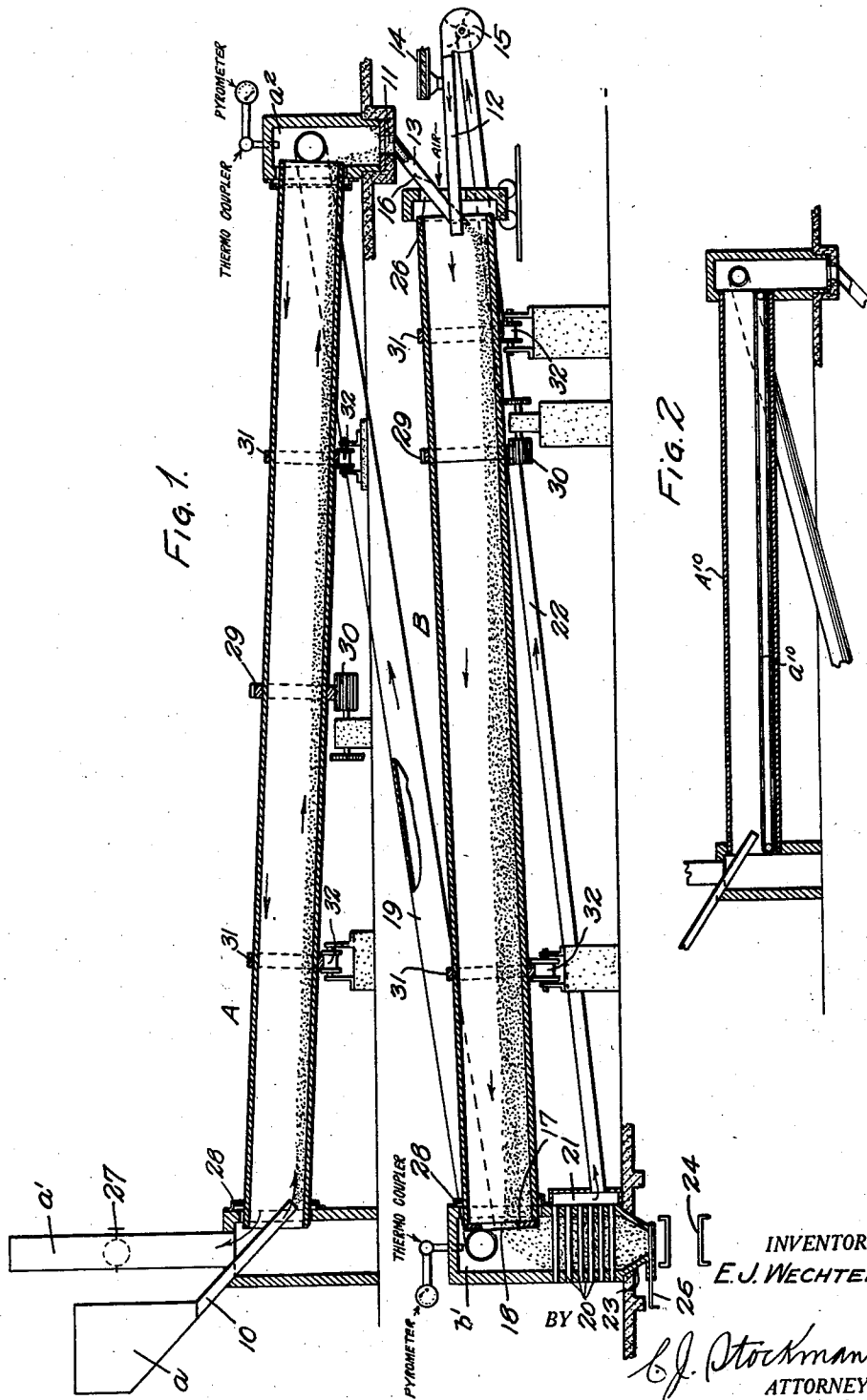


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METHOD OF ROASTING ORES

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There exists in Cuba large beds of complex ore which upon analysis has been found to be composed of valuable constituents, as iron, chromium, titanium, some nickel, copper, and traces of other materials, but which constituents have been so intimately intermingled that they cannot be separated, or put in condition whereby they may be separated, by the roasting processes commonly employed in the working of other ores, or ores from other beds. The result has been that the Cuban ore, referred to, known as "Mayari" ore has not hitherto been commercially worked. There may be and doubtless are in other places ores of similar nature with relation to which ordinary roasting processes have proved to be ineffective. It is a primary purpose of this invention, therefore, to provide a commercially practicable method by which these ores may be successfully roasted and placed in a condition whereby the valuable elements thereof may be subsequently separated from each other in the usual or any suitable manner.

The ore is first reduced to a suitable size in any appropriate manner. It is not essential that it be pulverized to the form of dust, since it is not entirely impracticable by this process to roast ore in the form of rocks of say two inches, or even somewhat greater diameter. It is preferable, however, that the ore be reduced to a fineness approximating that of sand and when in the form of rocks that the rocks be of as nearly uniform size as practicable.

According to this process, the ore which has been thus reduced or broken up is caused to travel continuously within appropriate chambers and in its course of travel through said chambers is brought into heat transferring relationship with a flowing current of a suitable heated medium by which: (1) the ore is first preheated to a temperature which preferably is somewhat below that at which a roasting action of the ore takes place; (2) is rapidly raised to the temperature at which the roasting action takes place; and (3) is maintained at the latter temperature until the roasting action is completed.

The temperature of the heating medium at the place where the sudden increase in the temperature of the ore is to be effected is very much greater than that to which ores are ordinarily subjected in a roasting process, and in order that it may be quickly effective upon the ore, the depth of the ore is so controlled at this stage of its movement that all of its particles come in direct contact with the heating medium. This stage or step during which the previously preheated material has its temperature rapidly raised to substantially the temperature of the heating medium, is immediately succeeded by a stage during which the material and the heating medium progress in the same general direction and are maintained at substantially a constant temperature for a sufficient length of time to assure the conversion of the constituents of the ore into compounds capable of being separated by the usual or any appropriate method or methods which do not form a part of this invention. To assure a sudden rise in the temperature of the ore and thereafter substantial constancy in the temperature to which it has been thus raised, the ore undergoing these two stages is formed into a mass whose depth for the first of these stages, namely, the stage in which its temperature is suddenly raised, is less than its depth throughout the other stage, namely, the stage at which its temperature is maintained substantially constant.

As a consequence of this relative difference in the depth of the mass at the two ends of the chambers and since the portion of the mass of the lesser depth comes in contact with the hottest part of the flame, it follows that the particles of the ore are so assembled as to contribute very substantially to the rapid increase in the temperature of the ore and to the retention of the temperature which it has attained. It will be noticed in this connection that the particles of the ore in that portion of the mass in which the ore has a lesser depth are in a relation which exposes them more fully to the flame or to the products of combustion and that the particles of the ore in that portion of the mass which is of the greater depth will be in a more com-

compact relation whereby they are enabled to transfer heat from one to another and thereby tend toward the maintenance of a uniform heat throughout this part of the mass. It may also be here mentioned that while the ore is being subjected to these two stages, it is preferably mixed with a suitable quantity of an appropriate alkaline material as soda ash, for example, and that the two stages are carried out in the presence of oxygen.

It is preferred to utilize the flame of a combustible mixture composed of preheated air and an appropriate fuel, as pulverized coal, producer gas, or a liquid hydrocarbon, and to inject this combustible mixture into that end of the chamber into which the ore which has been preheated as the first step and is to be suddenly raised in temperature as the second step, is introduced. The ore is thus brought into contact with the hottest part of the flame and at this time it is of the lesser depth. The products of combustion from the roasting step or stage are then led to the chamber in which the first stage, or preheating step, of the roasting process is carried out and flow in a direction counter to that of the ore undergoing said step or stage.

Suitable means are provided to assure continuous change of the products throughout the several stages or steps. Such means may comprise a fan for injecting the combustible mixture under pressure into the inlet end of the roasting chamber and a stack at the inlet end of the preheating chamber. Substantial uniformity in the temperature during the working periods is important and hence means, such as thermo-couples and pyrometers, are arranged at appropriate places in order that the temperature conditions may be observed.

In carrying out the process, and particularly in carrying out those steps or stages during which the temperature of the ore is suddenly raised and is then maintained substantially constant, it is preferred to impart gyratory motion to the mass and hence a rotary kiln is utilized for these steps. In fact, it is believed that a rotary kiln is essential in order that the process may be carried out effectively on a commercial scale.

It will be understood that in the practice of the process, the speed of flow of the material undergoing the stage in which its temperature is suddenly raised and the stage in which it is maintained constant at the raised temperature can be regulated in accordance with observed conditions by regulating the speed of rotation of the rotary chamber in which these two stages or steps are carried out.

It will be seen from what has already been stated that in the practice of the process the temperature of the raw material is raised

gradually to one much above that of the atmosphere but below that at which a roasting action will take place and is then raised suddenly to a roasting temperature and maintained substantially uniform at the roasting temperature throughout a period of time sufficient to convert the constituents of the ore into compounds capable of being separated in the usual or any appropriate way. I have found in my practice that in the first of these stages or steps the temperature of the ore should be gradually raised to about 800°-1000° F.; that in the second stage or step it should be suddenly raised from said temperature to about 1500°-1700° F., depending upon the peculiarity of the ore under treatment and that in the third stage or step it should be maintained substantially constant at the latter temperature for the required length of time, say for a period of about three hours. It should be understood that the particular temperatures and the time that the ore is subjected thereto is subject to variation. There should be about twenty percent or more of oxygen supplied for the second and third steps or stages over that required to support combustion. The result of the treatment referred to is such that the complex molecules originally present in the ore will be broken down into simple compounds capable of separation. It is difficult accurately to define all the reactions which take place, particularly since these may differ in the case of different ores even when the ores are of the complex nature for which this process particularly has been devised. It is my belief, however, that the following reactions take place in the case of Mayari ore, or like complex ores containing chromium, titanium and iron so intimately combined that they cannot readily be separated, namely:

The maintenance of the ore at the substantially constant referred to temperature for the length of time substantially as stated; in the presence of oxygen and soda ash has caused any of the iron molecules present in the ore in other than an oxide form to be converted into an oxide; and the chromium content of the ore to be converted into soluble sodium chromate, namely $2\text{Cr}_2\text{O}_3 + 4\text{Na}_2\text{CO}_3 + 3\text{O}_2 = 4\text{Na}_2\text{CrO}_4 + 4\text{CO}_2$; and the titanium to a titanium oxide. If copper is present as a sulfide in the ore, it probably will be converted into an oxide because of the excess oxygen and the high temperature to which the ore has been subjected.

The air employed to mix with the fuel to produce thereby a combustible mixture is preheated by being drawn through pipes which are in such relation to the roasted ore as to utilize the heat of said ore to preheat the air. The roasted ore is also cooled by this air. The air is drawn through the roast-

ed ore by a fan or the like and is discharged by said fan into the path of the fuel and injected with said fuel into the combustion end of the rotary kiln in a path which substantially intersects the path of the preheated ore entering said kiln.

The accompanying figures of drawings illustrate an apparatus suitable for carrying the process into practice, and illustrates also a modified form of that part of the apparatus in which the stage or step by which the raw material is gradually preheated may be carried out:—

Fig. 1 illustrates the complete apparatus in its preferred form; and

Fig. 2 illustrates the modification referred to.

Referring to Fig. 1, A designates the chamber in which the raw material is gradually preheated, or brought to a temperature favorable for its subsequent treatment, as the first stage or step in the roasting process; and B designates the chamber in which the second and third steps or stages of the roasting process are carried out. In this particular apparatus, both of these chambers are rotary and extend at a downward inclination from their material inlet ends to their material discharging ends. At the inlet end of the chamber A there is a hopper *a* and a stack *a'*. The hopper *a* is connected with the interior of the chamber A by a conduit 10, through which the ore passes from the hopper into the inlet the inlet end of the chamber A. At the outlet end of said chamber, there is a fixed chamber *a*² into which the ore whose temperature has been gradually raised in its passage through the chamber A is discharged. This fixed chamber *a*² has an opening 11 in its bottom and said opening is connected with the inlet end of the chamber B by a conduit 13. 12 designates a pipe through which the combustible mixture is introduced into the chamber B at a place immediately adjacent that at which the ore is discharged from the conduit 13 and in such relation to the discharge that it intersects the ore which is in a state of rotary motion derived from the rotation of the chamber B. This combustible mixture, in this exemplification of a suitable apparatus, is composed of a pulverized fuel, fed by a worm 14, and air which has been preheated, and said mixture is injected under pressure into the chamber B by a suitable fan whose casing is indicated at 15. The conduit 13 is provided with a check valve 16 which opens automatically under the weight of the ore flowing through the conduit and prevents direct egress of the flame or gases from the inlet end of the chamber B to the chamber *a*².

The outlet end of the chamber B extends into a fixed chamber *b'* into which the treated ore is discharged from the chamber B. At the discharge end of the chamber B there is a ring 17 of refractory material which par-

tially closes said end. This ring has its opening 18, through which the ore flows, in such relation to the bottom of the chamber B as to cause a backing up of the ore toward the discharge end of said chamber and for a distance considerably in advance thereof. Hence, there is a greater depth of ore in the rear portion of the chamber B than in the forward portion thereof. It is difficult to define the exact place in the length of the chamber at which the greater depth of the mass of ore commences and the lesser depth ends, but experience has demonstrated that the depth of the ore in the chamber from a point about midway of the length of the chamber is much greater than in the portion of the chamber forward thereof, due to the position of the outlet opening 18.

From the upper part of the chamber *b'*, a suitably insulated conduit 19 extends to the chamber *a*² and opens into said chamber at a place adjacent the discharge end of the chamber A. Through this conduit 19 the products which have passed into heat transferring relationship with the ore in the chamber B are led and are discharged into the chamber A and flow in said chamber A in a direction counter to the flow of the ore through the latter, thereby gradually preheating said ore. These products flow into the stack *a'* through the ore inlet end of the chamber A and are discharged into the atmosphere from said stack. The stack is of sufficient length to cooperate with the fan in the casing 15 to induce a rapid flow of these products through the chamber B, conduit 19 and chamber A.

The chamber *b'* is provided at a place below the discharge opening 18, with an appropriate number of pipes 20 whose outer ends are open to the atmosphere and whose inner ends open into a chamber 21 at the opposite side of the chamber *b'*. These pipes are embedded in the hot, roasted ore which has passed through the chamber B. A conduit 22 extends from the chamber 21 to the fan casing 15. Accordingly, it will be noted that atmospheric air is drawn through the pipes 20 and into the chamber 21 and through the conduit 22 and into the fan casing 15, by the fan in said casing, and is discharged thence into the pipe 12 in which it becomes mixed with the fuel, to thereby support combustion. It will also be noticed that the air drawn through the pipes 20 is heated by the roasted ore and cools said ore, and in its heated condition is discharged into the pipe 12.

The lower end of the chamber *b'* terminates in a hopper 23 through which the roasted ore flows onto a conveyor 24 by which it is carried off to any appropriate place. A valve 25 may be provided to control the discharge of the roasted ore onto the conveyor 24.

26 designates an opening at the inlet end of the chamber B through which air to supply

the necessary oxygen in the carrying out of the roasting step is admitted. Any suitable means to control this supply of air may be employed but I have found it sufficient in practice to control this through the medium of a damper 27 in the stack α' , adjustment of this damper also regulating the speed of flow of the products of combustion through the apparatus. It should be noticed also, in this connection, that the injection of the combustible mixture at a point adjacent the inlet opening 26 will draw air through said opening. The apparatus is preferably provided with a sealing ring 28 at the junction of the chamber B and b' to prevent inflow of air at this point.

Any suitable means for rotating the chambers A and B may be provided, the means here shown comprising ring gears 29 and pinions 30, the pinions intermeshing with said ring gears and deriving motion from a suitable source. Collars 31 riding upon trunnions 32 are employed at appropriate places to give proper stability to the chambers A and B.

I prefer in practice that the rotary chambers A and B, each, be one hundred or more feet in length, and that the depth of the material in the chamber B be so regulated that the mass of the lesser depth will be from eight to ten inches and the greater depth of from eighteen to twenty inches. The depth of the mass in the chamber A should preferably be from six to eight inches.

In any installation in which it is undesirable to use a rotary chamber for the preheating step, it is practicable to substitute for the chamber A a chamber such as shown in Fig. 2 and designated A^{10} . This chamber is horizontally disposed and may be provided with any suitable means for causing a progressive flow of the ore therethrough, such means being exemplified in the illustration by an endless conveyor α^{10} . In all other respects, the apparatus remains unchanged.

While the process has been particularly described in relation to the treatment of ores of a particular kind, typified by the Mayari ore hereinbefore referred to, and while its greatest benefits are derivable from its applicability to the successful commercial roasting of such ores, yet it is applicable in principle to the roasting of ores of a nature such that they are less difficult to work than the Mayari ore referred to, and is beneficial in comparison with other processes in the working of such less difficult ore. Therefore, I wish it to be understood that the invention in its broader aspects is not restricted to ores of the particular character exemplified by the Mayari ore but by proper changes in the temperatures to suit the changed conditions may be beneficially applied to the treatment of ores of various kinds.

Having thus described the invention, what

I believe to be new and desire to secure by Letters Patent, is:—

1. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which comprises as steps thereof, the subjection of a flowing mass of the ore to the action of a suitable heating agent in such relation thereto that the temperature of the ore will be first gradually raised to a point short of a roasting temperature, and then rapidly to substantially that of the heating agent and at which a roasting action may be effected and then, while mixed with a suitable alkali, maintained substantially constant at the latter temperature until the required roasting action has been effected.

2. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which includes the subjection of the ore while it is in a state of progressive gyratory motion and in a mass having lesser depth at its forward end than at its rear end, and is mixed with a suitable alkali, to the action of a suitable heating agent in such relation to said mass that the portion of the mass which is of the lesser depth will be in heat transferring relationship with the hottest part of the heating agent and thereby rapidly raised to a roasting temperature and the portion of the mass which is of the greater depth will be maintained substantially constant at said roasting temperature until the required roasting action has been effected.

3. A process according to claim 2 and in which the steps of rapidly raising the temperature of the ore and its maintenance substantially constant at the latter temperature while it is assembled into a mass having a greater depth at its rear end of the mass than at its forward end and while it is traversing a progressive gyratory path are carried out in a rotary kiln into the forward end of which both the ore and the heating agent are fed and flow to the rear end of the chamber.

4. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which comprises, as steps thereof, the subjection of a flowing mass of the ore to the action of a suitable heating agent whose direction of flow is counter to that of the ore and whose temperature is such that it will raise the temperature of the ore to a point short of a roasting temperature, the feeding of the thus preheated ore into the forward end of a chamber and its formation in said chamber into a mass which is mixed with a suitable alkali and is given a progressive gyratory movement from the forward to the rear end of the chamber, and the introduction into said forward end of the chamber of a suitable heating agent having heat trans-

ferring relation to the mass such that the temperature of the mass will be first rapidly raised to one at which the roasting action may be effected and then will be maintained substantially constant at the latter temperature until the required roasting action has been completed.

5. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which comprises, as steps thereof, the subjection of a flowing mass of the ore to the action of a suitable heating agent whose direction of flow is counter to that of the ore and whose temperature is such that it will raise the temperature of the ore to a point short of a roasting temperature, the feeding of the thus preheated ore into the forward end of a rotary chamber and its formation in said chamber into a mass which contains a suitable alkali and has a lesser depth at the forward end of the chamber and greater depth thence to the rear end of the chamber, and which mass is given a progressive gyratory movement from the forward to the rear end of the chamber, and the introduction into said forward end of the chamber of a suitable heating agent whose hottest part will be in heat transferring relation with the portion of the mass having the lesser depth and rapidly raises the temperature of the latter to that at which a roasting action may be effected and whose remaining portion within the roasting chamber is in such heat transferring relation with the portion of the mass having the greater depth that the temperature of the latter will remain substantially constant until the required roasting action has been effected.

6. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which comprises as steps thereof the preheating of a moving mass of the ore by the subjection thereof to the action of a heating agent having a direction of flow counter to that of the ore, the discharge of the thus preheated ore into the forward end of a rotary kiln and its subjection, while traversing a progressive gyratory path through said kiln and while in the presence therein of oxygen and a suitable alkali, to the action of a suitable heating agent introduced under pressure into the said forward end of the kiln and whose flow is lengthwise of the kiln and thence into heat transferring relationship with the ore for the preheating step.

7. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which comprises the subjection of a flowing mass of the ore to the action of a suitable heating agent in such relation thereto that the temperature of the ore will (1) be raised to a point short of the roasting tem-

perature and then, while the moving mass of the ore is mixed with a suitable alkali and in the presence of oxygen subjecting it to the action of a heating agent having a direction of flow parallel with that of the ore and such heat transferring relationship with the latter that the temperature of the ore will be (2) rapidly raised to a point at which a roasting action may be effected and (3) maintained substantially constant at the latter temperature until the required roasting action has been effected.

8. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which includes the subjection of the ore while it is in a state of progressive gyratory motion and is in the presence of oxygen and formed into a mass having a lesser depth at its forward end than at its rear end, and is mixed with a suitable alkali, to the action of a suitable heating agent in such relation to said mass that the portion of the mass which is of the lesser depth will be in heat transferring relationship with the hottest part of the heating agent and thereby rapidly raised to a roasting temperature and the portion of the mass which is of the greater depth will be maintained substantially constant at said roasting temperature until the required roasting action has been effected.

9. A process according to claim 8 and in which the ore before being rapidly raised to the roasting temperature and maintained at said temperature has been gradually preheated to a temperature favorable to its being so rapidly raised by its subjection while in motion to the action of a flow of the heating agent in a direction counter to that of the ore and which agent has first passed in heat-transferring relationship with ore which has undergone the later steps.

10. A process applicable to the roasting of oxide ores containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, comprising movement in counter directions and in heat transferring relationship with each other of a mass of raw ore and of a heating agent which has previously passed in heat transferring relationship with ore undergoing subsequent steps, to thereby gradually preheat the ore to a temperature short of a roasting temperature, and the subjection of the thus preheated ore, while it is in a state of progressive gyratory motion and is in the presence of oxygen and formed into a mass having a lesser depth at its forward end than at its rear end, and is mixed with a suitable alkali, to the action of a heating agent composed of a combustible mixture of a suitable fuel and air which has been drawn through pipes embedded in the roasted ore and which mixture is discharged under pressure into the end of the mass which is of the lesser depth.

11. A process of roasting Mayari ore which includes the preheating of the ore to about 800°-1000° F., and then, while it is in the presence of oxygen and mixed with a suitable alkali and is moving in a progressive path, rapidly raising it to a temperature of about 1500°-1700° F. and maintaining its temperature substantially constant until the desired roasting action has been effected.

12. A process of roasting Mayari ore which includes the preheating of the ore to about 800°-1000° F., and then, while it is in the presence of oxygen and mixed with a suitable alkali and moving in a progressive gyratory path, rapidly raising its temperature to about 1500°-1700° F. and maintaining it substantially constant at the latter temperature until the desired roasting action has been effected.

13. A process of roasting Mayari ore which includes the preheating of the ore to about 800°-1000° F., and then while it is in the presence of oxygen and mixed with a suitable alkali and formed into a mass moving in a progressive path and having lesser depth at its forward end than at its rear end, subjecting it to the action of a suitable heating agent whose hottest part is in heat transferring relationship with the portion of the mass having the lesser depth and whose temperature and direction of flow is in such relation to the mass that it will rapidly raise the temperature of the latter to about 1500°-1700° F. and maintain said temperature substantially constant until the desired roasting action has been effected.

14. A process of roasting Mayari ore which includes the gradual preheating of a moving mass of the ore to about 800°-1000° F., by subjecting it to a counter flow of a suitable heating agent, and then while it is in the presence of oxygen and mixed with an alkali and formed into a mass moving in a progressive gyratory path and having lesser depth at its forward end than at its rear end, subjecting it to the action of a suitable heating agent whose hottest part is in heat transferring relationship with the portion of the mass having the lesser depth and whose temperature and direction of flow is in such relation to the mass that it will rapidly raise the temperature of the latter to about 1500°-1700° F. and maintain said temperature substantially constant until the desired roasting action has been effected.

15. A process applicable to the treatment of oxide ore containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which includes the subjection of the ore, while it is in a state of progressive gyratory motion and is formed into a mass having a lesser depth at its forward end than at its rear end, and is in the presence of oxygen whose amount is greater than that necessary to support combustion and is

mixed with a suitable alkali, to the action of a heating agent, which is under forced draft and includes a flame whose hottest part is in intimate contact with that portion of the mass which is of the lesser depth, to thereby suddenly raise the temperature of the ore to one at which a roasting action may be effected, and the maintenance of that portion of the mass which is of the greater depth in intimate heat transferring relationship with the heating agent, at a substantially constant roasting temperature, until the desired roasting action has been effected.

16. A process applicable to the treatment of oxide ore containing iron and an amphoteric metal, as chromium, in a lower stage of oxidation, which includes the subjection of the ore while it is in a state of progressive gyratory motion and is mixed with a suitable alkali, first to the action of a heating agent having a direction of flow counter to that of the ore and a temperature such that it will gradually heat the ore to a point above that of the atmosphere and below that at which roasting may be effected and then to the action of a heating agent which is under forced draft and has a direction of flow parallel with that of the ore, the molecules of the ore while undergoing the latter action being assembled into a mass having a lesser depth at one end than at its other end and the relationship between the mass and the heating agent being such that the molecules in that portion having the lesser depth will be in intimate contact with the hottest part of the heating agent and thereby suddenly raised in temperature to one at which a roasting action may be effected and the molecules in that portion of the mass having the greater depth will be maintained at a substantially constant roasting temperature until the roasting action has been completed.

In testimony whereof I affix my signature.
EUGENE J. WECHTER.

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