

[54] CONTINUOUS PROCESS FOR REFINING SULFIDE ORES

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3,725,044 4/1973 Morisaki et al..... 75/74

[75] Inventors: Takashi Suzuki, Urawa; Kazuo Tachimoto, Tokyo, both of Japan

Primary Examiner—Walter Satterfield  
Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

[73] Assignee: Mitsubishi Kizoku Kabushiki Kaisha, Tokyo, Japan

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[57] ABSTRACT

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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 which slag is formed from a subsequent oxidizing 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 from each other, and transferred to this separator where they are separated and tapped out individually.

[52] U.S. Cl. .... 75/74; 75/72; 75/73; 75/75; 75/76; 266/37

[51] Int. Cl. .... C22b 15/00

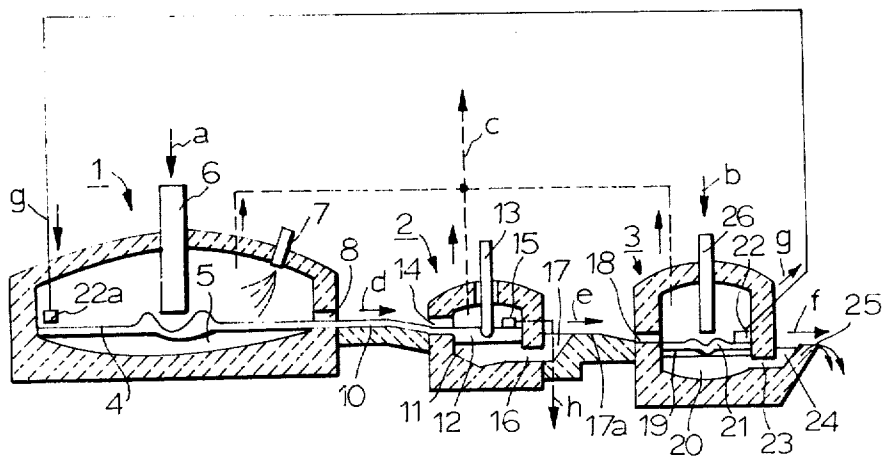
[58] Field of Search ..... 75/76, 72, 74, 73; 266/37

[56] References Cited

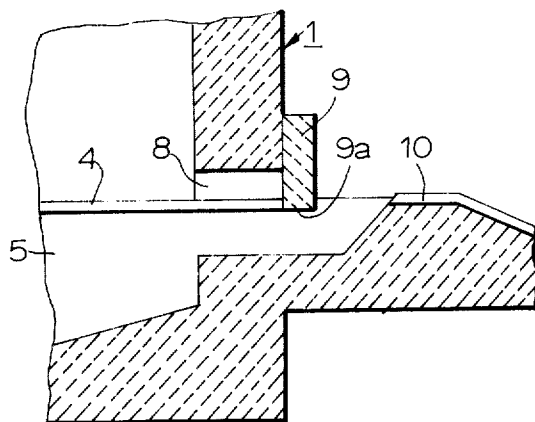
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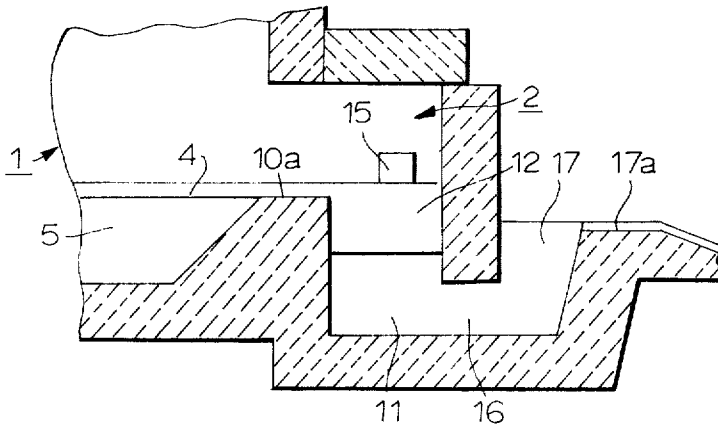
4 Claims, 5 Drawing Figures



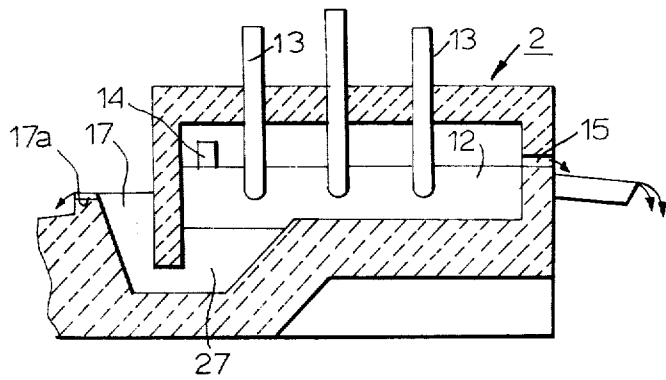
**FIG. 1**



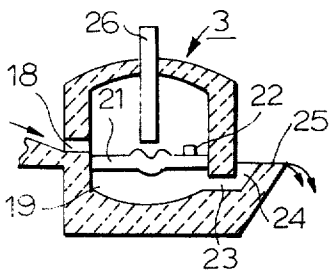
**FIG. 2**



**FIG. 3**



**FIG. 4**



**FIG. 5**

## CONTINUOUS PROCESS FOR REFINING SULFIDE ORES

The present invention relates to a continuous process for refining sulfide ores. More particularly, the present invention is directed to a continuous method for refining a sulfide ore of metals 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 large quantity and in the most economical manner.

This invention is an improvement in the invention disclosed in U.S. Pat. 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, wherein each of the process steps essential for the metal refining is connected to each other so as not to cause any difficulty in the operations as well as in sequence of the operations as a whole. The structure of the furnaces for the respective refining process steps and the devices connecting these furnaces with each other are made simple and durable to facilitate the construction, operation, and maintenance thereof. This enables the operation of the furnace to be carried out in a consistent and continuous manner over a very long period of time, thereby achieving 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 and 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 metal 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 which may be refined by the same or similar reaction as with copper. The present invention, however, 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, 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 fur-

naces corresponding to the abovementioned, respective process steps, i.e., a smelting furnace, a slagging furnace, and a blister furnace. Each of these furnaces is connected with the other to enable continuous transfer of a melt to be realized therebetween, and each of the furnaces is 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. A blister copper can thereby be produced in a continuous manner as a whole. In this process, wherein each process step for copper refining is carried out in a corresponding furnace, 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, which disturbance might arise in a furnace having a plurality of reaction zones by convection and agitation of the melt formed when raw material and air are supplied. The operational efficiency of the entire system can thereby be improved in each process step.

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, and when furnace efficiency is to be increased to a considerable extent, this would appear to be restrictive. Particularly, as the slag produced in the first process step is an ultimate tailing, reduction of the copper content in this slag to the minimum possible degree constitutes an important factor affecting the economy of the copper refining process.

To overcome this difficulty 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. As the matte to be recovered is small in quantity, it is troublesome and undesirable in actual operation to recycle the matte into the refining process in a continuous manner.

According to the present invention, 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 third process step into a matte layer, and the reaction products are all tapped out simultaneously without being separated from each other. After transfer to the subsequent separation step, these reaction products are separated and tapped out individually, thereby further improving the furnace efficiency of the smelting furnace, and ensuring the separation of the matte and the slag more satisfactorily. By 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 mainly sulfide ore (smelting furnace), a furnace for separating products formed in the smelting furnace into matte and slag (separator), and another furnace for 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, tem-

perature, surface level, and interfacial level of a melt therewithin may be controlled and maintained constant independently of the remaining furnaces, and the furnaces are further connected with 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 the grade of matte to be produced, the composition of slag, furnace temperature, and so forth. 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 mate. Simultaneously, the products formed in the smelting furnace are discharged 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" 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 any one time is so small in comparison with the residence quantity of the melt within the smelting furnace that variations in the reaction conditions 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 gravity, utilizing the 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 are continuously charged into the separator and caused to stand there-within 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. This admixture 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 either the crude metal or the blister furnace slag from the blister furnace to the smelting furnace or refining process is carried out by the gravity of the melt, utilizing the 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 a constant 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 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. 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 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 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 in a ratio 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 is most quickly and efficiently smelted when it is 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. A large quantity of the raw material is thus smelted quickly and the generation of dust is 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 in a volume which is sufficiently high to feed the gas current and the raw material directly into the melt. As a result of this, the melt is agitated satisfactorily, and the reaction within the furnace proceeds rapidly, thereby improving furnace efficiency. 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, an advantageous generation of heat from the 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 stated later on, will, to a certain extent, prevent the copper loss from increasing.

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 with an equivalent amount of oxygen. Fuel is necessarily fed to the same place in the furnace as that of the raw material, but it is best blown directly into the melt bath in the same manner as the raw material for the significantly increased heat transfer efficiency. As a result, 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 is remarkably extended.

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 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 escaping or the atmospheric air from infiltrating into the furnace. The slag layer 4 retained within the furnace can be controlled and kept at the 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. It should be noted that in the case where 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 through the lance is significantly improved.

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 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 retained 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 retained 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 port 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, and a slag discharging port 15 provided at the other end, whereby the matte particles in the slag can be more perfectly sedimented. In this case, the rate of recovery of the copper content in the slag may be further increased 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 2 together 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 heights of the slag discharging port and the matte overflow weir, respectively. As a consequence, the flow rates of the slag and the matte are equilibrated 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 blister copper 20, all of which are reaction products in the third process step, while air and a flux are simultaneously fed in directly and continuously. 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 further increase. These materials are fed into the blister furnace through lance 26 provided in the same manner as in the smelting fur-

nace. The total quantity of the air to be introduced into the blister furnace should be 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 the 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 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 is preferably 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 kept lower than that in the smelting furnace, and the melt bath level in the blister furnace is kept far lower than that in the separator, whereby the transfer of the matte is carried out by the gravity of the melt, 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 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.

While 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. As a result, 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 (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). In this way, the entire reaction system can be controlled under certain constant reaction conditions.

The reaction in the blister furnace may also be carried out under the co-existence of the two phases of slag and blister copper only, without the presence of a

white metal in the furnace, by charging a greater quantity of air into the furnace 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 percent, whereas the copper content may be increased to a range of from 40 to 50 percent when no white metal 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 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 the required feed rate 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 ordinary slag-forming process using 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, concentrating the copper content, 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 flowing 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. For instance, when the objective metal is nickel, 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 the white metal produced from a raw material contains 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 then processed to separate the objective metals from each other by such means as, for example, a floatation treatment after it has been slowly cooled. 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 is preferably 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 the same as that of the third process step in the foregoing first embodiment, except that the material processed is the white metal and the quantity of slag produced is extremely small. The quantity of the slag 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 percent, with the result that transfer of the slag in its molten state back to the smelting furnace becomes somewhat difficult. In this situation, the slag tapped out of the furnace is 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 aforementioned first embodiment.

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 than the batch system, and facilitating the introduction of an automatic control system, 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 functions only for reaction (i.e., smelting) of the raw material, while the separation of slag and matte produced in this smelting furnace is carried out in the separator. 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, so that 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 equilibrium 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 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 were found to have settled rapidly as readily calculated from the Stoke's equation and could be separated from the slag easily in the separation furnace, so that a satisfactory result could be obtained without installing a settling furnace along with the separator.

The thickness of the slag layer in the smelting furnace according to the present invention could be reduced to as thin as 1/10 to 1/20 of that formed in an ordinary reverberatory furnace. As the result of this, a sufficiently high rate of reaction in the furnace can be achieved, even if the pressure of air to be blown into the melt was low, without immersing the tip end of the lance into the melt. This makes for a considerable saving in power consumption and results in the extended life of the lance. In other words, as the air reacts mainly with the matte, and as there is only an extremely thin layer of the slag in the melt bath, the contact between the air and the matte is improved, since the slag layer does not prevent the air from contacting the matte. The reaction rate in the furnace is thereby significantly increased.

Also, a reducing agent such as pyrite may be added in 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 furnace control is facilitated. (It is a well-known fact that, when a flowing quantity of the melt in the launder is small, great difficulty is experienced in the transfer operation.)

Furthermore, in the process according to the present invention, corrosion of the bricks constituting the furnace is suppressed. Slag is the principal cause of corrosion of the bricks and in the present process, the slag layer is extremely thin, hence the area of contact between the slag and the furnace walls is small. This eliminates the added expense resulting from the use of a refractory material or jacket having exceptional durability (these being most expensive, of course) to cover such contact area.

In order to reduce the present invention 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 percent of copper, 34.2 percent of iron, 34.2 percent of sulfur, and 3.7 percent of  $\text{SiO}_2$ , 1,500 kg per hour of silica sand containing 90.0 percent of  $\text{SiO}_2$ , and 500 kg per hour of lime stone containing 53.4 percent of  $\text{CaO}$  were directly charged into a melt bath which was the reaction product in the smelting furnace together with 1,500  $\text{Nm}^3$  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, 2,500  $\text{Nm}^3$  per hour of air having a gauge pressure of 0.8 kg



per square centimeter and 500 Nm<sup>3</sup> per hour of oxygen for industrial use were mixed. 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 percent.

On the other hand, 250 liters per hour of fuel oil was burnt with the aid of 2,500 Nm<sup>3</sup> 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 gravity thereof. The SO<sub>2</sub> content in the exhaust gas discharged from the smelting furnace was from 8 to 10 percent. 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 percent 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 percent of copper, from 33 to 35 percent of SiO<sub>2</sub>, and from 5 to 6 percent 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 contain from 59 to 62 percent copper.

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 percent copper, together with 2,400 Nm<sup>3</sup> per hour of air at a gauge pressure of 2 kg per square centimeter were charged into the blister furnace. The charges were supplied directly into the melt bath formed by reaction 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 percent with the result that no white metal was formed in the furnace and the melt bath formed 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 percent of SiO<sub>2</sub>, from 4 to 6 percent of CaO, and from 38 to 45 percent of iron (most of the iron being composed of Fe<sub>3</sub>O<sub>4</sub>). 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 percent of copper and from 0.2 to 0.3 of sulfur.

When adjustment was made so as to cause a white metal layer to form in the blister furnace by changing the rate of feeding of the aforementioned silica sand and lime stone into the smelting furnace to 1,700 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 percent less than the aforesaid example, the slag produced was found to be composed of from 6 to 8 percent of copper, from 12 to 16 percent of CaO, and from 55 to 65 percent Fe<sub>3</sub>O<sub>4</sub>, and the quantity of copper recycled to the smelting furnace was reduced, whereas the sulfur content in the blister copper increased to 1 percent 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 percent.

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 in no way adversely affected the operation of the smelting furnace. Sulfur dioxide (SO<sub>2</sub>) contained in the exhaust gas discharged from the blister furnace was from 14 to 16 percent, and the temperature within the furnace was from 1,200° to 1,270°C.

The exhaust gas from each furnace was 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 percent with respect to the total quantity of the raw material used.

#### EXAMPLE 2

5,000 kg per hour of copper concentrate consisting of 18.9 percent of copper, 33.8 percent of iron, 36.5 percent of sulfur, and 1.5 percent of silicic acid, 1,400 kg per hour of silica sand containing therein 89 percent of SiO<sub>2</sub>, 570 kg per hour of lime stone containing therein 53.4 percent of CaO together with 200 Nm<sup>3</sup> per hour of air at a gauge pressure of 2 kg per square centimeter were charged into the smelting furnace. 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 Nm<sup>3</sup> per hour of air at a gauge pressure of 0.8 kg per square centimeter and 510 Nm<sup>3</sup> 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 Nm<sup>3</sup> 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 smelting furnace through the blister furnace slag charging port provided. 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 from 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 maintain 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 percent  $\text{SO}_2$ .

In the separator, the matte overflow weir provided 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 percent of  $\text{SiO}_2$  and from 5 to 6 percent of  $\text{CaO}$ . The slag contained from 0.30 to 0.45 percent 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 percent copper.

1,000 kg per hour of the aforementioned raw material ore and 500 kg per hour of silica sand together with 3,040  $\text{Nm}^3$  per hour of air at a gauge pressure of 2 kg per square centimeter were charged into the blister furnace. 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 metal and slag, and the slag layer within the furnace was kept at 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 percent  $\text{SiO}_2$  and from 2 to 6 percent copper, and the rate of production thereof was about 2,300 kg per hour according to calculation. The white metal thus produced, on the other hand, was caused to continuously flow out of the furnace through a siphon provided contiguous to the white metal tapping port and then forwarded to a copper refining process of known type. The white metal was controlled to contain from 77 to 79 percent of copper. The sulfur content therein was from 19 to 20 percent, 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 percent of  $\text{SO}_2$ . 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 heretoforeknown reverberatory furnace or an electric furnace may be employed in place of the abovementioned 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 into a melt bath within the furnace, or the whole or a part of the ore may be roasted 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 prod-

ucts 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 method for the continuous production of blister copper from sulfide copper ores in a smelting furnace unit, a separator furnace unit and an oxidizing furnace unit, each controllable in operation independently of the other as to compositions of melts therein, temperatures, levels of free surfaces of corresponding melts, and the thickness of the layers of the individual melts in the separator furnace unit and the oxidizing furnace unit including the corresponding slag therein, and wherein the rates of production of slag, matte and blister copper, the rate of transfer of matte from the separator furnace unit to the oxidizing furnace unit and the rates of transfer of blister copper and slag out of the oxidizing furnace unit are maintained in constant equilibrium with the rate of transferring smelted inputs from the smelting furnace unit to the separator furnace unit, which method comprises the steps of:

- a. continuously smelting in the smelting furnace unit inputs of sulfide copper ores, flux and oxygen-containing gas to yield a lower layer of matte and an upper layer of slag;
- b. simultaneously, while smelting said inputs, continuously transferring said matte and slag in admixture from said smelting furnace unit to a separator furnace unit, at a rate of transfer balancing the rate of production of matte and slag, wherein the matte and the slag are permitted to separate;
- c. continuously transferring slag out of said separator furnace unit for disposal at a rate balancing the rate of transfer of slag from the smelting furnace and continuously transferring matte out of said separator furnace unit to an oxidizing furnace unit at a rate of transfer balancing the rate of transfer of matte from the smelting furnace, both rates of transferring matte and slag being equal to the rate of transferring said matte and slag in admixture from the smelting furnace unit to the separator furnace unit by retaining a constant thickness of slag layer and a constant thickness of matte layer in the separator furnace unit, such that a definite amount of the matte is continuously transferred to said oxidizing furnace unit, which amount is equal to the amount transferred to the separator;
- d. introducing into said oxidizing furnace unit, flux and an oxygen-containing gas to convert said matte to blister copper and slag to produce layers thereof in said oxidizing furnace; and
- e. simultaneously, while oxidizing said matte in said oxidizing furnace unit, continuously transferring said blister copper out of said oxidizing furnace unit at a rate of transfer balancing the rate of production of said blister copper and simultaneously transferring said slag out of said oxidizing furnace unit at a rate balancing the rate of production of the slag in said oxidizing furnace unit, both rates of transferring the blister copper and the slag produced in said oxidizing furnace unit being balanced to the rate of feeding said matte, flux and oxygen-containing gas to said oxidizing furnace unit by retaining in said oxidizing furnace unit a constant

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thickness of the slag layer and a constant thickness of the blister copper layer, and the rates of transferring said blister copper and said slag out of said oxidizing furnace unit thereby being balanced to the rate of transferring said matte and slag in admixture out of the smelting furnace unit to the separator furnace unit.

2. The method according to claim 1, wherein said slag produced in said oxidizing furnace unit is introduced into said smelting furnace unit.

3. The method for continuous extraction and production of a white metal which is a sulfide of a metal selected from the group consisting of nickel, cobalt, copper, and mixtures thereof from the corresponding sulfide metal ore in a smelting furnace unit, a separator furnace unit and an oxidizing furnace unit, each controllable in operation independently of the other as to compositions of melts therein, temperatures, levels of free surfaces of corresponding melts, and the thickness of the layers of the individual melts in the separator furnace unit and the oxidizing furnace unit including the corresponding slag therein, wherein the rates of production of slag and matte and white metal, the rate of transfer of the matte from the separator furnace unit to the oxidizing furnace unit to be converted into white metal, and the rates of transfer of the white metal and slag out of the oxidizing furnace unit are maintained in constant equilibrium with the rate of transferring smelted inputs from the smelting furnace unit to the separator furnace unit, which method comprises the steps of:

- a. continuously smelting in the smelting furnace unit inputs of sulfide ores, flux and oxygen-containing gas to yield a lower layer of a matte and an upper layer of slag;
- b. simultaneously, while smelting said inputs, continuously transferring said matte and slag in admixture from said smelting furnace unit to a separator furnace unit, at a rate of transfer balancing the rate of production of said matte and slag, whereby the matte and the slag are permitted to separate into layers;
- c. continuously transferring said slag out of said separator furnace unit for disposal at a rate of transfer balancing the rate of transfer of the slag from the smelting furnace unit and continuously transferring the matte out of the separator furnace unit to an oxidizing furnace unit at a rate of transfer balancing the rate of transfer of matte from the smelting furnace, both rates of transferring the slag and the matte being equal to the rate of transferring said slag and matte from the smelting furnace unit to the separator furnace unit by retaining a constant thickness of slag layer and a constant thickness of matte layer in the separator unit furnace, such that a definite amount of matte is transferred to the oxidizing unit furnace, which amount is equal to the amount transferred to the separator;

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rator furnace unit for disposal at a rate of transfer balancing the rate of transfer of the slag from the smelting furnace unit and continuously transferring the matte out of the separator furnace unit to an oxidizing furnace unit at a rate of transfer balancing the rate of transfer of matte from the smelting furnace, both rates of transferring the slag and the matte being equal to the rate of transferring said slag and matte from the smelting furnace unit to the separator furnace unit by retaining a constant thickness of slag layer and a constant thickness of matte layer in the separator unit furnace, such that a definite amount of matte is transferred to the oxidizing unit furnace, which amount is equal to the amount transferred to the separator;

- d. introducing into said oxidizing furnace unit flux and oxygen-containing gas to oxidize the matte into white metal and slag to produce layers thereof in said oxidizing furnace unit; and
- e. simultaneously, while oxidizing said matte into white metal in said oxidizing furnace unit, continuously transferring the white metal out of said oxidizing furnace unit at a rate balancing the production of the white metal and simultaneously transferring said slag out of said oxidizing furnace unit at a rate balancing the rate of production of the slag in said oxidizing furnace unit, both rates of transferring said white metal and slag produced in said oxidizing furnace unit being balanced to the rate of feeding of said matte, flux and oxygen-containing gas to said oxidizing furnace unit by retaining in said oxidizing furnace unit a constant thickness of the slag layer and a constant thickness of the white metal, and the rates of transferring said white metal and slag out of said oxidizing furnace unit thereby being balanced to the rate of transferring said matte and slag in admixture out of the smelting furnace unit to the separator furnace unit.

4. The method according to claim 3, wherein said slag produced in said oxidizing furnace unit is introduced into said smelting furnace unit.

\* \* \* \* \*

UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,890,139 Dated June 17, 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**

*thirtieth Day of December 1975*

[SEAL]

*Attest:*

**RUTH C. MASON**  
*Attesting Officer*

**C. MARSHALL DANN**  
*Commissioner of Patents and Trademarks*