constant levels having a definite difference of height therebetween to maintain a constant thickness of the slag in the blister furnace as well as the residence quantities of the slag and white metal.

7. The system according to claim 1, in which levels of the melt overflow weirs of the smelting furnace, separator, and blister furnace are sequentially lowered to permit transfer of the melt under its own gravity, while the blister furnace slag is recycled to the smelting furnace by a forced transfer means.

8. The system according to claim 1, wherein the blister furnace slag discharging port is positioned at a level higher than the melt surface of the smelting furnace to permit the blister furnace slag to be transferred under its own gravity, while the matte from the separator is transferred to the blister furnace by a forced transfer means.

9. The system according to claim 1, wherein the liquid surface in both smelting furnace and separator is made common by maintaining the level of the melt discharging port 8 of the smelting furnace lower than the level of the slag discharging port 15 of the separator, thereby maintaining constant the residence quantities of the matter and the slag in the smelting furnace.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,901,489 Dated August 26, 1975

Inventor(s) SUZUKI et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

First page, Col. 1, in the line designated
"[73]", relating to the assignee's name, change
"Kizoku" to -- Kinzoku --.

Signed and Sealed this

ninth Day of December 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks